Tropical and Subtropical Agroecosystems, 14 (2011): 251 - 260

GROWTH AND HERBAGE YIELD OF *Celosia argentea* AS INFLUENCED BY PLANT DENSITY AND NPK FERTILIZATION IN DEGRADED ULTISOL

[EL CRECIMIENTO Y RENDIMIENTO DE FORRAJE DE *Celosia argentea* ES INFLUENCIADO POR LA DENSIDAD DE SIEMBRA Y LA FERTILIZACIÓN CON NPK EN SUELOS ULTISOLES DEGRADADOS]

Kolawole E. Law-Ogbomo* and Peter A. Ekunwe

Department of Agriculture, Benson Idahosa University, PMB 1100, Benin City, Nigeria
**e-mail: kolalawogbomo@yahoo.com*
**Corresponding Author*

SUMMARY

The effect of five plant densities (8,0000, 160,000, 250,000, 444,444 and 1,000,000 plants ha^{-1}) and three levels of fertilizer (0, 200 and 400 kg NPK ha^{-1}) on growth and yield of *Celosia argentea* was evaluated on a degraded ultisol at Evboneka, Edo State, Nigeria in 2005 and 2006 cropping seasons. The trial was a 5 x 3 factorial arrangement fitted into a randomized complete block design in three replicates. Results revealed that plant density and fertilizer application affected significantly ($p < 0.05$) plant height, stem girth, number of leaves, leaf area index and total dry weight leading to higher herbage yield. Plants grown under high plant density and fertilizer application level had higher degree of foliation and total dry weight than plants grown under lower plant density and fertilizer application levels. The greatest yield (13.67 ton ha^{-1}) was produced from a population of 444,444 plants with 400 kg fertilizer rate. Production cost increased from US$79.57 to US$790.18, revenue from US$1,008.00 to US$2,460.60, gross margin from US$948.08 to US$2151.00, net income from US$928.43 to US$2,072.92 and benefit-cost ratio from 1.34 to 14.55 for the various treatment combinations. The best herbage yield was a population of 80,000 plants with 400 kg fertilizer rate, with the greatest benefit-cost ratio (14.55).

Keywords: Fertilizer application level, leaf area index, plant density, relative yield, total dry matter.

RESUMEN

El efecto de cinco densidades de siembra (8,0000, 160,000, 250,000, 444,444 y 1,000,000 plantas ha^{-1}) y tres niveles de fertilización (0, 200 and 400 kg de NPK ha^{-1}) sobre el crecimiento y rendimiento de *Celosia argentea* fue evaluado en un suelo ultisol degradado en Nigeria. La densidad y aplicación de fertilizante tuvieron efecto ($P<0.05$) sobre altura de la planta, grosor del tallo, número de hojas, índice de área foliar y total de materia seca, produciendo mayores rendimiento de hierba. Las plantas cultivadas bajo una alta densidad y aplicación de fertilizante a niveles elevaos tuvieron más follaje y materia seca. La mayor productividad (13.67 ton ha^{-1}) se obtuvo con una densidad de 444,444 con 400 kg de fertilizante. El costo de producción se incrementó de US$79.57 a US$790.18 y el beneficio de US$1,008 a US$2460.6, margen bruto de US$948.08 a US$2151.00, ingreso neto de US$928.43 a US$2,072.92 y la razón beneficio-costo de 1.34 a 14.55, para las diversas combinaciones. La mejor productividad se obtuvo con la densidad de 80,000 plantas con 400 kg de fertilizantes, con la mayor razón beneficio costo (14.55).

Palabras clave: Tasa de fertilización; índice de área foliar; densidad; producción relativa.

INTRODUCTION

Celosia argentea commonly known as pumped cockscomb is an edible species of the genus *Celosia* of the Amaranthaceae family. Its centre of origin is India. It is widely grown in gardens and other parts of West Africa. It is an erect, short-lived annual herb, which grows up to 150 cm in height. The leaves are alternate and are light green to dark green in the green forms. The leaves of red *C. argentea* are pink and have a prominent dark purple marking. The flowering spike is pink becoming white when the seeds reach maturity. It is propagated by seeds; these are black and about one millimeter in diameter (Remison, 2005). It is tolerant to a wide range of soil conditions. They grow best in full sunlight. A temperature range of 25 to 30^{0}C is suitable. Both green and red forms grow well at low altitudes, where temperature fluctuations are limited.

