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Effect of Tillage Methods and Fertilizer Applications on *Amaranthus curentus* in Nigeria

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ABSTRACT

The response of *Amaranthus* to varying fertilizers application and different tillage practices for optimum vegetable production were investigated. This was to increase productivity for food security and reduced growing insecurity to achievable minimum. The optimum level of fertilizer applications and best tillage methods for improved productivity is unknown hence this study. Four treatments based on fertilizer applications viz; nitrogen, phosphorus and potassium, (N-P-K, 15-15-15), manure, peat and urea were administered on the vegetable in four different tillage methods namely: zero, bed, heap and ridge using standard procedures. The treatments were replicated using Randomized Complete Block Design (RCBD). Agronomic and soil parameters were determined and subjected to statistical analysis. From the study, responses of measured agronomic parameters showed that the ridge tillage method with N.P.K fertilizer application gave optimum yield among the treatments. The vegetables in this treatment had average leave length, root depth, plant height and Leaf Area Index (LAI) values of 29.8, 9.9, 143 and 13.8, respectively all at 8 Weeks After Planting (WAP). These were highest when compared with results from other treatments. Values of soil's nitrogen, phosphorus and potassium were 0.29, 8.66 and 0.22 mg kg^{-1}, respectively while calcium and magnesium were within acceptable limits for crop development with values ranging from 2.9 to 8 mol kg^{-1} and from 2 to 5 mol kg^{-1}, respectively. Statistical analysis among agronomic parameters showed significant difference ($p<0.05$). Ridge tillage and N.P.K application affected biomass yield and growth of *Amaranthus cruentus* considerably and is therefore suggested for increased vegetable productivity in Nigeria.

Key words: Tillage, fertilizer, *Amaranthus*, agronomic parameters, productivity

INTRODUCTION

Amaranths cruentus belong to the family of vegetable call *Amaranthaceous* and it is grown as a vegetable in western Africa and especially in Nigeria. *Amaranth* species is rich in proteins minerals, containing 15-22% protein, 3.0-11.5% fat and 9-16% dietary fibre depending on cultivation techniques and environmental effects (Tosi *et al.*, 2001). Other major consumers, according to Abu Ziada *et al.* (2008) come from other parts of Africa, China, India and Italy. *Amaranths* is also of significant importance to the Asian region because of the taste, colour and textures, they provide in meal however, the main constituent is starch 48-62% with small granule size which can easily be dispersed (Colla *et al.*, 2006). It was also reported by Abu Ziada *et al.* (2008) that the green leaves of *Amaranthus* were rich in water, energy, fats, proteins, minerals, amino acids and carotenoids. Protein deficiency is one of the major problems confronting the developing countries of the world. This may be due to the fact that animal source of protein is by far too expensive for an average household in the developing nation. Vegetable which would have being grown throughout the year, was not as a result of shortage of water supply during the dry season. Vegetable contains 80 to 95% of water and because of this, its yield and quality deteriorates rapidly when subjected to water stress. Hence, for a good yield and high quality, irrigation is essential to the production of most vegetables (Kemble and Sanders, 2000). If water shortages occur early in the crop development, maturity may be delayed and yield reduced. However, if moisture shortage occurs late in growing season, quantity is often reduce but the overall biomass yield may not be affected (Allen *et al*., 1998). Tillage practices have been reported to have significant impact on crop production (Awe and Abegunrin, 2009). Tillage and crop can play a role in creating or removing environmental stimuli that regulates germination of seeds (Steckel *et al*., 2007; Lal, 1991). Producing early maturing vegetables in commercial quantities in Nigeria required among other factors, fertilizer application in sufficient quantities and in accordance with tillage preparations. The use of soil amendments is mainly to improve crop yields while improved yields results from improved nutrient status in soil and other soil properties such as organic matter (Mungai *et al*., 2009). The response of ground vegetation to fertilization has received less attention especially in the tropics although their contribution to the annual nutrients cycling is great (Ong *et al*., 2008). Olaniyi *et al*. (2008) reported that there is limited preliminary information on fertility requirements of Amaranths. The effects of different types of fertilizers and tillage operations have on the development and growth of amaranths is unknown hence this study. This is a clear indication that there exists paucity of information on the effects of tillage practices and fertilizer application on the vegetable performance. Therefore, the objectives of the study were to determine the responses of *Amaranthus* to various types of fertilizer application and at different growth stages, determine its response to different tillage methods under standard and environmental conditions and to make recommendations to farmers and other end users about the effects of these findings on the vegetable yield in Nigeria for optimum production.

