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

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Author EOAD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author VEO managed the analyses of the study. Author OUN managed the literature searches. All authors read and approved the final manuscript.*

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## 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 at latitude 5°29'N and longitude 7°35E and on elevation of about 122 m abov e sea level with mean annual rainfall of

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about 2163 mm, mean daily temperature range of 35℃ to 20℃ and a relative humidity of about 72%. 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 the second factor was the application of N fertilizer (0, 40, 80 and 120 kg/ha). The observed responds were chemical soils properties (pH, organic carbon, 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 73.85 to 91.65%, while the application of N fertilizers without dried algae application increased only about 25.20 to 29 87% of the fresh crop yield. The application 4 ton $ha^{-1}$ dried algae without N-urea had the highest fresh yield of 89.87 g $plant^{-1}$, while the highest fresh yield of about 30.13 g $plant^{-1}$ without application of dried algae was obtained by the application of 120 kg $ha^{-1}$ N-urea. Generally, the highest fresh yield of 97.13 g $plant^{-1}$ was obtained by application of 4 ton $ha^{-1}$ dried algae and 80 kg $ha^{-1}$ N-urea. Consequently, the application of 4 ton $ha^{-1}$ dried algae and 80 kg $ha^{-1}$ N-urea has a great prospect to improve the properties of Ultisols, to enhance the fertilizers efficiency and to increase the yield of Amaranthus.

*Keywords: Algae; N-fertilizer; soil chemical properties.*

## 1. INTRODUCTION

Soil fertility maintenance under intensive cropping has been a major challenge that is still elusive [1]. 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 [2]. 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 [3]. [4] 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 [5]. Long term conservation of the soils health is the key benefit of organic fertilizers, which is vital to sustainable agriculture [6].

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 components 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 [7]. The potentials of algae in soil fertility management were discovered early in the history of agriculture in Coastal Asia and Island of Europe [8,9] 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 [10].

Adediran [11] observed that supplementation of organic and inorganic fertilizers were more superior to the application of either of the amendment alone. Similarly, [12] 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 [13]. *Amaranthus*, also called African spinach, produces the highest amount of protein and dry matter per unit area and time among vegetables

[14] and therefore could be a very valuable source of combating under nutrition and mal-nutrition in the tropics [15], 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.

## 2. MATERIALS AND METHODS

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°35E, elevation is about 122 m above sea level with mean annual rainfall of about 2163 mm, mean daily temperature range of 35°C to 20°C and a relative humidity of about 72% [16]. 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 [17].

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 $CaCl_2$ respectively which are below the pH range of 5.5-7.5 reported by Raemaeker [18] as optimum for amaranthus production. The low value of pH [19] indicated soil acidity and therefore suggested the need for liming in order to ensure the release of essential elements for plant growth [20,9]. Organic carbon was low (13%) indicating a low soil fertility status [21]. Total N was low with value of 0.103% which is less than the critical level of 0.15% reported by [22] 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 [2]. The soil also indicated a medium level of phosphorus with value 15.12 mg/kg which is slightly higher than the critical level of 15mg/kg for most tropical crops [23]. 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 (5) | 8.40 |
| Textural class | Loamy sand |
| pH ($H_2O$) | 5.01 |
| pH ($CaCl_2$) | 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 (Cmo/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 0-20 cm depth, air dried, sieved with 2 mm 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 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.

The algae contained high amount of N, P, Ca, Mg and OC, but moderately low in K and Na. [9] 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 alga which is in agreement with the findings of [9] and [10] 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.

**Table 2. Characteristics of the algae used for the study**

| Properties | Values |
|---|---|
| pH ($H_2O$) | 8.86 |
| pH ($CaCl_2$) | 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 |

### 2.1 Pot Experiment

The experiment was set up as randomized completely design with factorial pattern, consisted of two factors and provided with three replications. The first factor was application dried algae, comprised of 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$^{-1}$N). Five kg of air dried soil, 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 [24]. The entire plants were harvested by uprooting after five weeks of planting as described by [25] and the following agronomic and yield parameters measured: plant height, number of leaves per plant, fresh weight and stem girth.