This leafy vegetable is an essential component of people's diet in Nigeria and other parts of West Africa.

The leaves and young shoots of both forms are used in soups and stews. The leaves contain high levels of calcium, phosphorus and iron. This plant is an important source of proteins, calories, vitamins and minerals (Akinyemi and Tijani-Eniola, 1997) that enrich the diet the people of West Africa. The crop is predominantly produced in Nigeria by resource-poor farmers and compound gardens where it is intercropped with arable starchy staples to produce enough food to satisfy their dietary and cash requirements (Akinyemi and Tijani-Eniola, 1997), and to minimize the risk of crop failure.

The average yield of this crop (7.60 ton ha^{-1}) has been limited by obsolete cultural practices employed in its production, such as low plant density and non-use of manure/fertilizer input among others (FAO, 2004). Under these conditions, crop plots require constant weeding with the consequent increase on the cost of production.

For commercial production, optimum performance of the crop must be desirable through changes in cultural practices (Sterrett and Savange, 1989) including higher planting density and soil fertilization of the crop, with NPK fertilizer to increase plant growth and crop yield. Higher crop yields are desirable due to the increasing pressure for non-agricultural use of the land that has drastically reduced the fallow periods. There is therefore, an important need to increase the productivity of the land through the application of organic manure and/or inorganic fertilizer. The nutrient source of each plant is determined by the plant density of the crop more than any other single factor. Plant density therefore, affects total dry matter production and partitions. With increase in plant density per unit area, there is a corresponding increase in competition for nutrients. However, higher planting density has been found to increase yield optimally (Tijani-Eniola, 2002).

The aim of this trial was to evaluate the effect of planting density and NPK fertilizer application on the growth and yield of *Celosia argentea*.

MATERIALS AND METHODS

The study was conducted at Evboneka, Nigeria, in April to July 2005, and November to February 2006. Benin City is located on Latitude $5^0 45'$ N and Longitude $5^0 04'$ E, characterized by a tropical climate, lies within the humid region. The area has a bimodal rainfall with mean annual total of 1762 mm and mean daily temperature of 26.5 ^{0}C (EADP, 1995). The study area lies within rainforest, which degraded to secondary forest as a result of shifting cultivation. The site was previously cultivated with yam, melon and cassava and later allowed to fallow for two years before it was used for the trial. The dominant fallow plant species on the land was guinea grass (*Panicum maximum*). A composite soil sample was collected at 0 to 30 cm depth from the site using an auger. The sample was air-dried for two weeks, sieved and routinely analyzed for the soil physical and chemical properties prior to planting using standard laboratory procedures described by Mylavarapus and Kennelley (2002). The land was manually cleared of the existing vegetation, burned and bed constructed. The raised seedbeds of 1.0 m width, 4.0 m long and about 0.3 m height were prepared using hoes and shades. There were four beds per plot during the two cropping seasons. Each plot was separated from the next by 1.0 m border row, while the blocks were separated by 2.0 m border rows. The experimental layout was a 5 x 3 factorial arrangement fitted into randomized complete block design with three replicates. A total of 45 plots were used for the trial. The *C. argentea* varietal “TLV 8” obtained from National Horticultural Research Institute (NIHORT) Ibadan, was sown in the raised seedbed in April and November of the same year and spaced at 25 x 50 cm; 25 x 25 cm; 20 x 20 cm; 15 x 15 cm and 10 x 10 cm to achieve plant densities of 80,000, 160,000, 250,000, 444,444 and 1,000,000 plants ha^{-1} (pph), respectively. A complete NPK 15:15:15 fertilizer was applied to the soil in three equal but split doses at four, eight and twelve weeks after sowing (WAS) at the equivalent rate in kg NPK ha^{-1} of 0, 200 (30.00, 13.58 and 24.90 kg of NPK) and 400 (60.00, 27.16, and 49.80 kg of NPK). Seedlings were thinned to one plant per stand at two WAS. Plots were weeded when necessary. Harvesting was done by uprooting five plants per plot taken at random at six, ten and fourteen WAS. At each harvest, plant height, stem girth, leaf area, fresh weight and total dry matter (biomass) of each sampled plant were measured. Plants were taken from the inner rows at each plot. Leaf area was determined by using the tracing method, which involves tracing leaf samples on centimeter graph paper (Remison, 1997). Leaf Area Index (LAI) was computed as:

