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Influence of Intercrop Population and Applied Poultry Manure Rates on Component Crops Productivity Responses in a Snake Tomato/Celosia Cropping System

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Abstract

Productivity responses using organic approaches will assist to elucidate crop responses under different intercrop population levels. Experiments were conducted to determine the growth, yield and productivity responses of component crops in snake tomato/celosia mixtures to intercrop population and organic manure application rates. The 4 × 4 factorial experiment arranged in completely randomized design (CRD) was replicated three times. The snake tomato using potting media was cultivated in 2013 and 2014 at 100,000 plants/ha (one plant/pot) alongside intercrop celosia at three population levels of 100,000 (P1), 200,000 (P2) and 300,000 plant/ha (P3) (10, 20 and 30 plants/pot respectively) where sole crops (P0) served as control. The crop mixture was supplied with poultry manure (PM) at 5 (F1), 10 (F2) and 20 t/ha (F3) using the unfertilized (0 t/ha-F0) as control. The result showed that plants in "year II" had longer vines, thicker girth and more side-vines while those in "year I" had more leaves, more male/female flowers, longer and thicker fruit sizes and heavier fruit yield. Intercropping with celosia at P1 produced plants with thicker girth and more leaves, plants at P1 - P3 had more side-vines while all intercropped plots had more female flowers, but P1 had thicker fruit girth compared to sole crops. Plants with F3 had longer vine length, more leaves and more number of side-vines, more female flowers, longer fruits, thicker fruit girth and heavier fruit yield, but those with F1 or F3 had thicker girth compared to other rates while those with F2 had better productivity advantage with LER and ATER at >1.0. In conclusion, snake tomato and celosia in crop mixture were best with F2 and F3 respectively, although intercropping retarded growth and yield of the component crops but P1 was comparable with sole.

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Keywords

Celosia, Growth, Intercrop Population, Productivity Indices, Snake Tomato, Yield

1. Introduction

Snake tomato (*Trichosanthes cucumerina*) is one among the many traditional food plants that have been widely documented as the major sources of nutrition for rural dwellers that cannot pay for milk and egg [1]. The crop has been listed among the lost crops [2] and categorized among the under-utilized indigenous edible plant species that are important to the livelihoods of local population [3]. The snake tomato utilized for the leaf and fruit as vegetables contain many antioxidant components which as good sources of natural antioxidants in the human diet, provide protection against harmful free radicals. These natural antioxidants have been strongly associated with reduced risk of chronic diseases, and age-related functional decline in addition to other health benefits [4] [5]. The medicinal importance of the plant also includes uses as a therapeutic agent for AIDS [6], as a tonic and in curing coughs while the seeds are used as purgative, anthelmintic and in the treatment of syphilis [7].

Among the important qualities is the crop great potential to replace the conventional Lycopersicon tomato owing to the rich pulp which apart from being a good source of ascorbic acid can be blended as a puree or tomato paste used in household cooking [8]. The seed, a good source of edible oil [9] with the rich content of 26.2% - 26.6% crude protein and 44.6% - 57.7% fat [8] contains antioxidants, such as, caroteniods, flavorioids, lycopene, phenolics and β-carotene which helps in protection against diseases like cardiovascular, diabetes, and so on [10]-[14], but unlike most oil producing crops, both the pulp and the seed are nutritionally useful. More importantly the Compound Q, the drug for treating HIV infected patients, is a refined protein called trichosanthin which is derived from the trichosanthes (snake gourd) family and has been shown to possess the ability to reduce viral activity and improve certain symptoms in healthy AIDS-related complex (ARC) patients and HIV + asymptomatics which has positively demystified the dreaded disease [15].

Multiple cropping the agricultural practice that results in more than a single crop being harvested from a field during one year has such advantages as increased total production per unit year, improved cash flow, and improved water and N use efficiency thus preventing loss during non-crop period [16], which have been attributed to greater long-term yield stability, a more efficient utilization of finite resources such as light, nutrients and water, and reduced weed, insect and disease pressure [17]. In multiple cropping systems, however, there is a distinct difference between intercropping and mixed cropping practices. Thus while mixed cropping deals with two or three subsidiary crops sown with the main crop in a fixed ratio, intercropping deals with short duration crops raised in a long duration main crop without any reduction in the population of the main crop [16]. Thus the main principle involved is that the intercrops are complementary and will not in any way adversely affect the main crop or become competitive with the main crop for the required growth resources. [18] cited by [19] reported that peasant farmers in the humid tropics in the practice of multiple cropping allocate optimum space to long duration crops such as tree crops, or yam or cassava which are regarded as major economic crops in intercropping systems while minor crops with relatively lower monetary value per hectare such as early maturing, cereals, legumes, fruit and leaf vegetables are introduced in the early growth stage of the major crop to complement it in the utilization of growth resources.