### 2.2 Laboratory Analysis

Pre-treatment and post harvest soil samples were subjected to the following chemical analysis: pH [26,19], organic carbon [27] total N [28], available P [29] and ECEC [30] as modified [19].

### 2.3 Statistical Analysis

Data collected from both yield parameters and soil analyses were subjected to analysis of variance (ANOVA) and means were separated using ($FLSD_{0.05}$).

## 3. RESULTS AND DISCUSSION

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

The application of dried algae and N fertilizer had improvement on soil pH relative to control. Significant differences ($P<0.05$) were observed when the materials were added to the soil both as lone and combined treatments. The highest mean pH value of 6.06 was obtained when 4tons ha$^{-1}$ dried algae was combined with 40 kgha$^{-1}$ N fertilizer, suggesting its suitability as a good replacement for commercial lime in acid soils. (9) in a similar experiment showed that there was a reduction in soil acidity when algae were incorporated into the soil as compost.

The result showed that the treatments both as lone and their interaction led to increase on the available phosphorus. Dried algae as single treatment showed consistence higher values compared to lone addition of N fertilizer. This observation may be attributed to, on one hand to the high content of organic phosphorus in algae which mineralized to release solution phosphorus and on the other hand to the high organic carbon and basic cations which helped in reducing the soil pH and thus, P adsorption [9,10]. Similarly, [31] noted that algae help in releasing adsorbed P during weathering. The highest value of 65.00 mgkg$^{-1}$ was obtained when 4tons ha$^{-1}$ dried algae was combined with 40tons ha$^{-1}$ N fertilizer.

Significant differences ($P<0.05$) were observed when the dried algae and N fertilizer were applied to the soils as lone and combined treatments. The organic carbon increased with the rate of dried algae application, but increased rate of N fertilizer application consistently decreased the amount of organic carbon. This can be attributed to the fact that algae when decomposed add large quantity of organic matter to the soil [32]. [33,34] reported that algae have pronounced effect in the generation of organic matter from inorganic substances. The superior values of P observed when both materials were interacted compared to their lone applications is in line with the findings of other researchers

**Table 3. Effect of dried algae and N fertilizer on pH ($H_2O$)**

| N-fertilizers (kg ha$^{-1}$) | Dried algae rate (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | $a_0 = 0$ | $a_1 = 1$ | $a_2 = 2$ | $a_3 = 3$ | $a_4 = 4$ |
| 0 | 4.95$^{e}$ | 5.24$^{cd}$ | 5.59$^{cd}$ | 5.90$^{ab}$ | 6.03$^{a}$ |
| 40 | 5.07$^{d}$ | 5.32$^{cd}$ | 5.65$^{c}$ | 5.94$^{ab}$ | 6.06$^{a}$ |
| 80 | 5.05$^{d}$ | 5.14$^{d}$ | 5.66$^{c}$ | 5.97$^{a}$ | 5.98$^{a}$ |
| 120 | 4.98$^{e}$ | 5.09$^{d}$ | 5.25$^{cd}$ | 5.78$^{b}$ | 5.84$^{b}$ |

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

**Table 4. Effect of dried algae and N fertilizer on soil available phosphorus**

| N-fertilizers (kg ha$^{-1}$) | Dried algae rate (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | a0 = 0 | a1 = 1 | a2 = 2 | a3 = 3 | a4 = 4 |
| 0 | 21.80$^{ab}$ | 39.93$^{a}$ | 39.60$^{a}$ | 42.20$^{a}$ | 48.33$^{a}$ |
| 40 | 28.80$^{b}$ | 27.93$^{c}$ | 28.13$^{c}$ | 46.20$^{c}$ | 65.00$^{c}$ |
| 80 | 32.47$^{b}$ | 29.80$^{c}$ | 29.90$^{c}$ | 32.00$^{c}$ | 56.60$^{c}$ |
| 120 | 43.60$^{a}$ | 52.73$^{c}$ | 53.33$^{c}$ | 54.74$^{c}$ | 56.60$^{c}$ |