$$LAI = \frac{L}{A} \text{ (Remison, 1997).}$$

Where: L = leaf area
A = land area

The productivity of treatment combination was determined by the Relative Herbage Yield Index (RHY):

$$RHY = \frac{WTC}{WC} \text{ (Remison, 1997).}$$

Where: WTC = Weight of treatment combination
WC = Weight of unfertilized 8000 pph.

Year-wise data were analyzed using analysis of variance, followed by combined analysis over the two years in GENSTAT version 8.1 (GENSTAT, 2005). Means were compared using Tukey’s test ($p > 0.05$).

Linear correlation linking variables were also computed using GENSTAT. Economic analysis was used to determine the cost and economic return for *C. argentea* production from treatment combinations. The net farm income (NFC or profit) is the difference between return (R) and the total cost of production (TC) (Olukosi and Erhabor, 1988).

NFC = R – TC

The model used for estimating net farm income can be expressed by the equation:

$$\text{NFI} = \sum_{i=1}^{n} P_{yi} Y_i - \sum_{j=1}^{m} P_{xj} X_j - \sum_{k=1}^{k} F_k$$

Where: NFI = Net farm income
Y_i = Enterprise's product(s) (where I = 1, 2, 3 …….n products)
P_{yi} = Unit price of the product
X_j = Quantity of the variable inputs (where j = 1, 2, 3…….m variable inputs)
F_k = Cost of fixed inputs
$\sum$ = Summation

The total variable cost (TVC) includes items like total cost of labor (land preparation, planting, weeding, fertilizer application and harvesting), fertilizer, planting materials and transportation. The total fixed cost (TFC) includes the cost of renting land, the depreciation of farm tools (like cutlasses and hoes) and the opportunity cost of capital.

RESULTS AND DISCUSSION

Physiochemical properties of soil

Results of soil analysis presented in Table 1 show a sandy loam slightly acidic (pH 6.20), containing low N, P, K, Ca and Mg with values below the critical level outlined by Ibedu *et al*. (1988). Plants growing on the characteristics of this ultisol (acidic sand) derived from coastal plain sand could not achieve optimum growth and yield without supplementary nutrients through the addition of fertilizers.

Growth parameters

The height of plant is an important growth character directly linked with the productive potential of a plant in terms of herbage. An optimum plant height is claimed to be positively correlated with productivity of the plant (Saeed *et al.*, 2001). In this trial, plant height generally increased progressively throughout the sampling periods. Plant height increased as plant density and fertilizer application increased at 10 and 14 WAS without declining (Table 2). A treatment combination of 444,444 pph and 400 kg NPK ha^{-1} had the tallest plants (Table 2). The results observed show that plant height is sensitive to adequate nutrient supply (Sharma, 1997) and light interception. However, plant height did not follow a definite trend as at six WAS, there was no significant ($p > 0.05$) difference among fertilizer application levels and plant densities (Table 2).

Changes in stem girth were significant ($p < 0.05$) as fertilizer application level and plant density increased throughout the sampling periods (Table 3). This observation is supported by work of Aliyu and Olanrewaju (1996) on *Capsicum annum*, where they observed that the beneficial effects of N, P and K could be seen in the increase of stem girth and thus interpreted as accumulative growth. Lower plant densities led to increase in the stem girth, where 1,000,000 pph had the thinnest stem girth while 80,000 pph had the largest stem girth throughout the sampling period. This was due probably to differences in improved light interception and utilization capacity of plants (Robert and Andrew, 1997).