MATERIALS AND METHODS

Description of the project site: The study was conducted from March through June, 2010 at the teaching and research farm of the Department of Agricultural Engineering, Federal University of Technology, Akure, Ondo State, Nigeria. Akure, the capital of Ondo State which lies between latitude 5°45" and 8°15" North and longitudes 4°30" and 6° East in the rain forest belt of the tropics. Akure has a tropical climate with distinct wet and dry seasons. A warm rainy season spans April to October followed by a hot dry period from November to March. The annual rainfall ranges from 1405 to 2400 mm with August as the wettest month and November as the driest month. The average monthly temperature is 26.5°C; a maximum temperature of 36°C is recorded during the dry season while the minimum temperature is about 27°C. The city has humidity range of 56 and 59% during the dry season and about 51-82% during the wet season with average sunshine hours of 4.5 h which varies between 1.8 hours and 5.9 hours. The shortest hours are in August while the longest is in September. Generally, the topsoil is composed of sand varying from 76-85%. Profile (0-40 cm) analysis from a number of locations within the study is clay loam (Akinbile, 2006).

Land preparation and experimentation: The site was prepared using conventional equipment for the experiment. An area of 5×5 m^2 was selected and four treatments and four replicates using

Randomized Complete Block Design (RCBD) were adopted. The distinction between the treatments was due to tillage practices while each of the four replicates in each treatment contained the four fertilizers administered in pre-determined quantities. Treatment A (zero or no till), B (bed), C (heap) and D (ridge) were replicated in four plots with each plot having NPK, manure, peat and urea administered to them in 2.0 kg ha^{-1} and in line with convectional practices (Olaniyi *et al*., 2008). Normal irrigation (in form of rainfall) was applied to each of the treatments in the same quantities to observe its effects on varying soil and fertilizer applications. *Amaranthus cruentus* seeds were obtained from the Agricultural Development Project (ADP) office Akure, Ondo state and the seedlings were air-dried and treated before planting by broadcast method. Seed germination took place within one week after planting and thinning was done 2 Weeks After Planting (WAP). Soil analysis was performed to determine the percentage of residual constituents of some of the ions such as Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg) and Calcium (Ca) organic matter and the pH. Also, soil's classification was determined while its moisture content was monitored from 3 WAP and measurements taken. Agronomic parameters such as plant height, root depth, Leaf Area Index (LAI), number of leaves, leaves length and width were measured throughout the growing season of *Amaranthus* using standard and convectional procedures.

Statistical analysis: All the agronomic parameters were measured from 3 Weeks After Planting (WAP)and the results were subjected to statistical analyses using ANOVA't' test procedure on Excel software spreadsheet considered at 95% level of significance ($p<0.05$).

RESULTS AND DISCUSSION

Soil moisture regimes: The average soil moisture content in all the four treatments from 3 Weeks After Planting (WAP) was presented in Table 1. There were noticeable soil moisture increased from 10 to 40 cm depth in all the treatments indicating a well-watered scenario throughout the experiment. In 3 WAP, soil moisture ranged between 0.98 and 1.42 cm down the profile but there was a reduction a week later down the profile. This may be due to the metabolic activities picking up at the vegetative stage of crop development and since the roots will have to access water and nutrients, reduction in soil moisture was probable. This was similar to the observations of Akparobi (2009). From 5 WAP through 8 WAP, a relative water balance in the profile was maintained, an indication of saturation and field capacity status of the soil. Since water applied was not regulated, availability of more moisture for the vegetable metabolic activities was possible. This was similar to the opinions of Steckel *et al.* (2007) in one of his studies. Having more quantities of water as the depth increases was also an indication of the fine soil aggregates down the profile which permitted smooth infiltration and appreciable retention of water as soil depth increases. Akande (2006) showed similar observations in his findings. Lack of water on soil surface as runoff and low volume in the 10 cm profile also indicated suspected presence of sandy loam soil which permits free flow of water and supports enhanced crop development due to presence of nutrients from remains of dead leaves. Sandy loam is known for it good aeration and porosity capacities hence its ability to permit free water movement within the profile (Allen *et al*., 1998).