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

**Table 5. Effect of dried algae and N fertilizer on organic carbon (%)**

| N-fertilizers (kg ha$^{-1}$) | Dried algae rate (tons kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | a0 = 0 | a1 = 1 | a2 = 2 | a3 = 3 | a4 = 4 |
| 0 | 1.332$^{j}$ | 1.400$^{g}$ | 1.517$^{ef}$ | 1.710$^{d}$ | 1.804$^{b}$ |
| 40 | 1.366$^{i}$ | 1.419$^{f}$ | 1.521$^{e}$ | 1.741$^{c}$ | 1.806$^{b}$ |
| 80 | 1.392$^{h}$ | 1.414$^{f}$ | 1.522$^{e}$ | 1.766$^{c}$ | 1.834$^{a}$ |
| 120 | 1.305$^{k}$ | 1.400$^{g}$ | 1.517$^{ef}$ | 1.766$^{c}$ | 1.827$^{a}$ |

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

**Table 6. Effect of dried algae and N fertilizer on total nitrogen (%)**

| N-fertilizers (kg ha$^{-1}$) | Dried algae rate (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | a0 = 0 | a1 = 1 | a2 = 2 | a3 = 3 | a4 = 4 |
| 0 | 0.123$^{i}$ | 0.141$^{f}$ | 0.153$^{e}$ | 0.165$^{cd}$ | 0.172$^{c}$ |
| 40 | 0.138$^{h}$ | 0.153$^{e}$ | 0.158$^{e}$ | 0.166$^{cd}$ | 0.182$^{b}$ |
| 80 | 0.148$^{g}$ | 0.155$^{e}$ | 0.162$^{d}$ | 0.167$^{c}$ | 0.192$^{a}$ |
| 120 | 0.156$^{e}$ | 0.161$^{d}$ | 0.164$^{cd}$ | 0.169$^{c}$ | 0.192$^{a}$ |

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

**Table 7. Effect of dried algae and N-fertilizer on total exchangeable bases**

| N-fertilizers (kg ha$^{-1}$) | Dried algae rate (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | a0 = 0 | a1 = 1 | a2 = 2 | a3 = 3 | a4 = 4 |
| 0 | 5.49$^{f}$ | 6.65$^{e}$ | 9.68$^{c}$ | 11.49$^{b}$ | 12.69$^{a}$ |
| 40 | 5.49$^{f}$ | 7.96$^{d}$ | 9.73$^{c}$ | 11.64$^{ab}$ | 12.74$^{a}$ |
| 80 | 5.42$^{f}$ | 9.38$^{c}$ | 10.95$^{b}$ | 12.16$^{ab}$ | 12.80$^{a}$ |
| 120 | 5.05$^{f}$ | 8.09$^{d}$ | 10.31$^{c}$ | 11.15$^{b}$ | 12.52$^{a}$ |

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

**Table 8. Effect of dried algae and N-fertilizer on total exchangeable acidity**

| N-fertilizers (kg ha$^{-1}$) | Dried algae rate (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | a0 = 0 | a1 = 1 | a2 = 2 | a3 = 3 | a4 = 4 |
| 0 | 1.32$^{c}$ | 0.86$^{a}$ | 0.44$^{c}$ | 0.32$^{c}$ | 0.31$^{c}$ |
| 40 | 1.33$^{c}$ | 0.59$^{b}$ | 0.43$^{b}$ | 0.40$^{b}$ | 0.37$^{c}$ |
| 80 | 1.34$^{c}$ | 0.43$^{b}$ | 0.54$^{b}$ | 0.43$^{b}$ | 0.51$^{b}$ |
| 120 | 1.36$^{c}$ | 0.53$^{b}$ | 0.55$^{b}$ | 0.53$^{b}$ | 0.57$^{b}$ |