Table 1: Physical and chemical properties of the experimental site before cropping with *C. argentea*

Soil properties	Results	Soil properties	Results
pH (H_2O)	6.20	Potassium	0.62
Organic carbon (%)	0.82	Exchangeable acidity	0.42
Total Nitrogen (%)	0.17	Base saturation	89.83
Available phosphorus (mg kg^{-1})	1.57	Particle size (g kg^{-1})	
Exchangeable cations (cmol kg^{-1})		Clay	66.00
Calcium	0.93	Sand	726.80
Magnesium	1.56	Silt	207.20
Sodium	0.60	Textural class	Sandy loam

Table 2: Plant height (cm) of *C. argentea* as influenced by NPK fertilization and plant density.

Plant Density (plants ha^{-1})	6 WAS Fertilizer application level (kg ha^{-1})				10 WAS Fertilizer application level (kg ha^{-1})				14 WAS Fertilizer application level (kg ha^{-1})			
	0	200	400	Mean	0	200	400	Mean	0	200	400	Mean
80,000	20.14^{d}	23.16^{d}	27.5^{bc}	23.60	60,00^{de}	63.13^{cd}	68.18^{bc}	65.10	82.15^{g}	92.60^{f}	103.75^{d}	92.83
160,000	17.05^{e}	25.17^{c}	29.25^{b}	23.92	59.40^{e}	65.03^{c}	70.00^{b}	64.70	80.16^{g}	92.60^{f}	115.70^{c}	97.15
250,000	17.15^{e}	26.15^{c}	26.51^{c}	23.27	55.00^{f}	62.85^{d}	71.16^{ab}	63.00	80.05^{g}	98.40^{e}	121.40^{b}	99.95
444,444	25.18^{c}	32.08^{ab}	34.18^{a}	30.48	52..50^{fg}	65.20^{c}	72.00^{a}	62.67	96.20^{f}	104.00^{d}	135.30^{a}	106.40
1,000,000	20.32^{d}	25.14^{c}	30.18^{b}	25.21	50.15^{g}	63.15^{cd}	70.30^{b}	61.77	80.40^{g}	120.00^{bc}	119.40^{bc}	119.30
Mean	19.97	26.34	29.52	25.28	56.21	63.86	70.33	63.47	83.79	102.12	119.03	101.65

WAS = Weeks after sowing

Means with the same superscript do not differ significant at 5% level of probability.

Table 3: Stem girth (cm) of *C. argentea* as influenced by NPK fertilization and plant density.

Plant Density (plants ha^{-1})	6 WAS Fertilizer application level (kg ha^{-1})				10 WAS Fertilizer application level (kg ha^{-1})				14 WAS Fertilizer application level (kg ha^{-1})			
	0	200	400	Mean	0	200	400	Mean	0	200	400	Mean
80,000	0.90^{c}	1.03^{a}	1.05^{a}	0.99	1.10^{e}	1.60^{b}	1.63^{a}	1.44	1.03^{d}	1.78^{a}	1.80^{a}	1.54
160,000	0.88^{cd}	1.02^{ab}	1.04^{a}	0.98	1.00^{e}	1.50^{ab}	1.54^{b}	1.35	1.00^{d}	1.75^{ab}	1.78^{a}	1.51
250,000	0.84^{d}	1.01^{b}	1.03^{a}	0.96	0.94^{fg}	1.40^{d}	1.43^{cd}	1.26	0.96^{d}	1.60^{b}	1.65^{b}	1.4
444,444	0.84^{d}	1.00^{b}	1.02^{ab}	0.95	0.92^{g}	1.46^{c}	1.49^{b}	1.29	0.95^{d}	1.50^{c}	1.53^{c}	1.33
1,000,000	0.72^{S}	1.00^{b}	1.03^{b}	0.92	0.97^{f}	1.43^{cd}	1.46^{c}	1.29	0.97^{d}	1.57^{c}	1.62^{b}	1.39
Mean	0.80	0.92	1.00	0.90	0.90	1.18	1.23	1.10	0.92	1.24	1.32	1.16

WAS = Weeks after sowing

Means with the same superscript do not differ significant at 5% level of probability.

Number of leaves increased progressively throughout the sampling period. Increasing plant density resulted in a greater the number of leaf per unit area (m^2). This effect was stronger at higher levels of fertilizer (Table 4). The increase in number of leaves was due to additional number of stands per unit area leading to additional number of leaves being produced from the extra stands. Changes in the number of leaves are bound to affect the general plant growth and vigor, as they are the major organs of photosynthesis of the plant. Increasing plant density resulted in plants producing smaller leaves, but the increase in fertilizer application level led to the production of wider leaves. Increasing plant density and fertilizer application level caused the production of larger sizes of leaves.