Soil physical and chemical properties: Results of the soil's physical and chemical properties of the study area were as shown in Table 2. The pH values ranged from 5.66 to 5.82 indicating that the soil was acidic. This promoted good crop development and growth as vegetables generally thrives well on mildly acidic soil. Below this range poses severe danger for the crop development

Table 1: Average soil moisture content (%) for during the period of the study

Treatment	Soil depth (cm)	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP	8 WAP
A	0-10	0.98	1.10	2.52	2.73	0.44	2.45
B	10-20	0.64	0.11	1.19	2.88	0.97	2.95
C	20-30	1.16	0.42	1.42	3.02	1.16	2.83
D	30-40	1.42	0.80	1.22	2.88	1.58	2.93

Table 2: Soil's physical and chemical properties in the study area

pH	O. matter (%)	N (mg kg^{-1})	P (mol $kg)^{-1}$	K^+ (mol $kg)^{-1}$	Ca^{2+} (mol kg^{-1})	Mg^{2+} (mol kg^{-1})	Sand (%)	Clay (%)	Silt (%)
5.75	3.65	0.32	9.55	0.27	5.20	4.10	60	28	12
5.82	3.23	0.28	10.15	0.21	8.00	5.00	62	26	12
5.66	3.00	0.26	6.29	0.19	2.90	2.00	63	26	11

and above may not be too harmful but definitely takes its toll on its optimum yield. Several researchers including Mungai *et al.* (2009) have reported the beneficial effect of soil acidity on shallow-rooted crops such as vegetables for optimum growth and development. Organic matter was within the range 3.00 and 3.65 acceptable for excellent vegetable growth. The remains of dead leaves, earthworms and other animals may have enriched the soil's organic matter. The area was also allowed to fallow for four years which may also be responsible for high organic content. This increased the soil nutrient and promoted good crop development with the different types of fertilizer administered to the soil. Buah and Mwinkaara (2009) reported the influence of nitrogen-composed fertilizer on the organic content of the soil as to promote germination and plant's development. While the soil's nutrients such as phosphorus (P), potassium (K) and calcium (Ca) which had values ranging between 6.29 to 10.15, 0.19 to 0.27 and 2.90 to 8.0 mol kg^{-1}, respectively were expectedly within acceptable limits for crop growth, the soil's profile was also good for genuine crop growth. N ranged between 0.26 and 0.32 mg kg^{-1} was also within desirable limit in soil for optimum crop production. Ong *et al.* (2008) remarked that under repeated short rotations of fast growing spieces such as vegetables, N and P are the two most important nutrient elements determining the productivity of most tropical plantations as base cations are important in highly acidic soils. The results using the United States Department of Agriculture (USDA) textural triangle indicated a sandy clayey soil with the average sand composition of 62%, clay 27% and silt 12%. This soil class have high porosity and permeability profiles in the aggregates thereby enabling easy access of roots, especially shallow roots of vegetables to quick water and nutrient uptake, good aeration and also excellent drainage possibilities. Polthanee and Changdee (2008) reported that significant interaction effects was mostly probable between root management and fertilizer application in a soil constituents such as this due to the porosity and degree of aggregates present due to its formation.