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

**Table 9. Effect of dried algae and N-fertilizer on ECEC**

| N-fertilizers (kg ha$^{-1}$) | Dried algae rate (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | **a0 = 0** | **a1 = 1** | **a2 = 2** | **a3 = 3** | **a4 = 4** |
| 0 | 6.81$^{f}$ | 7.51$^{f}$ | 10.12$^{d}$ | 11.81$^{c}$ | 12.99$^{b}$ |
| 40 | 6.82$^{f}$ | 8.54$^{e}$ | 10.16$^{d}$ | 12.04$^{b}$ | 13.12$^{b}$ |
| 80 | 6.76$^{g}$ | 9.51$^{e}$ | 11.49$^{c}$ | 12.58$^{b}$ | 13.31$^{a}$ |
| 120 | 6.41$^{g}$ | 8.63$^{e}$ | 10.85$^{d}$ | 11.68$^{c}$ | 13.09$^{b}$ |

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

[35,11] who reported better improvement on soil P when organic and inorganic fertilizers were combined compared to their single application.

The effect of dried algae and N-Fertilizer on total nitrogen is presented in Table 6. Results showed that relative to control, the application of dried algae and N-Fertilizer as single and combined treatment had significant (P<0.05) improvement on the nitrogen content of the soil and the observed improvement increased with the rate of application. Both materials are known to be excellent sources of nitrogen [32]. Apart from the nitrogen fixing ability of algae, they also create favourable environment for microbial mineralization of organic matter to release nitrogen [34]. Thus, the performance of urea which is rated as superior to other forms chemical fertilizer in terms of nitrogen content can be enhanced by combining it with algae as this could increase the nitrogen content of the soil by more than 50% as observed in this study.

The application of dried algae and N-fertilizer as lone and combined treatments exhibited varietal significant (P<0.05) differences on the exchangeable bases content of the soil. Algae applied as lone treatment showed consistent higher improvement on the basic cations compared to single application of N-fertilizer. The exchangeable bases increased with the rate of algae, but decreased with increased rate of N-fertilizer. [6] had observed that algae had the ability to remove $H^{+}$ and $Al^{+3}$ from soils, leaving behind the basic cations. [9] have also reported better improvement of soil cations when algae were applied.

The result of the effect of dried algae and N-Fertilizer showed that the application of these materials as lone treatments was significant (P<0.05) in influencing the exchangeable acidity. However, interaction was only significant at the treatment combinations of 4tons ha$^{-1}$ dried algae and 40 kgha$^{-1}$ N-fertilizer, 4tons ha$^{-1}$ algae and 80 kgha$^{-1}$ N-fertilizer, 4tons ha$^{-1}$ dried algae and 120 kgha$^{-1}$ N-fertilizer and 2tons ha$^{-1}$ dried algae and 80kgha$^{-1}$ N-fertilizer. It was also observed that algae application lowered the exchangeable acidity consistently, while the exchangeable acidity increased with rate of the N-Fertilizer. Mineral fertilizers have been linked to soil acidity, while organic manures have been known to lower soil acidity [5]. The Effective Cation Exchange Capacity (ECEC) of the soils was significantly improved with the application of dried algae and N-Fertilizer both as lone and combined treatments. 4tons ha$^{-1}$ and 80kgha$^{-1}$ N-Fertilizer gave the best result in terms of ECEC, Table 9. According [35], algae in addition to improving the organic carbon content of the soil, also enrich the soil with basic cations, thereby improving the cation exchange capacity of soils.

### 3.1 The Growth and yield of Amaranthus

Application of dried algae as organic fertilizers and N fertilizers gave a significant effect on plant height (Table 10), number of leaves (Table 11), stems girth (Table 12) and fresh yield (Table 13). In general, application of dried algae as organic fertilizers has a significant effect on the increasing of growth parameters (plant height, number of leaves and stem girth) and the crop yield. This observation may be attributed to the fact that algae contains large amount of basic cations that reduces the acidic nature of ultisols, thus making most nutrients available to the growing plants [9,10].