Leaf area index (LAI) increased as plant density and fertilizer application increased throughout the sampling periods except 1,000,000 pph which peaked at 10 WAS and declined thereafter (Table 5). The LAI of any plant is a measure of the capacity of the photosynthetic system and translocation. Increasing plant density augmented the LAI through the production of additional numbers of branches with nodes and leaves per unit area, while increasing fertilizer application level made it more pronounced through larger leaf size (leading to greater leaf area per stand), number of leaves, leaf area and length of vegetative growth phase (crop growth duration).

Total dry matter was increased as plant density and fertilizer application level augmented (Table 6). The total dry matter and LAI were positively correlated(r = 0.63, .0.62 and 0.65, $p < 0.05$) at six, ten and fourteen WAS, respectively. This implies that LAI resulting from increasing plant density and fertilizer application level led to higher total dry matter production, probably due to better utilization of solar radiation which favored photosynthetic capacity of the plant (Law-Ogbomo and Egharevba, 2008).

Herbage Yield

Different treatment combinations produced different herbage yield (Table 7). However, treatment combination of 444,444 pph and 400 kg NPK ha^{-1} consistently produced the best herbage yield (13.67 ton ha^{-1}). Combination of 444,444 pph and 200kg NPK ha^{-1} closely follow this (Table 7). An increase in plant density corresponded to an increase in herbage yield up to 444,444 pph. This finding is comparable with results obtained by Law-Ogbomo and Egharevba (2008) where high plant density favored vegetable growth. Low plant density is a common cause of poor fertilizer response (David, 1986). At low soil fertility levels, farmers tend to have fewer plants ha^{-1} so that each plant gets a better share of the scarce nutrients in the soil. However, if fertilization has been applied, low planting densities may result in underutilization of the added nutrients and thus in a failure to increase yield. As a result of this, there is need to increase planting density for efficient utilization of added nutrients when fertilizer is introduced in order to maximize yield. Nevertheless, if planting density is too high, even with abundant nutrients, due to insufficient light interception some plants may etiolate or use up of the limited soil moisture in drought-prone areas.

Relative Herbage Yield Index (RHY) values increased with plant density and fertilizer application level and ranged from 0.63 to 2.44. RY mean values peaked (2.44) at 444,444 pph and 400 kg NPK ha^{-1} treatment combination and declined thereafter (Table 7). This implies that RY increased at higher density provided the field is not overcrowded. The highest Relative Herbage Yield Index was obtained at a treatment combination of 444,444 pph and 400 kg NPK ha^{-1}. Relative Herbage Yield Index values were however below 1.00 where plant density was increased without corresponding fertilizer application.

Economic analysis

The gross margin, net return and benefit-cost ratio was highly influenced by plant density and fertilizer application. The total cost of production increased as plant density and fertilizer rate increased and ranged from US$79.57 to US$790.18, which is an indication of 830% difference between unfertilized 80,000 pph and 1,000,000 pph with 400kg (Table 8).

Table 4: Number of leaves of *C. argentea* as influenced by NPK fertilization and plant density.

Plant Density (plants ha^{-1})	6 WAS Fertilizer application level (kg ha^{-1})				10 WAS Fertilizer application level (kg ha^{-1})				14 WAS Fertilizer application level (kg ha^{-1})			
	0	200	400	Mean	0	200	400	Mean	0	200	400	Mean
80,000	19.30^{bc}	20.40^{b}	22.60^{b}	20.77	39.60^{f}	75.4^{g}	66.8^{g}	60.6	50.00^{e}	156.00^{c}	150.60^{cd}	118.69
160,000	20.40^{b}	21.30^{b}	23.90^{b}	21.87	41.30^{f}	80.10^{f}	71.70^{g}	64.37	46.40^{f}	158.00^{c}	160.10^{c}	121.5
250,000	20.40^{b}	25.40^{ab}	27.60^{a}	24.47	45.20^{f}	99.00^{c}	108.40^{b}	84.2	48.00^{f}	164.00^{c}	206.40^{b}	139.47
444,444	19.50^{bc}	25.50^{ab}	28.60^{a}	24.53	43.60^{f}	101.60^{c}	116.40^{a}	87.2	53.00^{e}	204.50^{b}	217.40^{a}	158.3
1,000,000	18.60^{c}	25.80^{ab}	29.40^{a}	24.6	40.60^{f}	76.00^{g}	92.00^{d}	69.53	43.00^{f}	146.00^{c}	164.10^{c}	117.7
Mean	19.64	23.68	26.42	23.25	42.06	86.42	91.06	73.18	48.08	165.7	179.6	131.13