Agronomic parameters

Plant height: Figure 1 showed the average plant height with weeks after planting in all the treatments. The same growth was observed in all the treatment in the 3rd and 4th week after planting. After 5 WAP, the effect of fertilizer application and tillage practises was visible as the weeks progressed. It was evident that treatment D (ridge tillage) had the pronounced response to crop growth. The distinction in its height was visible despite its initial slow start especially within the first 4 WAP. This may be due to the effect of tillage which enabled the roots reach out to nutrients and water for development when compared with other treatments. The distinction began to manifest just after the 4 WAP when the height reached 17 cm compared with the ones in other

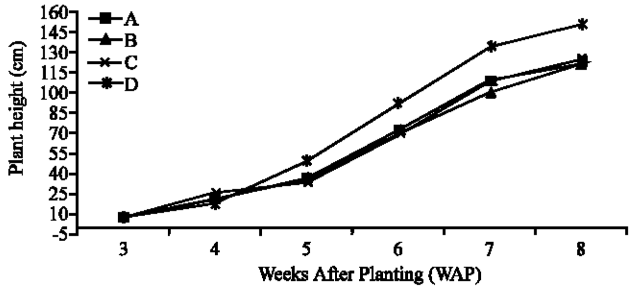

Fig. 1: Average plant height and Weeks After Planting (WAP) in all the four treatments

treatments that was 20 cm (Fig. 1). By the time it was 8 WAP, the distinction was very obvious with more than 20 cm difference in height. At 8 WAP, average plant height in D was 143 cm while the average plant heights in treatments A, B and C was 120 cm. Similar observations were made by Makinde *et al.* (2010), Olaniyi *et al.* (2008) and Akande (2006) all of whom reported that the application of each of N and P significantly increased the plant height, number of leaves and fresh shoots. Fertilizer and its interaction with proper tillage have significant effect on total plant height, root depth and length of leaf. Awe and Abegunrin (2009) and Steckel *et al.* (2007) also agreed that tillage played a role in the behaviour of the agronomic parameters, especially the plant height development. This was also an indication that degree of soil aggregates, pulverisation, porosity and pore spaces within the soil profile have tremendous effect on roots accessibility to water and nutrients uptake hence pronounced and noticeable development. It was reported by Oryokot *et al.* (1997) that *Amaranthus* densities were much higher in till environments compared with no-till environments due to the roots' easy accessibility to water and nutrients' uptake from the soil. Though urea, manure and peat also supported plant height development (Fig. 1), the effect of NPK was mostly distinct on the overall. Modisane *et al.* (2009) reported the considerable influence of NPK on *Amaranthus* in their studies which were similar to the findings of this study thereby justifying the visible effect of NPK on the vegetable from this study.

Root depth: Figure 2 showed the average root depth compared with the weeks after planting during the experiment. Treatment D was clearly distinct as the depths of roots were obviously the deepest when compared with the remaining treatments. From 3 WAP, all through than growing season, roots in D were deeper than in other treatments. It was 4 cm in 4 WAP while others were lower with the exception of C which was closer (3.6 cm) perhaps due to tillage method (heap). The tendency to reach out to higher quantities of nutrient and water was more in treatment D compared to others hence the root elongation. It was also inferred that the ridge tillage method may have affected the crop greatly, having responsible for the roots deep penetration into the soil. Similar observation was observed by Afolayan *et al.* (2004) in their study. The maximum root depth of 9.9 cm was recorded in D while the least of 8 cm was recorded in A at 8 WAP. This was unexpected due to the fact that the tillage method in A was zero tillage and so the root encountered greater difficulty in accessing nutrients and water for optimum sustainability. However, getting to 8 cm depth may be due to the nature of the soil (sandy clay loam) which still supported crop development due to the loosely-packed nature of the topsoil. Aon *et al.* (2001) disagreed with the observations but Haque *et al.* (2001) reported similar results.

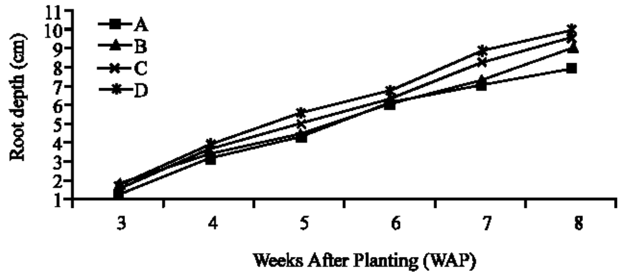

Fig. 2: Average root depth of *Amaranthus* with Weeks After Planting (WAP) in all the treatments