Data on plant height (Table 10) showed that relative to control, the application of dried algae and N-urea increased the plant height and the dried algae as lone treatments consistently showed greater improvement than the lone addition of N-urea. The highest plant height of 64.80 cm was obtained with the application of 4 tons ha$^{-1}$ dried algae, while the lone application of N-urea had the highest value of 29.70 cm at 120 kg ha$^{-1}$. Similarly, data on Table 11 revealed that both amendments increased the stem girth compared to the control and dried algae also showed greater improvement on the stem girth. The highest value of 6.57 cm was obtained with the application of 4 tons ha$^{-1}$ dried algae and the application of 120 kg ha$^{-1}$ N-urea had the highest stem girth of 3.43 cm. The number of leaves (Table 12) followed similar trend to that of stem girth.

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 of 1-4 tons of dried algae has increased the crop yield about 73.85 to 91.65%, while the N fertilizers increased the yield about 25 to 29.87. The application 4 ton ha$^{-1}$ dried algae without N-urea had the highest fresh yield of 89.87 g plant$^{-1}$, while the highest fresh yield about 30.13 g plant$^{-1}$ without application of dried algae was obtained by the application of 120 kg ha$^{-1}$ N-urea.

It was generally observed that the interaction effect of the dried algae and N-urea were greater in improving both the growth parameters and yield. The highest plant height of 65.17 cm, number of leaves of 70.33, stem girth of 6.93 cm and fresh yield of 97.13 g plant$^{-1}$ were obtained by application of 4 ton ha$^{-1}$ dried algae and 80 kg ha$^{-1}$ N-urea. This observation justifies the higher improvement on soil fertility properties in soils that had dried algae and N-Fertilizer combined as observed earlier in this study. Other research work [35] also observed a greater yield by the integrated use of inorganic and organic fertilizers compared to either of them.

**Table 10. Effect of dried algae and N-fertilizer on plant height (cm)**

| N-fertilizers (kg ha$^{-1}$) | Dried algae rate (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | a0 = 0 | a1 = 1 | a2 = 2 | a3 = 3 | a4 = 4 |
| 0 | 19.27$^{c}$ | 52.93$^{ab}$ | 57.33$^{a}$ | 61.13$^{a}$ | 64.80$^{a}$ |
| 40 | 24.40$^{a}$ | 50.13$^{a}$ | 56.47$^{a}$ | 61.63$^{a}$ | 63.80$^{a}$ |
| 80 | 25.37$^{a}$ | 54.33$^{a}$ | 59.90$^{a}$ | 64.09$^{a}$ | 65.17$^{a}$ |
| 120 | 29.70$^{a}$ | 47.43$^{a}$ | 47.60$^{a}$ | 51.87$^{a}$ | 51.73$^{a}$ |

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

**Table 11. Effect of dried algae and N-fertilizer on number of leaves**

| N-fertilizers (kg ha$^{-1}$) | Dried algae rate (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | a0 = 0 | a1 = 1 | a2 = 2 | a3 = 3 | a4 = 4 |
| 0 | 16.00$^{d}$ | 51.67$^{c}$ | 61.67$^{ab}$ | 66.33$^{a}$ | 68.67$^{a}$ |
| 40 | 23.67$^{a}$ | 50.67$^{e}$ | 62.00$^{e}$ | 66.33$^{e}$ | 68.67$^{e}$ |
| 80 | 24.33$^{a}$ | 53.00$^{e}$ | 63.33$^{e}$ | 67.67$^{e}$ | 70.33$^{e}$ |
| 120 | 26.67$^{a}$ | 47.67$^{e}$ | 47.00$^{e}$ | 53.00$^{e}$ | 57.67$^{e}$ |