WAS = Weeks after sowing
Means with the same superscript do not differ significant at 5% level of probability.

Table 5: Leaf area index of *C. argentea* as influenced by NPK fertilization and plant density**.**

Plant Density (plants ha-1)	6 WAS Fertilizer application level (kg ha^{-1})				10 WAS Fertilizer application level (kg ha^{-1})				14 WAS Fertilizer application level (kg ha^{-1})			
	0	200	400	Mean	0	200	400	Mean	0	200	400	Mean
80,000	1.45^{e}	3.40^{d}	3.80^{d}	2.88	1.48^{d}	3.91^{c}	4.10^{c}	3.16	1.50^{c}	4.34^{b}	4.65^{b}	3.5
160,000	1.40^{e}	3.80^{d}	4.03^{bc}	3.08	1.45^{d}	4.20^{c}	4.41^{c}	3.35	1.49^{c}	4.56^{b}	4.86^{b}	3.64
250,000	1.32^{e}	4.32^{bc}	4.68^{b}	3.44	1.41^{d}	4.98^{bc}	5.07^{b}	3.82	1.46^{c}	5.09^{ab}	5.06^{ab}	3.87
444,444	1.30^{e}	4.85^{b}	4.97^{ab}	3.71	1.39^{d}	5.42^{b}	6.48^{a}	4.43	1.44^{c}	5.02^{ab}	5.86^{a}	4.11
1,000,000	1.26^{e}	5.38^{a}	5.17^{a}	3.94	1.35^{d}	5.87^{ab}	6.33^{a}	4.52	1.42^{c}	5.01^{ab}	4.32^{bc}	3.58
Mean	1.35	4.35	4.53	3.41	1.42	4.88	5.28	3.85	1.46	4.80	4.95	3.74

WAS = Weeks after sowing
Means with the same superscript do not differ significant at 5% level of probability.

Table 6: Total dry matter (biomass) of *C. argentea* as influenced by NPK fertilization and plant density.

Plant Density (plants ha^{-1})	6 WAS Fertilizer application level (kg ha^{-1})				10 WAS Fertilizer application level (kg ha^{-1})				14 WAS Fertilizer application level (kg ha^{-1})			
	0	200	400	Mean	0	200	400	Mean	0	200	400	Mean
80,000	0.04^{ns}	0.08^{ns}	0.15^{ns}	0.12	0.08^{ns}	0.16^{ns}	0.24^{ns}	0.16	0.09^{d}	0.18^{c}	0.27^{a}	0.21
160,000	0.04^{ns}	0.11^{ns}	0.16^{ns}	0.1	0.07^{ns}	0.17^{ns}	0.26^{ns}	0.17	0.09^{d}	0.20^{c}	0.31^{a}	0.2
250,000	0.03^{ns}	0.11^{ns}	0.17^{ns}	0.1	0.07^{ns}	0.17^{ns}	0.27^{ns}	0.17	0.08^{d}	0.20^{c}	0.33^{a}	0.2
444,444	0.03^{ns}	0.13^{ns}	0.20^{ns}	0.12	0.06^{ns}	0.20^{ns}	0.24^{ns}	0.17	0.07^{d}	0.23^{c}	0.37^{a}	0.22
1,000,000	0.03^{ns}	0.12^{ns}	0.21^{ns}	0.12	0.06^{ns}	0.19^{ns}	0.26^{ns}	0.17	0.09^{d}	0.23^{c}	0.34^{a}	0.22
Mean	0.03	0.13	0.18	0.11	0.07	0.18	0.25	0.17	0.08	0.21	0.32	0.21

WAS = Weeks after sowing
Means with the same superscript do not differ significant at 5% level of probability.
ns = Not significant

Table 7: Herbage yield and relative herbage yield of C. *argentea* as influenced by NPK fertilization and plant density.

