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Responses of Leaf Yield and Chemical Composition of *Amaranthus cruentus* L. and *Celosia argentea* L. to Land Use Types and Fertilizer Regimes*

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Abstract: At the Teaching and Research Farm, University of Ado-Ekiti, Ado-Ekiti, Nigeria, studies were conducted during the late season of 2004 and early season of 2005 to determine the leaf yield and chemical composition of *Amaranthus cruentus* L. (V_1) and *Celosia argentea* L.(V_2) as affected by land use types and fertilizer regimes. The four land use types selected were fallow upland (L_1), fallow wetland (L_2), continuously cultivated lowland (L_3) and cultivated upland (L_4), while the fertilizer regimes were control (no fertilizer application), blanket (application based on previous general recommendation) and fertilizer factor (Ff-application based on soil test values). The fertilizer sources were urea (46% N), single super phosphate (7% P) and muriate of potash (55% K). Results showed that significantly ($p \leq 0.05$) higher leaf yields were recorded for *A. cruentus* (28.9 tons ha^{-1}) and *C. argentea* (35.8 t ha^{-1}) under the L_1 using the Ff compared to other land use types and fertilizer regimes. The least leaf yields were recorded for the two vegetables under the control (no fertilizer) regime. Statistical analyses ($p \leq 0.05$) showed that the total carotenoids, crude protein and calcium contents of V_1 were significantly higher than that of V_2 under all land use types. The oxalate and ether extract composition of the two vegetables in all land use types and fertilizer regimes did not differ significantly. Except for the oxalate and ether extract contents, the plants under Ff had significantly higher contents of carotenoids, calcium, ascorbic acid, crude protein and crude fibre compared to plants under blanket and control treatments. The results of this study showed that higher leaf yields and optimum nutrient composition of *A. cruentus* and *C. argentea* can be realized by a proper combination of land use type and fertilizer rates. The use of fertilizer factor (Ff) in determining nutrient amendment required for a particular soil provides a better picture of actual fertilizer rate required and also promotes higher vegetable leaf yield and quality.

Key words: Vegetables, land use type, fertilizer regimes, leaf yield, chemical composition

Introduction

The influence of land use and cultural management and their consequences to the environment and to the crop production capacity for a wide range of climatic and edaphic conditions has been the subject of research recently. In agricultural fields, yield variability is partly caused by soil variability and varying topographic features of the field (Jiang and Thelen, 2004). Although yield is a function of a host of factors, including soil properties, field topography, climate, biological factors and management, in certain years as much as 60% or even more of the yield variability

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can be explained by a combination of soil properties and topographic features (Yang *et al*., 1998; Kravchenko and Bullock, 2000). Many soil properties such as available water, texture, bulk density, clay content (Stone *et al*., 1985; Miller *et al*., 1988; Wright *et al*., 1990), organic C (Ciha, 1984; Stone *et al*., 1985; Wright *et al*., 1990), pH (Kreznor *et al*., 1989; Moore *et al*., 1993), subsoil acidity (Wright *et al*., 1990), fertility and soil thickness (Kreznor *et al*., 1989) have been found to affect crop yield. Mechanized crop cultivation has also been shown to increase soil hardness, reduce water infiltration rate into the soil and altered root distribution. Also different crops have been reported to cause changes in soil properties due to different micro-environments created by the plant (Kang, 1977). These effects, when significant could cause problems in land use planning, practical farming and experimental agriculture.

The impact of land use type on the performance of leaf vegetables has not been given any serious research attention in Nigeria. Several studies have documented the role of leaf vegetables in human nutrition (Chweya and Eyzaguirre, 1999, Adebooye, 1996; Schippers, 2000; Adebooye *et al*., 2003, 2005; Abukutsa-Onyago, 2003). *Amaranthus cruentus* L. and *Celosia argentea* L have been reported to be good sources of dietary fiber and contain high amounts of protein, vitamins and minerals (Makus and Davis, 1984; Teutonico and Knorr, 1985; Willis *et al*., 1984). During the dry season, Adebooye *et al*. (2005) reported that the price per bunch of leaf vegetables rises in Nigeria because only few farmers do irrigation farming. Similar report in Tanzania showed that farmers' expenses on vegetables were 50-80% of the total for household budget (Spore, 2005).

As part of the effort to improve the cultivation and food value of leaf vegetables with a view to making the high quality vegetable available at bearable and affordable prices, there is therefore the need to investigate management practices that will bring about optimum leaf yield and quality of the vegetables. It was in view of the above that this study was designed to investigate the influence of land use types and fertilizer regimes on leaf yields and quality of two high premium leaf vegetables of Africa: *Amaranthus cruentus* L. and *Celosia argentea* L.