The beneficial effects of intercropping systems compared to sole cropping have been widely reported by many workers [16] [20] [21]. Moreover, intercropping offers the tropical farmers an early income from the annual vegetable intercrops before the main crop is harvested [22] [23]. [24] observed that annual vegetable crops such as celosia, okra and pepper occupy valuable ecological niche in tropical agriculture and play significant roles in the eco-physiology of mixed systems. Nonetheless, studies on mixed cropping have indicated that intercropping systems despite the reduced individual crop performances of component crops [25] not only produced more overall yield because of more efficient utilization of environmental resources compared to sole cropping [22] [26]-[30], but is also very advantageous in the maintenance of soil fertility through effective soil cover and amelioration of the environment [29]-[32]. However, [33] observed that LER was greater than unity, and that LEC and ATER values followed a trend similar to that of LER, thus demonstrating yield advantages for the intercropped plots. The important criteria therefore involved in making comparisons among intercropping systems and in comparing them with sole cropping are varied and include such indices as land equivalent ratio LER [34]-[36], aggressivity [37], relative crowding coefficient RCC [38], area × time equivalent ratio ATER [39], land equivalent concept LEC [40], area harvest equivalency ratio AHER [41], monetary equivalent ratio MER [19], and others.

Although intercropping is practiced with the sole aim of maximizing plant cooperation in order to maximize crop yields [42], nonetheless in intercropping systems, a component crop is often affected by an array of environmental factors while the other component crop has the ability to directly or indirectly alter some subset of that array. In the case of fertilizer trials, the amount of nutrient concentration available to a component crop is partly the result of the actions of the second component crop [43]. In such a case, the second component crop has a competitive effect on the environment while the first component crop responds to that effect indicating that through nutrient extraction, a slightly depleted environment is created which affects the growth and yield responses of the first component crop. Moreover, aside the macro-environmental variation, [44] cited by [45] observed that a micro-environment exist where competing plant species coexist having vertical leaf profiles that overlap with both plant species shading each other as well as themselves. In such a case either through horizontal space or time, a vertical gradient of light intensity is created by the plant leaves that form the foliage canopy. [46], also observed that when one component is taller than the other in an intercropping system, the taller component intercepts major share of the light such that growth rates of the two component crops will be proportional to the quality of the photo-synthetically active radiation they intercepted.

Celosia argentea, with the generic name derived from the Greek word (Kelos) meaning “Burned” that refers to the flame-like flower heads, has dark-green or red coloured leaves which are valued for promoting physical stamina in human because of it richness in nutritive value they can likely play a part in reducing chronic malnutrition [47]. The fresh young leaves, stems and young flower spikes are used to produce a nutritious and tasty soup: especially in West Africa. [24] had stated that vegetables such as leafy (celosia and amaranthus) or fruit types (okra and pepper) occupy a valuable ecological niche in tropical agriculture and play significant roles in the eco-physiology of mixed systems. Moreover, celosia competes better with weeds and tolerates dry soil better than other vegetable crops and also it responds well to nutrients or fertilizer (organic).

Organic agriculture includes such agricultural practices which utilize natural (non-synthetic) nutrient-cycling processes; that exclude or rarely use synthetic pesticides; to sustain or regenerate soil quality, like the use of cover crops, manures, compost, crop rotation, intercropping, and biological pest control [48]. Many castoff resources possess great amount of nutrient that can be used as organic manure and these abound in great quantities as city waste but may become pollutants especially to water environment if not properly recycled, [49]. However, due to the bulky nature of organic manure, the application to field may attract great transportation costs but the method is regarded as a safer source of nutrients compared to conventional fertilizers as they are environment friendly materials that through the activation of soil microbial activities releases nutrients in a slow and steady manner to crops [50]. Also, the application of organic manures sustain cropping systems through better nutrient recycling and improvement of soil physical, chemical and biological properties. Despite the numerous benefits of organic manure application, critics have argued that there are insufficient organically acceptable fertilizers to produce enough organic food without substantially increasing the land area devoted to agriculture while also organic crop production is still lacking in terms of yield security and production cost compared with conventional and integrated crop production [51], however, when practiced on long duration, the direct and indirect effects could contribute to better crop yield on a sustainable basis compared to obtainable under conventional farming.

Moreover, the good food value of snake tomato plant is an indicator that its cultivation and utilization should be promoted [8] [52], hence to promote its cultivation, there is the need to develop agronomic practices package that farmers would need [53]. Most previous works mainly considered the proximate analysis and nutritional benefits of the crop [8] [53], and crop response to inorganic fertilizer rates [54] [55]. There is need therefore to evaluate the crop responses to intercrop population when in crop mixture with celosia and the optimum manure application rates in the bid to proffer a valuable agronomic package for snake tomato production and thereby enhance the productivity. The general objective is to determine the interactive effects of cropping system at different population level and manure application effects on the crop mixture. The specific objectives include determination of the optimum intercrop population and best manure rate for a sustainable production system in snake tomato/celosia mixture.