Plant Density (plants ha^{-1})	Herbage yield (t ha^{-1}) Fertilizer application level (kg ha^{-1})				Relative herbage yield Fertilizer application level (kg ha^{-1})			
	0	200	400	Mean	0	200	400	Mean
80,000	5.60^{e}	7.00d	7.90^{d}	6.83	1.00^{f}	1.25^{df}	1.41^{d}	1.22
160,000	5.20^{e}	7.97^{d}	9,00^{c}	7.39	0.93^{f}	1.42^{d}	1.61^{c}	1.32
250,000	4.64^{ef}	8.10^{cd}	9.27^{c}	7.34	0.83^{fg}	1.45^{d}	1.66^{c}	1.31
444,444	3.76^{f}	12.40^{ab}	13.67^{a}	9.94	0.67^{g}	2.21^{ab}	2.44^{a}	1.77
1,000,000	3.52^{f}	9.10^{c}	11.17^{b}	7.93	0.63^{g}	1.63^{c}	2.00^{b}	1.42
Mean	4.54	8.91	10.20	7.89	0.81	1.59	1.82	1.41

WAS = Weeks after sowing
Means with the same superscript do not differ significant at 5% level of probability.
ns=not significant

Table 8: Economic analysis of the effect of plant density and fertilizer rate on the performance of *C. argentea*

Items	Plant density (plants per hectare)								
	80,000			100,000			250,000		
	Fertilizer rate (kg ha^{-1})								
	0	200	400	0	200	400	0	200	400
Output (t ha^{-1})	5.60	7.00	7.90	5.20	7.97	9.00	4.64	8.11	9.27
Revenue ($0.18 kg^{-1})	1,008.00	1,260.00	1,422.00	936.00	1,434.60	1,620.00	835.20	1,459.80	1,668.60
Total variable cost ($)	59.92	67.20	74.47	83.49	98.04	122.58	130.45	153.18	175.91
Total fixed cost ($)	19.65	21.38	23.29	21.12	24.03	28.39	33.00	38.30	44.36
Total cost ($)	79.57	88.58	97.76	104.61	122.07	140.97	163.45	191.48	220.27
Gross margin ($)	948.08	1,192.80	1,347.53	852.51	1,336.56	1,507.42	704.75	1,306.62	1,492.69
Net profit ($)	928.43	1,171.42	1,324.24	831.39	1,312.53	1,479.03	671.75	1,268.32	1,448.33
Benefit-cost ratio	12.67	14.22	14.55	8.95	11.75	11.49	54.11	7.62	7.58

Items	Plant density (plants per hectare)					
	444,444			1,000,000		
	Fertilizer rate (kg ha^{-1})					
	0	200	400	0	200	400
Output (t ha^{-1})	3.76	12.40	13.67	3.52	9.10	11.17
Revenue ($0.18 kg^{-1})	676.8	2,232.00	2,460.60	633.60	1,638.00	2,106.00
Total variable cost ($)	229.60	269.60	309.60	340.00	521.82	612.73
Total fixed cost ($)	58.08	66.08	78.08	132.00	150.18	177.45
Total cost ($)	287.68	335.68	387.68	472.00	678.00	790.18
Gross margin ($)	447.20	1,962.40	2,151.00	293.60	1116.18	1493.27
Net profit ($)	389.12	1,896.32	2,072.92	161.60	966.00	1315.82
Benefit-cost ratio	3.35	6.65	5.35	1.34	2.42	2.67

Assumption for economic analysis: Exchange rate, N 110 = US$1 at the time of trial

The accrued revenue ranged from US$1,008.00 and US$2,460.60, which is an indication of 144% difference between unfertilized 80,000 pph and 444,444 pph fertilized with 400 kg (Table 8). In general, revenue increased as plant density and fertilizer rate increased up to a population of 444,444 plants fertilized with 400 kg NPK, but declined thereafter. The gross margin and net returns followed the same trend as the total cost and revenue. The population of 444,444 plants with 400 kg fertilizer rate had the highest gross margin and net profit of US$2,151.00 and US$2,072.72, respectively.

