

Original Research Article

Effect of Dried Algae and N Fertilizers to 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 at latitude 5°29'N and longitude 7°35'E and on elevation of 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%. 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 fertilizers (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 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 97.13g 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*

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 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 (Joseph, 2007). The potentials of algae in soil fertility management were 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.

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_2 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_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

107 B.S (%) 48.32

108
109 Soil samples were collected with the soil **auger** from 0-20cm depth, air dried, sieved with 2mm sieve, after which
110 sub-samples of 5kg each were weighed into 12L capacity plastic buckets perforated at the bottom to allow for air
111 and water movement.

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

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

116	Properties	Values
117	pH (H ₂ O)	8.86
118	pH (CaCl ₂)	7.92
119	Av.P (%)	19.04
120	Nitrogen (%)	2.28
121	Calcium (%)	6.66
122	Magnesium (%)	2.81
123	Potassium (%)	0.53
124	Sodium (%)	0.04
125	Organic carbon (%)	2.03

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

132 **Pot Experiment**

133 The experiment was set up as randomized completely design with factorial pattern, consisted of two factors and
134 provided with three replications. The first factor was application dried algae, **comprised** five rates (0, 1, 2, 3 and
135 4t/ha) algae, while N fertilizer was set up as the second factor, consisted of four rates ((0, 40, 80 and 120 kg/ha⁻¹N).

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_{0.05}).

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 ECEC (Table 9).

Table 3: Effect of dried Algae and N fertilizer on pH (H₂O)

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 ^c	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 ^c	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%.

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 kg ha^{-1} N fertilizer, suggesting its suitability as a good replacement for commercial lime in acid soils. Eneje and Azu (2009) in a similar experiment showed that there was a reduction in soil acidity when algae were incorporated into the soil as compost.

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%.

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 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 (Eneje and Azu, 2009; Azu *et al.*, 2017). Similarly, Issa (2007) noted that algae help in releasing adsorbed P during weathering. The highest value of 65.00 mg kg^{-1} was obtained when 4tons ha^{-1} dried algae was combined with 40tons ha^{-1} N fertilizer.

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

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 (Brady and Weil, 2008). Mike (2011) and Parshikova et al., (2006) 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 (Ano and Asumugha, 2000; Adediran et al., 1999) who reported better improvement on soil P when organic and inorganic fertilizers were combined compared to their single application.

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%.

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 (Brady and Weil, 2008). Apart from the nitrogen fixing ability of algae, they also create favourable environment for microbial mineralization of organic matter to release nitrogen (Parshikova et al., 2006). 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.

198 **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

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

200 The application of dried algae and N-fertilizer as lone and combined treatments exhibited varietal significant
 201 (P<0.05) differences on the exchangeable bases content of the soil. Algae applied as lone treatment showed
 202 consistent higher improvement on the basic cations compared to single application of N-fertilizer. The exchangeable
 203 bases increased with the rate of algae, but decreased with increased rate of N-fertilizer. Young et al., (2000) had
 204 observed that algae had the ability to remove H⁺ and Al³⁺ from soils, leaving behind the basic cations. Eneje and
 205 Azu (2009) have also reported better improvement of soil cations when algae were applied.

206 **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

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

208 The result of the effect of dried algae and N-Fertilizer showed that the application of these materials as lone
 209 treatments was significant (P<0.05) in influencing the exchangeable acidity. However, interaction was only
 210 significant at the treatment combinations of 4tons ha⁻¹ dried algae and 40kg ha⁻¹ N-fertilizer, 4tons ha⁻¹ algae and
 211 80kg ha⁻¹ N-fertilizer, 4tons ha⁻¹ dried algae and 120kg ha⁻¹ N-fertilizer and 2tons ha⁻¹ dried algae and 80kg ha⁻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 (Awodun, 2007). 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 80kg ha⁻¹ N-Fertilizer gave the best result in terms of ECEC, table 9. According to Wohler et al., (1999), 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.

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%.

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 (Eneje and Azu, 2009; Azu et al., 2017).**

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 of 64.80cm was obtained with the application of 4 tons ha⁻¹ dried algae, while the lone application of N-urea had the highest value of 29.70cm at 120kg 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 6.57cm was obtained with the application of 4 tons ha⁻¹ dried algae and the application of 120kg ha⁻¹ N-urea had the highest stem girth of 3.43cm. The number of leaves (Table 12) followed similar trend to that of stem girth.

237 **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

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

239 **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 ^c	62.00 ^c	66.33 ^c	68.67 ^c
80	24.33 ^a	53.00 ^c	63.33 ^c	67.67 ^c	70.33 ^c
120	26.67 ^a	47.67 ^c	47.00 ^c	53.00 ^c	57.67 ^c

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

241 **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
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242 Means having the same letters within a row/ column are not significantly different at 5%.

243 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

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

245 The data in Table 13 revealed that application of either dried algae or N fertilizers gave a significant effect on the
246 increasing crop fresh yield. Compared to the control, application of 1-4 tons of dried algae has increased the crop
247 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
248 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
249 plant⁻¹ without application of dried algae was obtained by the application of 120 kg ha⁻¹ N-urea.

250 It was generally observed that the interaction effect of the dried algae and N-urea were greater in improving both the
251 growth parameters and yield. The highest plant height of 65.17cm, number of leaves of 70.33, stem girth of 6.93cm
252 and fresh yield of 97.13g plant⁻¹ were obtained by application of 4 ton ha⁻¹ dried algae and 80 kg ha⁻¹ N-urea. . This
253 observation justifies the higher improvement on soil fertility properties in soils that had dried algae and N-Fertilizer
254 combined as observed earlier in this study. Other research work (Ano and Asumugha, 2000) also observed a greater
255 yield by the integrated use of inorganic and organic fertilizers compared to either of them.

256

257 CONCLUSION

258 Potentials for sustained *amaranthus* production in southeastern Nigeria are very limited in the absence of
259 amendments due to the inherent low soil fertility status of the zone. Generally, application of dried algae as organic
260 ameliorant with N fertilizer has increased and improved the soil properties (pH, organic carbon, available
261 phosphorus, total nitrogen, exchangeable bases, exchangeable acidity and effective cation exchange capacity) of
262 Ultisol of southeastern Nigeria and the fresh yield of amaranthus. The highest pH (6.06), organic carbon (1.82%)
263 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 97.13g 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

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