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

**Table 12. Effect of dried algae and N-fertilizer on stem girth (cm)**

| N-fertilizers (kg ha$^{-1}$) | Dried algae rate (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | a0 = 0 | a1 = 1 | a2 = 2 | a3 = 3 | a4 = 4 |
| 0 | 2.47$^{e}$ | 4.20$^{c}$ | 4.90$^{b}$ | 5.47$^{b}$ | 6.57$^{a}$ |
| 40 | 3.03$^{d}$ | 4.27$^{c}$ | 4.73$^{c}$ | 5.63$^{b}$ | 6.53$^{a}$ |
| 80 | 2.90$^{d}$ | 4.56$^{c}$ | 5.10$^{b}$ | 6.43$^{a}$ | 6.93$^{a}$ |
| 120 | 3.43$^{d}$ | 3.67$^{d}$ | 4.33$^{c}$ | 4.33$^{c}$ | 5.20$^{b}$ |

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

**Table 13. Effect of algae and urea on Fresh yield**

| N-fertilizers (kg ha$^{-1}$) | Dried algae rate (kg ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | a0 = 0 | a1 = 1 | a2 = 2 | a3 = 3 | a4 = 4 |
| 0 | 17.43$^{g}$ | 46.17$^{e}$ | 62.67$^{d}$ | 76.37$^{c}$ | 89.87$^{b}$ |
| 40 | 23.57$^{f}$ | 52.43$^{e}$ | 63.40$^{d}$ | 79.53$^{c}$ | 92.37$^{b}$ |
| 80 | 25.57$^{f}$ | 52.17$^{e}$ | 65.07$^{d}$ | 81.33$^{b}$ | 97.13$^{a}$ |
| 120 | 30.13$^{f}$ | 44.43$^{e}$ | 48.07$^{e}$ | 57.77$^{d}$ | 62.50$^{d}$ |

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

## 4. CONCLUSION

Potentials for sustained *amaranthus* production in southeastern Nigeria are very limited in the absence of amendments due to the inherent low soil fertility status of the zone. Generally, application of dried algae as organic ameliorant with N fertilizer has increased and improved the soil properties (pH, organic carbon, available phosphorus, total nitrogen, exchangeable bases, exchangeable acidity and effective cation exchange capacity) of Ultisol of southeastern Nigeria and the fresh yield of amaranthus. The highest pH (6.06), organic carbon (1.82%) and ECEC (13.31 Cmol $kg^{-1}$) were obtained by the application of 4 tons $ha^{-1}$ dried algae and 40 kg $ha^{-1}$ N-urea, 4 tons $ha^{-1}$ dried algae and 80 kg $ha^{-1}$ N-urea and 4 tons $ha^{-1}$ dried algae and 120 kg $ha^{-1}$ N-urea respectively. The highest fresh yield of 89.87 g $plant^{-1}$ was obtained by application 4 ton $ha^{-1}$ dried algae, while the highest fresh yield about 30.13 g $plant^{-1}$ without application of dried algae was obtained by the application of 120 kg N-urea. Generally, the highest fresh yield of 97.13 g $plant^{-1}$ was obtained by application of 4 ton $ha^{-1}$ died algae and 80 kg $ha^{-1}$ N-urea. Consequently, the application of 4 ton $ha^{-1}$ dried algae and 80 kg $ha^{-1}$ N-urea has a great prospect to improve the properties of Ultisols, to enhance the fertilizers efficiency and to increase the yield of Amaranthus. Comparable soil chemical properties and yields obtained indicated that detrimental effects on soil and crops associated with consistent and prolonged use of large amount of mineral nitrogen fertilizers could be reduced by supplementation with dried algae as organic manure. It is therefore recommended that to reduce or avoid the residual adverse effects resulting from the over-use of mineral N-fertilizers, soil fertility management strategy of combining 4tons $ha^{-1}$ algae with 80 kg $ha^{-1}$ N-fertilizers should be adopted. This will help farmers develop interest on the potentials of algae as a farm resource which when effectively and properly used, has direct positive effect on soil nutrient properties and yield of crops.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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