Benefit-cost ratio (BCR) is an indication of the return per US dollar invested and was greater than 1.00 at all plant density and fertilizer rate combinations. The population of 80,000 plants with 400 kg fertilizer rate had the highest BCR of 14.55. This implies that maximum yield does not indicate maximum profit (Doll and Osazem, 1957). These findings also imply that profitable crop production depends on adequate essential nutrients and plant density but not excessive plant stands.

CONCLUSION

NPK and planting density have a profound effect on the overall performance of *A. argentea* in Evboneka, Nigeria, a humid forest zone. Best herbage yield (7.90 ton ha^{-1}) and benefit-cost ratio (14.55) were recorded with 80,000 pph and 400 kg NPK ha^{-1}.

REFERENCES

Aliyu, L. and Olanrewaju, J.D. 1996. Response of pepper to fertilizers. Nutrient concentration and uptake as affected by nitrogen and phosphorus level. In: Proc. 14th Horton Conference, Ago-Iwoye, 1-4 April 1996.

Akinyemi, S.O.S. and Tijani-Eniola, H. 1997. Effects of cassava density on productivity of productivity of plantain and cassava intercropping system. Fruits 50 : 17-23.

David, L. 1986. Soils, Crops and fertilizer use: A field manual for development worker. Peace Corps of the United States of America. Information, collecting and exchange. 338 p.

Doll, J.P. and Osarem, F. 1957. Production economic theory with application. Macmillian Publisher, London. pp. 58-59.

EADP (Edo State Agricultural Development Project). 1995. Edo State Agricultural Development Project Annual Report. 1995.

FAO. 2004. Food and Agriculture Organisation statistical database. FAOSTAT website, http//faostat.fao.

Genstat 2005. Gentstat Release 8.1. Statistical Software. VSN International Ltd, Rothamsted, UK.

Ibedu, M.A., Unambra, R.P.A. and Udealor, A. 1988. Soil management strategies in relation to farming system development in the south eastern agricultural zone of Nigeria. Paper presented at the National Farming System Research Workshop, Jos, Plateau State, Nigeria. pp. 26-29.

Law-Ogbomo, K.E. and Egharevba, R.K.A. 2008. Effects of planting density and NPK fertilizer on growth and fruit yield of tomato (*Lycospersicon esculentum* Mill). Research Journal of Agriculture and Biological Sciences 4: 265-272.

Mylavarapus, R.S. and Kennelley, D.E. 2002. UF//IFAS extension soil testing laboratory (ESTL): Analytical procedures and training manual. Institute of Food and Agricultural Science, University of Florida, Gainsville, USA. 28 pp.

Olukosi, J.O. and Erhabor, P.O. 1988. Introduction to farm management-economic; principles and application. AGITAB Publisher, Zaria, Nigeria. pp: 48-56.

Remison, S.U. 1997. Basic principles of crop physiology. Sadoh Press. Benin City, Nigeria. pp: 163.

Robert, K.M. and Andrew, W. 1997. An introduction to the physiology of crop yields. John Wiley and Sons Inc. New York.

Saeed, I.N, Abbasi, K. and Kazim, M. 2001. Response of maize (*Zea mays*) to nitrogen and phosphorus fertilization under agro-climatic condition of Rawalokot Azad Jammu and Kashmir. Pakistan Journal Biological Sciences. 4: 53-55.

Sharma, R.A. 1997. Influence of conjunctive uses of organic and fertilizer nutrients on nutrient uptake and productivity of soyabean-sunflower cropping sequence in typic chromusterts. Crop Research, 13: 321-325.

Sterrett, S.B. and Savange, G.P. 1989. Culinary herbs as alternative crops. The Vegetable Growers News, 42: 3-4.

Tijani-Eniola, H. 2002. Influence of seedbed type and crop density on the yield performance of *Celosia argentea* (I). Proceedings of the 20th Annual Conference of the Society of the Horticultural Society of Nigeria. pp: 30-35.

Submitted January 21, 2010 – Accepted June 28, 2010
Revised received June 28, 2010