Leave length: From Fig. 3, it was evident that treatment D had the averagely longest leaves when compared with other treatments. The ridge tillage method allowed the roots access to the fertilizer applied (NPK) which take up nitrogen, phosphorus and potassium necessary for crop's photosythesis which gave the green colouration and elongation to the leaves. The maximum leave length was 27.8 cm found in D while the minimum was recorded in B, treatment with bed tilage method with the value 24.8 cm at 8 WAP. Treatment B was particularly neagatively dinstict from the rest despite being bed tillage method. This may be due to the unhealthy competiton and demand for nutrients by the *Amaranthus* planted on bed hence the manifestations on the length of the leaves. This was however, in sharp contrast with other treatment, particularly in D where the crops were planted in rows along each ridge, each plant stand accessing basic needs with minimal competiton from other crops other than weeds which were being removed periodically. The pronounced effect of soil macroporosity was evident in the development of leave length. Hearda *et al.* (1988) reported that increased access to the soil nutrients by the roots was evident on the leaves development in a tilled environment.

Leaf Area Index (LAI): Figure 4 showed the relationship between the leaf area index (LAI) and the weeks after planting (WAP) in all the four treatments. The LAI values in treatment D were disntict throughout the experiment due to the high values of LAI from 5 WAP till the end of the study. LAI values in 5 WAP was 13.8, about 2.1 over other values in other treatments in the same WAP. The development increased and maximum LAI values was reported in 8 WAP (34.5) and still remained the highest during the study. Since other agronomic parameters such as plant height, no of leaves, root depths were greater in D as compared with other treatments, it could be inferred that LAI should not be an exception as the nutrients from soil through the roots were accessed by plant shoot for development. The formation of canopy shading for denser foliage cover is a function of well developed foliages (leaves) which is also dependent on the accessability of the plant to water and nutrient uptake in sufficient quantities. Akinbile (2010) reported similar results in NERICA rice (New Rice for Africa) under similar conditions. *Amaranthus currentus* in treatment D were planted on ridge and applied with NPK fertilizer and when compared with other treatment methods, it proved to be the best in response to tillage methods and fertilizer application during the growing season of the crop. Apart from tillage practises and fertilizer applications, other factors that may be responsible for the high LAI values according to Akinbile *et al.* (2007) included; photosynthesis, direct incidences of solar radiation, weed control, water application, seed variety and cultural practises.

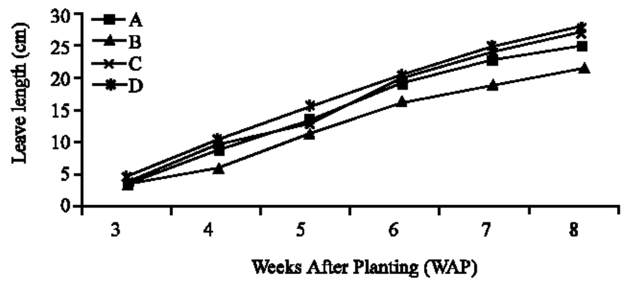

Fig. 3: Average leave length with Weeks After Planting (WAP) in all the treatments