2. Methods

2.1. Description of Experimental Site

Experiments were conducted in 2013 and 2014 at the Federal University of Agriculture Abeokuta (FUNAAB), Nigeria (latitude 7˚12'N, longitude 3˚20'E) at altitude 100m above sea level using the potting media. The environmental condition of the experimental site is described in **Table 1**. The year one had an annual rainfall of 906.0 mm and in year two it was 1068.2 mm, where the maximum temperature was 32.06˚C and 31.8˚C in 2013 and 2014 respectively, and the minimum temperature was 22.9˚C and 22.98˚C respectively. However, for the duration of the experiment, the rainfall in year I was 246.0 mm while in year II it was 384.3 mm, the maximum temperature was 31.2˚C and 30.9˚C in 2013 and 2014 respectively, while the minimum temperature was 23.0˚C and 22.4˚C respectively. The analysis of the physico-chemical properties of the soil and of the poultry manure shown in **Table 2** describe the fertility status of both the soil and manure used in the experiment.

2.2. Description of Test Crop

The test crops include snake tomato (*Trichosanthes cucumerina*), and Celosia (*Celosia argentae*). The snake tomato a member of the botanical family Cucurbitaceae is cultivated as an annual but minor vegetable crop in Southern Nigeria. The drought hardy, 3 - 4 months duration crop, a climbing vine often left trailing on fences grows as an annual vegetable crop and bears long snake-like fruits [56]. The crop variant used for the experiment is of the Iwo landrace described as belonging to the third morphotype [57]. Celosia is an annual herbaceous vegetable of the family Amaranthaceae, it is a productive leafy vegetable although is sometimes used elsewhere as ornamental plant to beautify the environment but is cherished in the tropical Africa as a nourishing food item in local diet.

2.3. Research Design, Treatments and Treatment Combinations

The factorial experiments conducted in 2013 and 2014 were arranged in completely randomized design (CRD) at three replications. Seed of snake tomato (*Trichosanthes cucumerina*) obtained from a backyard farm in Iwo,

Table 1. Weather data showing the rainfall (mm), relative humidity (%) and maximum/minimum temperature (˚C), observed under experimental periods.

Weather Data in 2013/2014								
Months	R/Fall (mm)		R/Humidity (%)		Max Temp (˚C)		Min Temp (˚C)	
	2013	2014	2013	2014	2013	2014	2013	2014
Jan	39.8	8.2	51.6	59.35	36.0	34.2	21.6	23.6
Feb	23.5	15.5	57.5	53.35	35.4	35.2	23.9	23.4
Mar	78.1	149.1	63.2	59.05	34.9	34.0	24.6	23.6
Apr	82.4	87.2	64.1	65.7	31.4	32.9	23.2	23.5
May	128.2	113.8	71.1	67.7	32.1	32.1	23.5	23.4
Jun	**53.7**	**116.5**	**71.0**	**64.35**	**31.1**	**32.5**	**23.3**	**23.4**
Jul	**202.6**	**90.7**	**76.2**	**68.8**	**28.7**	**29.9**	**22.3**	**23.3**
Aug	**35.2**	**92.7**	**71.7**	**70.35**	**28.6**	**29.1**	**20.0**	**22.1**
Sep	136	160.8	69.6	71.05	28.9	29.8	22.4	22.7
Oct	94	208.9	67.2	70.15	31.7	30.5	23.1	22.0
Nov	15.6	17.6	60.0	67.25	33.1	32.4	23.5	22.6
Dec	16.5	0.0	58.5	56.8	33.0	34.6	22.4	19.8
Total	291.5	299.9	- -	- -	- -	- -	- -	- -
Mean	- -	- -	73.0	67.8	29.5	30.5	21.9	22.9

Months and figures in bold indicate the period of study and data values that were obtained for the experiment in 2013 and 2014. Source: Ogun Oshun River Basin Authority, Abeokuta, Nigeria.

Table 2. The Physico-chemical properties of the soil and manure used.

Parameters	Soil Sample		Poultry Manure
	Experiment I	Experiment II	
pH (H_2O)	7.75	7.72	
Fe ($mg \cdot kg^{-1}$)	0.87	0.92	4.8
Ca ($cmol \cdot Kg^{-1}$)	3.48	1.66	0.97
Mn ($mg \cdot kg^{-1}$)	23.5	32.9	12.4
Mg ($cmol \cdot Kg^{-1}$)	0.52	0.18	0.90
Na ($cmol \cdot Kg^{-1}$)	0.35	0.43	0.78
K ($cmol \cdot Kg^{-1}$)	0.31	0.15	0.33
CEC ($cmol \cdot Kg^{-1}$)	29.0	40.2	
Organic matter (%)	1.86	0.76	
Nitrogen (%)	0.08	0.055	4.89
Avail. P ($mg \cdot kg^{-1}$)	6.74	10.05	0.53
Sand (%)	61.20	73.40	2.20
Silt (%)	22.00	14.60	
Clay (%)	16.80	7.30	
Textural Class	Fine loamy	Sandy	

Nigeria was sown into nursery bags and later transplanted into 10 kg sized bags which were arranged at a spacing of 1 m by 1 m. The seeds which were sown on the 13th May, in 2013 and transplanted at the rate of one plant per pot in June, 2013 when they have attained 3 - 4 full leaves stages at two weeks-age after germination had a repeat experiment the following year to validate the earlier result and determine the effect of season on crop mixture. The seeds of the repeat experiment were sown on 15th May, 2014 and transplanted in June same year. The experiment, in a 4 × 4 factorial arranged in completely randomized design (CRD) considered the response of snake tomato to crop mixture with celosia at four intercrop population levels when supplied with four levels of manure application rates at three replications. The main crop snake tomato was planted at the population of one plant per pot while the intercrop celosia was sown by broadcasting into the pots same time as the main crop which were later thinned to 10, 20 and 30 plants per bag at the population rate of 100,000, 200,000 and 300,000 plants per hectare where a sole crop of both snake tomato and celosia served as control experiment. The manure was applied using the furrow slide formula to obtain the manure rate at 5, 10 and 20 t/ha where the unfertilized 0 t/ha served as control. The well decomposed poultry manure obtained from the Teaching and Research Farm of FUNAAB was thoroughly mixed at the time of potting the soil media.