Materials and Methods

The study was conducted at the Teaching and Research Farm, University of Ado Ekiti, Nigeria during the late season of 2004 and early season of 2005. The experiments were located on a field of about 10 ha that span from an upper slope into a valley bottom. Four land use types selected along the toposequence were fallow upland (L_1), fallow wetland (L_2), continuously cultivated lowland (L_3) and cultivated upland (L_4). Prior to the commencement of planting, top (0-15 cm depth) soil samples were taken in each land use type for chemical analyses.

The soil samples were air-dried, crushed and sieved through a 2 mm sieve. Particle size distribution was done using the hydrometer method and pH measured using the glass electrode pH meter at 1:1 soil to water ratio. The organic carbon content was determined by Walkley-Black wet oxidation method while the percent total N; was determined by macro Kjeldahl method. Available P was determined by Bray P-1 method while the exchangeable cations were determined by extracting with neutral normal NH_4 OA_C. The K was measured using the flame photometer (Model PFP7, Burkard Scientific, Uxbridge UK) while Mg and Ca was determined using a UV-Visible spectrophotometer Model UV 1601 Version 2.40 (Shimadzu, Japan).

The fertilizer regimes used were control (no fertilizer application), Blanket (application based on 60:50:50 N: P: K recommended for southwest Nigeria) and Ff (application based on Fertilizer Factor (Ff) derived from soil test values for the study sites). Estimation of N, P and K Fertilizer Factors (Ff) on the basis of the soil test values was based on the N-availability index of soils of South Western Nigeria according to the model of Adeoye (1987). Based on that model, for Fertilizer Factor (Ff) plots, N:P:K was applied at the rate of 30: 20: 20, 45: 35: 40, 50: 50: 60 and 65: 60: 65 for L_1, L_2, L_3 and L_4, respectively. The fertilizer sources were urea (46% N), single super phosphate (7% P) and muriate of potash (55% K). The N:P:K treatments were calculated based on the results of soil analyses in comparison with the critical values of 0.15, 10-16 and 0.45 cmol kg^{-1} , respectively, for southwest Nigeria (Sobulo *et al*., 1975; Aduayi *et al*., 2002). Concentrations of Mg and Ca were considered adequate considering the critical values of 0.30 and 2.5 cmol kg^{-1}, respectively, reported for the soil of this location (Adeoye and Agboola, 1985; Aduayi *et al*., 2002).

The experiment was planted in a split plot design replicated three times. Under each land use type, the fertilizer regime formed the main plot while the vegetables (*Amaranthus cruentus* L. var. Local [Coded V_1] and *Celosia argentea* L. var. Purple [Coded V_2]) formed the sub-plots. Each plot measured 2.5 × 2.5 m. Planting was done at the rate of 5 g seed/plot by drilling for each vegetable. Plantings were done on September 4 and April 10 in 2004 and 2005, respectively. Both the 2004 and 2005 studies were rain fed. Emerging weeds were handpicked. The different fertilizer regimes were applied by banding at four days after emergence.

At 32 days after planting when the plants were fully grown and still succulent, harvesting was done by cutting and the leaf yield per plot was determined. About 500 g fresh leaf samples from each plot were immediately bagged and taken to the laboratory for chemical analyses. The samples were dried in a Gallenkamp oven (Model OMT 075, Loughborough, UK) at 80°C for 24 h. The dried samples were ground into powder separately using a Wiley micro hammer stainless mill (Wiley, Philadelphia, PA). The samples were subjected to chemical analyses separately. To ensure quality control, the ground samples were stored separately in screw-capped bottles and stored in a refrigerator at -5°C until they were needed for analyses.

All the chemical analyses were done in triplicate and each followed the method of Association of Official Agricultural Chemists (AOAC) (1995). For the determination of total carotenoids, about 5 mg fresh sample for each treatment was weighed in triplicate and extracted in 50 mL of 80:20 v/v acetone using pestle and mortar. The extraction was repeated until a colourless residue was obtained and the mixture was filtered. The filtrates (extracts) were made up to 50 mL with acetone. One ml of the extract was taken and diluted to 10 mL using 80:20 v/v acetone and thereafter the concentration of carotenoids was measured at 440 nm using a UV-Visible spectrophotometer Model UV 1601 Version 2.40 (Shimadzu, Japan). The ether extract content was determined by Soxhlet extraction method. Nitrogen content was determined by the Kjedhal Method. The crude protein content was determined by multiplying the nitrogen value by factor 6.25. The moisture content was determined by drying 10.0 g of the ground samples in the oven at 80°C for 48 h. The proportional difference in weight converted to percentage was expressed as percent moisture content. The ash contents of the samples were obtained by digesting 5 g ground sample in a muffle furnace at 550°C for 6 h. The proportional difference in weight converted to percentage is expressed as percent ash content. The crude fibre was determined by digesting 5.0 g of the ground sample in 1.25% H_2SO_4 and 1.25% NaOH. The oxalate content was determined by using the HPLC method as described by Wilson *et al*. (1982). Calcium was determined by flame photometry. For total carotenoids determination 80:20 v/v acetone was used for extraction and the absorbance was measured at 440 nm using a UV-Visible spectrophotometer Model UV 1601 Version 2.40 (Shimadzu, Japan).