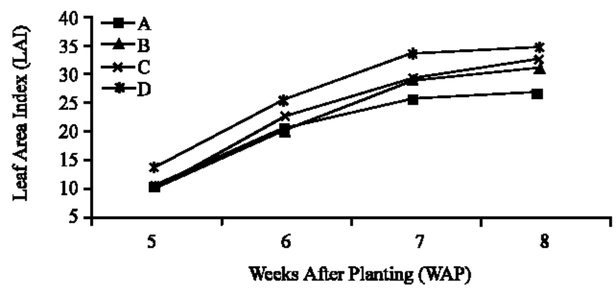

Fig. 4: Leaf Area Index (LAI) vs weeks after planting in all the treatments

The results from this study have shown that the type of tillage method and type of fertilizer applications has direct implications on plant height, root depth and leaves length of *Amaranthus currentus*. At 2 WAP, there were significant differences in stem girth between ridge and other tillage methods but difference seems to be not significant when compared with others tillage methods. For other weeks (3 to 8 WAP), similar trend was observed indicating that ridge tillage method and N.P.K application gave optimum and desirable results in the production of *Amaranthus cruentus*. This showed clearly that ridge method was the best in the given circumstance for producing vegetables such as *Amaranthus* and may be due to the fact that ridging reduces soil density, increased soil macro porosity thereby reducing conduction of heat into the soil during the day. Although in other tilled plots (bed and heap), considerable good performances were observed on the total parameters, the crop arrangement, leaves overlay and competing demand for nutritients and food denied them improved performance as in ridge method. This is because there was a better uptake of nutrient especially phosphorus which resulted due to mineralization and organic matter when mixed with soil during tillage (Lal, 1991). However, loosening of soil enabled root elongation and better uptake of nutrient below the surface due to downward movement of the absorbing roots. Afolayan *et al*. (2004) and Guerif *et al*. (2001) reported similar results that was observed that plants in tilled plots performed better than untilled plots, especially with respect to leaf area, root density and shoot yield. Also, the composition of nutrients needed for increased development was more in NPK, due to its organic nature when compared with other types of fertilizer used such as manure, peat and urea (Olaniyi *et al*., 2008). Peat is the accumulation of partially decayed vegetative matter and since it store nutrients although not itself fertile hence its effect in catalyzing crop development may not be visible as compared with other fertilizers. Urea on the other hand, had highest nitrogen content of all solid nitrogenous fertilizers in common use

Table 3: Correlation coefficient of different physiochemical variables from the study data

Variable	LL	RD	PH	LAI
LL	1	0.51	0.69	0.48
RD		1	0.68	1.0
PH			1	0.72*
LAI				1

Significant at *p<0.05; LL = Leaf length, RD = Root depth, PH = Plant height, LAI = Leaf area index

but its addition failed to improve the enhancement of already-degraded soil, particularly in an area prone to continuous cropping due to limited land availability, hence its limitation (Akparobi, 2009). However, as the latter (peat and urea) would not leave residue behind in the soil due to their inorganic nature, NPK residue in form of salts causes injuries to the soil, hasten depletion and on the long run cause severe injuries to the crops. Over irrigation to dissolve the salts residue and flush away from farmlands has been done over the years to mitigate this.

Test of significance of the observed correlation coefficients: The significance of the observed correlation coefficients has been tested and the results were as shown in Table 3. Out of the total 6 correlations found between two parameters, 2 were found to have significant at 5% level, (r>0.7). However, there was no negative correlation. The correlations observed existed between Plant Height (PH) and Leaf Area Index (LAI) (0.72), Root Depth (RD) and (PH) (0.68) and Leaf Length (LL) and RD (0.51), respectively. Others were between LL and PH (0.69) and LL and LAI (0.48). The only highly significant correlation was between RD and the LAI (r = 1). In all the parameters tested using t-test correlation analysis, there were significant differences in all the parameters considered at 95% confidence interval also confirming the influence of tillage methods and fertilizer type application on growth and yield of *Amaranthus curentus*.

CONCLUSION

The pronounced effects of tillage practices and fertilizer application on the growth, development and yield of *Amaranthus* were visible in the study as shown in the results. From the study, it was evident that ridge tillage method and NPK fertilizer applications were most suitable for the optimum production of the vegetable both as food crop and also for economic considerations. The responses of plant height, leaves numbers and length pointed to this fact. These signs were clearly distinct as from 8 WAP and throughout the experiment when compared with the responses of the crop in other treatments and replicates. This may be attributed to the fact that ridging reduces soil density, increases soil macro porosity thereby reducing conduction of heat in the soil during the day. Ridging facilitated uptake of nutrients especially phosphorus which resulted due to mineralization or organic matter when mixed with soil during tillage, loosening of soil enables root elongation and better uptake of nutrient by absorbing roots. It could be concluded that the use of ridge tillage and with NPK fertilizer has proved to be most effective because it stimulated profuse shoot growth and massive root development of *Amaranthus*. Consequently, it increased nutrients composition of plant hence, increases crop growth and yield.

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