2.4. Field Management Practices and Harvest Methods

Plants were maintained with poultry manure application applied to soil at bagging two weeks before the seedling transplant. The fruits were harvested when matured indicated by the level of firmness of the fruit. A fruit is considered ripe when firmness begins to reduce (that is fruit soften) or when the green colour of the fruits begins to change to yellowish or orange colour. The celosia was harvested by total uprooting at 4 weeks age and weighed for total biomass per plant using five plants at random sampling. Agronomic practices of weeding at regular two weeks intervals and watering at every three days interval to sustain plants were done. Pest and disease were controlled according to the method described by [58].

2.5. Productivity Indices and Competitive Effects of Component Crops

The crop productivity using fruit weight of snake tomato and plant fresh biomass as the yield of celosia was evaluated using the following productivity indices. These indices not only evaluate competitive effects of component crops in intercropping systems but also highlighted and described the nature of the competition.

1) Land equivalent ratio LER

$$= \frac{\text{Yab}}{\text{Yaa}} + \frac{\text{Yba}}{\text{Ybb}}$$

where Yab and Yba are the individual crop yields in intercropping and Yaa and Ybb are the yields in sole crop [34] [35].

2) Land equivalent coefficient LEC

$$= \text{LA} \times \text{LB}$$

where LA = LER of main crop and LB = LER of intercrop [40].

3) Area × Time Equivalent Ratio ATER

$$= \frac{(\text{Rya} \times \text{ta}) + (\text{Ryb} \times \text{tb})}{\text{T}}$$

where Ry = Relative yield of intercrop/yield main crop, *i.e.* species "a" or "b", t = duration (days) for species "a" or "b" and T = duration (days) of the intercropping system [39].

4) Agressivity, Aab

$$= \left(\frac{\text{Yba}}{\text{Ybb} \times \text{Zba}} - \frac{\text{Yab}}{\text{Yaa} \times \text{Zab}} \right)$$

where, Yab and Yba are the individual crop yields in intercropping and yaa and ybb are their yields in sole crop. Zab and Zba were proportion of land area occupied in intercropping when compared to sole crops for species "a" and "b" respectively [37].

5) Relative crowding coefficient RCC

$$\text{RCC} = \text{Kab} \times \text{Kba}$$

where, $\text{kab} = \frac{\text{Yab}}{\text{Yaa} - \text{Yab}}$, $\text{kba} = \frac{\text{Yba}}{\text{Ybb} - \text{Yba}}$.

Kab and Kba are the RCC for species "a" and "b" respectively [38].

2.6. Data Collection and Analysis

Data collection and analysis was done on both vegetative and reproductive growth parameters of both component crops. The vegetative growth obtained for snake tomato included weekly measurement of main vine length (cm), weekly count of number of side vines, and number of leaves. The snake tomato reproductive growth obtained on daily/weekly basis beginning at 6 weeks after transplanting (WAT) was measured using daily count of male/female flowers, weekly and cumulative count at harvest times of number of fruits, the cumulative weight of fruits (g/plant) and final fruit yield (t/ha). The vegetative growth of celosia was measured using plant height (cm), stem girth (cm) and number of leaves. The celosia yield of plant fresh biomass at 4 weeks using total uprooting of plants was obtained by measurement of five plants selected by random sampling and taking the mean as data for analysis. The data collected were subjected to statistical analysis of variance (ANOVA) [59] for the 4 × 4 factorial experiment and the means were separated by least significant difference (LSD) [60]. The graphical trends and correlation/regression analysis were done to describe the various trends and relationships using Excel package and the SAS package [61] respectively.

3. Result

3.1. Vegetative and Reproductive Growth Responses

The crop yield responses observed for both component crops in response to seasonal variation showed that more yield retardation occurred for snake tomato compared to celosia. Seasonal variation had significant influence on vegetative growth where plants cultivated in year II obtained longer vines, thicker girth, and more side-vines compared to those in year I, which however, obtained more leaves compared to obtainable in year II (**Table 3**). Seasonal variation had significant influence on reproductive growth where plants in year II recorded higher total male flowers (TMF), total female flower (TFF), fruit length (FL), fruit circumference (FC) and fruit yield values

Table 3. Growth and yield responses of snake tomato to intercropped celosia population and manure application rates.