The ascorbic acid was determined by extracting 10 g of fresh sample in 90 mL distilled water for 1 h. The mixture was filtered and stored in at -5°C. A standard indophenol solution was prepared and

2 mL of it was filled in a burette while the 10 mL sample filtrate was filled in the burette. Titration was done and the titre value was used in calculating the ascorbic acid concentration.

Data collected were analyzed using analysis of variance (ANOVA) (Steele and Torrie, 1995). Means were separated using the least mean square analyses at 5% level of probability.

Results and Discussion

As shown in Table 1, the soils of the fallow upland (L_1) and fallow wetland (L_2) had higher contents of total N, available P, K, Ca, Mg and organic carbon compared to the soils of continuously cultivated lowland (L_3) and cultivated upland (L_4). The implication of this is that soils of L_1 and L_2 are richer compared to L_3 and L_4. Physical analyses also showed that L_1 and L_2 had lower sand contents when compared to L_3 and L_4. The implications of these observations are that soils of L_1 and L_2, having been under fallow for a long time, have better fertility, better aeration and water holding capacity compared to L_3 and L_4. The results obtained in this study therefore confirm previous studies on fallow land by Nye and Greenland (1960), Fasina (2003, 2004) among others.

Table 2 shows that L_1 produced statistically significant ($p \leq 0.05$) higher leaf yields for both vegetables and this is followed by L_2, L_3 and L_4 in that order. This study confirmed earlier report that the role of fallow phase is to facilitate the regeneration of soil productivity. This result shows that soil of L_4 was more depleted than all other land use types used for the study and this can be explained by the run-off that takes place frequently during rains from the upland to the lower slope. For each land use type, *C. argentea* (V_2) significantly out-yielded *A. cruentus* (V_1). The leaf yield of V_2 was 21.2, 22.2, 33.1 and 26.1% higher than V_1 at L_1, L_2, L_3 and L_4, respectively. The results of chemical analyses of the vegetables showed that significantly higher contents of total carotenoids, calcium, crude protein and ascorbic acid were recorded under L_1 followed by L_2 then L_3 and L_4 in that order. Statistical analyses showed that the total carotenoids, crude protein and calcium contents of V_1 were significantly higher than that of V_2 under all land use types. Comparison showed that the ether extract, crude fibre, ascorbic acid and oxalate composition of the two vegetables under each land use types did not differ significantly. The oxalate content of V_2 was numerically higher than that of V_1. Bear (1948) reported that there were many environmental and cultural factors that influence the nutritional composition of produce and these may ultimately play a greater role in food quality than simple organic versus conventional logic. Environmental conditions likely to affect food quality include geographical area, soil type, soil moisture, soil health (humus content, fertility, microbial activity, etc.), weather and climatic conditions (temperature, rainfall, flooding, drought) and pollution. According to Hornick (1992)

Table 1: Physical and chemical properties of the experimental plots

	L_1	L_2	L_3	L_4
pH (H_2O) 1:2	6.4	6.8	6.4	6.6
Organic Carbon (%)	0.98	0.98	0.74	0.76
Total N (%)	0.096	0.080	0.071	0.068
Available P (mg kg^{-1})	8.60	7.30	5.40	4.60
Exchangeable bases (cmol kg^{-1})				
K (cmol kg^{-1})	0.40	0.31	0.16	0.14
Ca (cmol kg^{-1})	0.57	0.48	0.45	0.46
Mg (cmol kg^{-1})	2.84	2.86	2.74	2.65
Sand (g kg^{-1})	78.2	79.0	82.4	81.0
Silt (g kg^{-1})	9.7	9.9	9.6	10.6
Clay (g kg^{-1})	12.1	11.1	9.0	8.4

Each value is a mean of triplicate laboratory analyses

Table 2: Influence of land use types on the leaf yield and chemical composition of *Amaranthus cruentus* and *Celosia argentea*

Land use Type		Total carotenoid (mg/100 g)	Leaf yield (t ha^{-1})	Calcium (mg/100 g)	Ether extract (g/100 g)	Crude protein (g/100 g)	Crude fiber (g/100 g)	Ascorbic acid (mg/100 g)	Oxalate (mg/100 g)
L_1	V_1	26.3	28.2	395	0.3	5.8	0.8	58.8	5.1
	V_2	21.1*	35.8*	361*	0.2ns	4.1ns	0.6ns	57.4ns	6.7ns
L_2	V_1	21.1	24.6	371	0.3	4.2	0.8	41.4	5.2
	V_2	17.4*	31.6*	335*	0.3ns	3.2ns	0.7ns	40.9ns	6.6ns
L_3	V_1	20.2	18.4	345	0.2	3.4	0.7	33.6	5.5
	V_2	16.8*	27.5*	311*	0.4ns	2.3ns	0.6ns	32.4ns	6.8ns
L_4	V_1	17.1	13.6	314	0.3	3.3	0.8	27.6	5.3
	V_2	12.8*	20.4*	305*	0.3ns	2.1ns	0.6ns	27.1ns	6.4ns

*, ns: indicate significant and non significant at 5% level of probability, respectively by Least Mean Square Analysis. All values were means of triplicates analyses

Table 3: Influence of fertilizer regimes on the leaf yield and chemical composition of *Amaranthus cruentus* and *Celosia argentea*

Fertilizer Regime		Total carotenoid (mg/100 g)	Leaf yield (t/ha^{-1})	Calcium (mg/100 g)	Ether extract (g/100 g)	Crude protein (g/100 g)	Crude fiber (g/100 g)	Ascorbic acid (mg/100 g)	Oxalate (mg/100 g)
Blanket	V_1	20.4	22.6	362	0.3	5.8	0.6	41.8	5.1
	V_2	18.2*	30.8*	341*	0.2ns	4.1*	0.6ns	41.4ns	6.7ns
Ff	V_1	28.4	26.6	398	0.3	7.2	0.8	59.4	5.2
	V_2	24.1*	37.6*	365*	0.3ns	5.2*	0.7ns	58.9ns	6.6ns
Control	V_1	16.4	14.9	334	0.3	3.8	0.4	37.6	5.3
	V_2	12.6*	18.4*	305*	0.3ns	2.1*	0.4ns	37.1ns	6.4ns

*, ns: indicate significant and non significant at 5% level of probability, respectively by Least Mean Square Analysis. All values were means of triplicates analyses

cultural practices likely to affect food quality include humus management techniques such as green manuring and composting, variety, seed source, length of growing season, irrigation, fertilization, cultivation and postharvest handling (especially temperature and relative humidity). Variation in the nutrient composition of the two vegetables was thought to be due to genotype.

Table 3 shows that the two vegetables produced significantly higher leaf yields at Ff (application based on soil test values) compared to the blanket and control treatments. Comparison showed that at Ff, V_1 produced 17.5 and 47.9% more leaf yield while V_2 also produced 14.6 and 46.0% more leaf yield than blanket and control fertilizer treatments, respectively. Except for the oxalate and ether extract contents, the plants under Ff had significantly higher contents of carotenoids, calcium, ascorbic acid, crude protein and crude fibre compared to plants under blanket and control treatments. Earlier studies on nitrogen (N) and phosphorus (P) agree that supplemental N and P are required for optimum yield of *A. cruentus* and *C. argentea* (Keskar *et al*., 1981; Subhan, 1989; Ramachandra and Thimmaraju, 1983). However, the N and P needed for the growth of a crop will vary depending on the N and P status of the soil and potential for mineralization. Therefore, optimum N and P amount reported for maximum growth by different researchers are substantially different. The reported range varies from 50-200 kg N ha^{-1} and 60-350 kg P ha^{-1}. Nitrogen fertilization applied at the rate of 90 kg ha^{-1} produced highest vegetable amaranth yields (Singh and Whitehead, 1996). The values of chemical composition recorded for the two vegetables were consistent with the values reported by Adebooye (1996) for some indigenous leaf vegetables of southwest Nigeria and those reported by Chweya and Eyzaigguire (1999) for *Solanum nigrum* L. The leaf yields are also consistent with those reported for some varieties of *A. cruentus* and *C. argentea* by Schippers (2000). The oxalate composition of these two vegetables are low and are in the range reported by Adebooye *et al*. (2005) for *Trichosanthes cucumerina* and Adebooye and Phillips (2006) for *Mucuna urens*. Low oxalate foods have been shown to contain less than 10 mg 100 g on dry matter basis (Adebooye *et al*., 2005). The implication of this oxalate content is that Ca and Mg in these plants will not be held in unavailable form in human digestive system. The results of this study showed that higher leaf yields and optimum nutrient composition of *A. cruentus* and *C. argentea* can be realized by a proper combination of land use type and fertilizer rates. The use of Fertilizer Factor (Ff) in determining nutrient amendment required for a particular soil provides a better picture of actual fertilizer rate required and also promotes higher vegetable leaf yield and quality.

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