Treatments	Vegetative Growth			Reproductive Growth						
								Fruit Size		
	Vine Length (cm)	Stem Girth (cm)	No. of Leaves	No. of Side-Vines	No. of Male Flowers	No. of Female Flowers	No. of Fruits	Fruit Length (cm)	Fruit Circumference	Fruit Yield (t/ha)
	$10^{\dagger}$	$11^{\dagger}$	$11^{\dagger}$	$11^{\dagger}$	$13^{\dagger}$	$13^{\dagger}$	$13^{\dagger}$	$13^{\dagger}$	$13^{\dagger}$	$13^{\dagger}$
Season										
Year I	168.	0.60	57.0	2.0	48.3	2.8	3.1	44.0	24.0	1.2
Year II	283.0	0.70	49.3	3.5	5.6	1.8	2.9	24.5	15.6	0.4
LSD	26.0	0.03	3.8	0.6	6.2	0.4	ns	9.0	4.5	0.2
Intercrop Population										
NC (no intercrop)	178.2	0.62	43.3	2.1	16.0	1.5	2.7	35.1	19.8	1.3
10PC (100,000)	255.5	0.67	56.0	3.0	14.9	2.4	3.6	39.8	24.2	0.7
20PC (200,000)	217.5	0.65	55.8	3.1	34.7	2.6	3.0	32.3	17.4	0.5
30PC (300,000)	252.4	0.66	53.7	2.8	42.2	2.7	2.5	29.8	17.8	0.5
LSD	ns	0.05	5.4	0.8	8.7	0.6	ns	Ns	6.4	0.2
Manure Rate										
0 t/ha PM	208.0	0.61	48.9	2.5	15.6	1.8	3.0	20.4	11.2	0.3
5 t/ha PM	232.4	0.69	52.4	2.4	26.6	2.2	2.3	33.5	18.2	0.6
10 t/ha PM	209.8	0.62	50.9	2.5	32.3	2.1	2.6	42.3	21.2	0.8
20 t/ha PM	253.4	0.69	60.5	3.7	33.3	3.0	3.9	40.7	28.7	1.4
LSD	36.7	0.05	5.4	0.8	8.7	0.6	ns	12.7	6.4	0.24
Interaction										
S × P	*	Ns	ns	ns	**	**	ns	ns	**	**
S × M	ns	*	**	ns	**	**	ns	*	**	**
P × M	ns	Ns	*	ns	**	Ns	ns	ns	Ns	**
S × P × M	ns	Ns	ns	ns	*	Ns	ns	ns	Ns	**

ns = not significant; * = significant at 0.05, ** = significant at 0.01, † = weeks after transplanting.

compared to those in year I, although no significant difference was obtained in the number of fruits (**Table 3**). The seasonal variation effect had its toil more on snake tomato crop yield which had a decreased in year II compared to celosia that obtained no significant difference in crop yield for both years (**Figure 1**).

Significant influence of intercrop presence on snake tomato was obtained in the crop mixture, where intercropping at population I produced plants with thicker girth and more leaves, but snake tomato intercropped with celosia population I, II and III had more number of side-vines compared to those planted sole. Significant influence in reproductive growth was obtained for snake tomato where plants in either population II or III had more TMF, and all intercropped plots had more TFF compared to those planted sole, while only plants intercropped with lower population I had thicker fruit girth compared to the sole and other intercropped plots. Nonetheless, sole snake tomato obtained more fruit yield compared to those in intercropped plots (**Table 3**). The intercrop population levels had significant influence on crop yield responses as shown in **Figure 2** where compared to the higher response from the control (at point-1 in the figure), all the intercrop population levels obtained lower crop yield values for both the snake tomato and celosia components. Although lower intercrop population obtained higher crop yield value for the snake tomato, the higher intercrop population on the other hand obtained higher crop yield values for celosia component compared to lower intercrop population.

Significant influence of manure rate was obtained in vegetative growth where plants treated with 20 t/ha poultry manure (PM) had longer vine length, more leaves and more number of side-vines, while those with either 5 or 20 t/ha PM had thicker girth compared to other rates. Significant influence in the reproductive growth

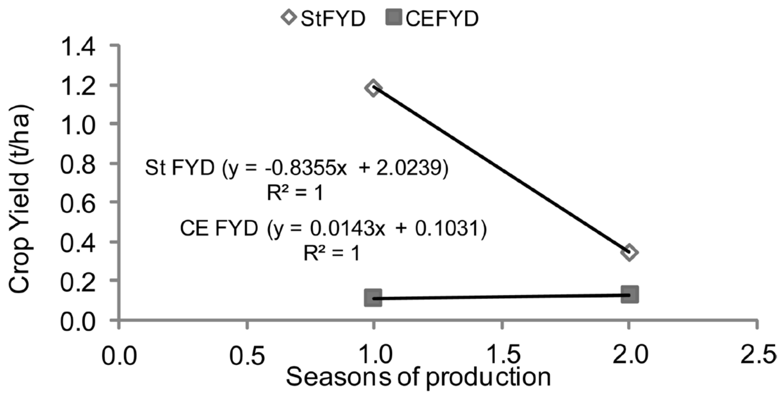

Figure 1. Crop yield of snake tomato/celosia component crops to seasonal variation. St FYD = snake tomato fruit yield, CE FYD = celosia total plant biomass. St FYD = □, CE FYD = ■.

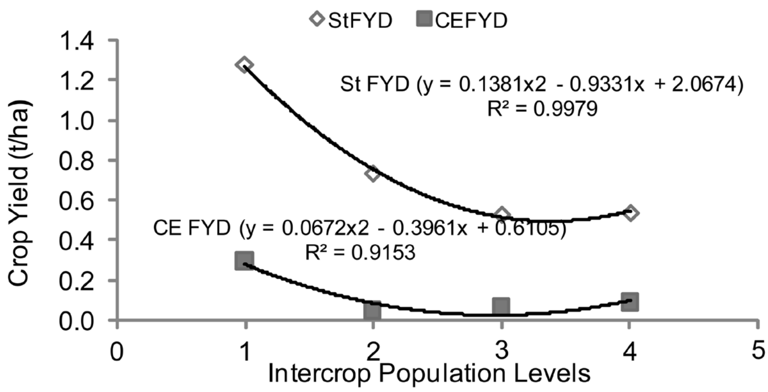

Figure 2. Crop yield of snake tomato/celosia component crops to intercrop population level. St FYD = snake tomato fruit yield, CE FYD = celosia total plant biomass. St FYD = □, CE FYD = ■.

was obtained where all rates (5, 10 and 20 t/ha PM) had more TMF, only 20 t/ha had more TFF and longer fruits, while fruit girth had a trend of 20 t/ha > 5 t/ha and 10 t/ha > 0 t/ha but a different trend was obtained in the fruit yield where the trend was 20 t/ha > 10 t/ha > 5 t/ha > 0 t/ha poultry manure. The manure rate showed a difference in crop yield responses where a linear response with increasing crop yield values was obtained for snake tomato with increasing manure rate while a linear but decreasing value was obtained for the celosia component (**Figure 3**).

3.2. Productivity Indices in Responses to Intercrop Population Levels

Significantly higher values in relative yield total for snake tomato (RYTa), and in land equivalent ratio (LER), land equivalent coefficient (LEC), Area × Time Equivalent Ratio (ATER) but lower negative values in aggressivity was obtained for plants cultivated under the year II environmental condition compared to under year I environment (**Table 4**). Significantly higher values in relative yield total for snake tomato (RYTa) and for celosia (RYTb), and higher LER, LEC, ATER values but lower RCC value was obtained for sole compared to intercropped plots while intercrop population I, had lower negative value in aggressivity compared to other population levels and the sole (**Table 4**). Significantly higher RYTa was obtained for the plants treated with 10 t/ha PM compared to other rates, also higher RYTb was obtained for the plants treated with 20 t/ha compared to those with 0 t/ha and 5 t/ha while 10 t/ha was least, nonetheless plants treated with both the 10 and 20 t/ha were higher in LER and LEC while those with lower 5 t/ha were lower in ATER compared to those treated with either 0, 10 or 20 t/ha PM, although both 10 and 20 t/ha PM were higher in aggressivity while those with 0 t/ha were least in RCC (**Table 4**).

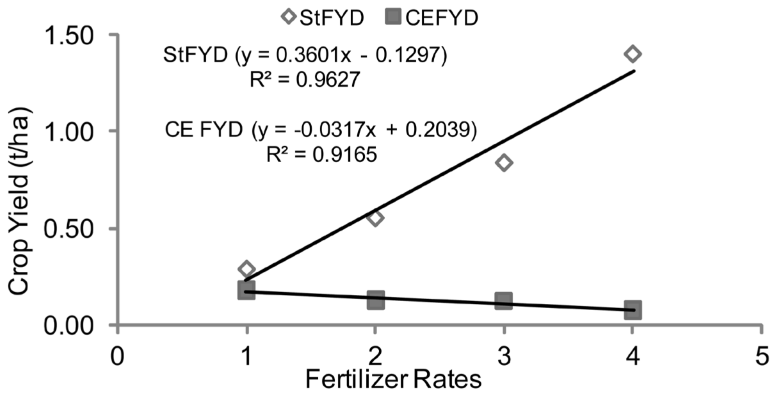

Figure 3. Crop yield of snake tomato/celosia component crops to fertilizer rates. St FYD = snake tomato fruit yield, CE FYD = celosia total plant biomass. St FYD = □, CE FYD = ■.

Table 4. Productivity responses of snake toamto to intercropped celosia population and manure application rates.

Treatments	Relative Yield Total		Land Equivalent Ratio	Land Equivalent Coefficient	Area Time Equivalent Ratio	Aggressivity	Relative Crowding Coefficient
	RYTa	RYTb	LER	LEC	ATER	Aab	RCC
Season							
Year I	0.41	0.46	0.87	0.26	0.57	−0.71	0.14
Year II	1.03	0.41	1.44	0.41	1.16	−2.85	0.00
LSD	0.09	0.02	0.10	0.06	0.09	0.31	0.04
Intercrop Population							
NC (no intercrop)	0.92	1.00	1.92	0.92	1.25	−1.63	0.00
10PC (100,000)	0.72	0.18	0.90	0.11	0.78	−2.15	0.07
20PC (200,000)	0.64	0.24	0.88	0.13	0.72	−1.79	0.10
30PC (300,000)	0.61	0.32	0.93	0.18	0.71	−1.56	0.10
LSD	0.13	0.02	0.13	0.09	0.13	0.44	0.06
Manure Rate							
0 t/ha PM	0.68	0.43	1.12	0.31	0.83	−1.66	0.02
5 t/ha PM	0.64	0.42	1.06	0.28	0.78	−1.51	0.05
10 t/ha PM	0.80	0.40	1.20	0.36	0.93	−2.09	0.10
20 t/ha PM	0.76	0.48	1.24	0.39	0.92	−1.86	0.10
LSD	0.13	0.02	0.13	0.09	0.13	0.44	0.06
Interaction							
S × P	**	**	**	ns	**	**	**
S × M	**	**	*	ns	**	**	*
P × M	ns	**	ns	ns	ns	ns	Ns
S × P × M	ns	*	ns	ns	ns	ns	Ns

ns = not significant; * = significant at 0.05, ** = significant at 0.01, RYTa = relative yield for snake tomato, RYTb = relative yield for celosia.

3.3. Correlation Relationship among Treatments and Growth and Yield Parameters

Season was positively correlated with vine length, but negatively correlated with TMF (Table 5). Both population and manure rates were not significantly correlated with any of the growth and yield parameters. However, season was positively correlated with RYTa and ATER but negatively correlated with RYTb, LER, LEC, while

Table 5. Correlation analysis showing season, population and manure rates in relationship with yield determinants and productivity indices.

Parameters	Season	POP	MNR	Parameters	Season	POP	MNR	Parameters	VLG	TMF	TFF	NFR	FYD
VLG	0.59**	0.21*	0.13 (ns)		--	--	--	SGT	0.40**	−0.22*	0.13 (ns)	−0.12 (ns)	−0.06
SGT	0.49**	0.10 (ns)	0.17 (ns)	RYTa	0.73**	−0.27**	0.11 (ns)	RYTa	0.46**	−0.51**	−0.12 (ns)	0.24*	0.12
NLVS	−0.29**	0.23*	0.28**	RYTb	−0.08 (ns)	−0.66**	0.04 (ns)	RYTb	−0.34**	−0.07 (ns)	−0.23*	−0.07 (ns)	0.33**
NSVN	0.42**	0.16 (ns)	0.25*	LER	0.48**	−0.58**	0.10 (ns)	LER	0.14 (ns)	−0.41**	−0.22*	0.14 (ns)	0.27**
TMF	−0.65**	0.33**	0.20 (ns)	LEC	0.20 (ns)	−0.65**	0.10 (ns)	LEC	−0.13 (ns)	−0.24*	−0.23*	0.07 (ns)	0.35**
TFF	−0.34**	0.28**	0.28**	ATER	0.66**	−0.41**	0.11 (ns)	ATER	0.35**	−0.49**	−0.17 (ns)	0.21*	0.19
NFR	−0.04 (ns)	−0.05 (ns)	0.12 (ns)	Aab	−0.76**	0.04 (ns)	−0.09 (ns)	Aab	−0.58**	0.49**	0.04 (ns)	−0.27**	−0.00
FYD	−0.43**	−0.28**	0.41**	RCC	−0.49**	0.26*	0.23*	RCC	−0.30**	0.50**	0.336**	−0.19 (ns)	0.00

ns—not significant, *—significant at $p \leq 0.05$, **—significant at $p \leq 0.01$, SGT—stem girth, NLVS—number of leaves, NSV—number of side-vines, TMF—total male flowers, TFF—total female flowers, NFR—number of fruits, FYD—fruit yield, POP—population, RYTa—relative yield total for snake tomato, RYTb—relative yield total for celosia, LER—land equivalent ratio, LEC—land equivalent coefficient, ATER—area × time equivalent ratio, Aab—aggressivity, RCC—relative crowding coefficient.

manure was not correlated with any productivity indices. Among the growth and yield parameters, vine length was negatively correlated with aggressivity, TMF was negatively correlated with RYTa, but positively correlated with RCC. The TFF, number of fruits and fruit yield were not correlated with any of the productivity indices (**Table 5**).

3.4. Season, Population and Manure Rates Interaction Effects on Growth and Yield

3.4.1. Season × Intercrop Population Interaction Effect

Significant season × intercrop population interaction effects was obtained in longer vine length for plants cultivated under pop III and pop I in year II compared to those under pop II which also was longer than the control (no intercrop) of both years I and II, although both were not different form each other and were also not different from pop I of year I and were longer compared to pop II and III of year I (**Table 3** & **Table 6**). Significant more male flowers was obtained for intercropping at higher pop II and III compared to control of year I while intercropping at pop I of year I was least. More male flowers production was obtained in year I compared to year II where no significant difference was obtained among intercrop population levels which although were higher compared to control in year II (**Table 3** & **Table 6**). In female flowers production, there was generally no significant difference in the female flowers production responses among intercropped plots which were generally lower compared to the control in year I but all year I responses were higher compared to female flowers production responses obtained in year II where generally all intercrop populations levels in year II were higher compared to the control (**Table 3** & **Table 6**).

3.4.2. Season × Manure Interaction Effect

Significant season × manure rates interaction effects was obtained with stem girth, number of leaves, number of male flowers, number of female flowers fruit length, fruit circumference and fruit yield (**Table 3**). In year II condition, thicker stem girth with more leaves was obtained compared to year I, in which the reverse was the case with male flower, female flower, fruit length/circumference and fruit yield where year I was higher than year II responses (**Table 3** & **Table 7**). Except for thicker stem girth observed with plants treated with 5/ha, all manure rates in year II were not different from one another but generally were significantly higher than those in year I. although in the year I, those treated with 20 t/ha were thicker compared to other manure rates which were thicker than plants treated with 0 t/ha (**Table 3** & **Table 7**). There was no significant difference in number of

Table 6. Season × intercrop population interaction effects on growth and yield of snake tomato.

Parameters	Season Effect	Intercrop Population Levels			
		No CE	CE Pop I	CE Pop II	CE Pop III
Vine Length	First Year	174.6^{de}	192.8^{d}	159.5^{e}	148.1^{e}
	Second Year	181.8^{de}	318.2^{b}	275.6^{c}	356.7^{a}
No of Male Flowers	First Year	30.3^{c}	24.3^{d}	62.0^{b}	76.8^{a}
	Second Year	1.8^{f}	5.5^{e}	7.4^{e}	7.5^{e}
No of Female Flowers	First Year	2.9^{a}	2.8^{ab}	2.6^{b}	2.9^{a}
	Second Year	0.0^{d}	2.1^{c}	2.6^{b}	2.4^{b}
Fruit Circumference	First Year	17.3^{c}	35.8^{a}	21.7^{b}	21.3^{b}
	Second Year	22.2^{b}	12.5^{d}	13.2^{d}	14.3^{d}
Fruit Yield	First Year	2.2^{a}	1.1^{b}	0.7^{c}	0.7^{c}
	Second Year	0.3^{d}	0.4^{d}	0.4^{d}	0.4^{d}

Means of data across rows and columns followed by same letters are not significantly different by Fisher's test, ns = not significant, † = weeks after transplanting, CE Pop = celosia population.

Table 7. Season × manure rate interaction effects on growth and yield of snake tomato.

Parameters	Season effect	Manure Rates (t/ha)			
		0	5	10	20
Stem Girth	First year	0.5^{d}	0.6^{c}	0.6^{c}	0.7^{b}
	Second year	0.7^{b}	0.8^{a}	0.7^{b}	0.7^{b}
No of Leaves	First year	46.1^{e}	56.3^{b}	58.3^{b}	67.5^{a}
	Second year	51.8^{c}	48.6^{d}	43.6^{f}	53.4^{c}
No of Male Flowers	First year	24.4^{c}	46.5^{b}	60.0^{a}	62.4^{a}
	Second year	6.8^{d}	6.7^{d}	4.7^{d}	4.1^{d}
No of Female Flowers	First year	1.3^{e}	2.7^{b}	2.9^{b}	4.3^{a}
	Second year	2.2^{c}	1.8^{d}	1.3^{e}	1.8^{d}
Fruit Length	First year	12.9^{e}	40.8^{b}	63.3^{a}	58.9^{a}
	Second year	27.8^{c}	26.2^{c}	21.3^{d}	22.5^{d}
Fruit Circumference	First year	7.4^{f}	21.2^{c}	24.1^{b}	43.4^{a}
	Second year	14.9^{e}	15.2^{e}	18.2^{d}	14.0^{e}
Fruit Yield	First year	0.2^{e}	0.7^{b}	1.3^{a}	0.3^{d}
	Second year	0.3^{d}	0.4^{c}	0.4^{c}	0.4^{c}

Means of data across rows and columns followed by same letters are not significantly different by Fisher's test.

leaves between plants treated with 0 t/ha and 20 t/ha which had more leaves compared to those treated with 5 t/ha > 10 t/ha in year II, which were lower compared to higher responses in year I, where those treated with 20 t/ha were higher compared to those treated with 5 and 10 t/ha but the 0 t/ha (control plot) was least (**Table 3** & **Table 7**).

In the number of male flowers, plant responses in year II were generally lower compared to obtainable in year I and no significant difference was observed among all manure treated plots in the year II, while all crops treated with manure rates in the year I produced significantly more number of male flowers compared to the control (0 t/ha) (**Table 3** & **Table 7**). In the number of female flowers, while plants treated with 20 t/ha had more flowers in year I, and all manure treated plots were more than control in flower production, the year II environment produced more flowers in control plants compared to obtainable with plants treated with manure rates where the 10 t/ha was least (**Table 3** & **Table 7**).

3.4.3. Intercrop Population × Manure Rates Interaction Effect

Significant intercrop population x manure rates interaction effects was obtained with number of leaves, number of male flowers and fruit yield (**Table 3** & **Table 8**). In number of leaves, 20 t/ha had the highest influence with a trend of 20 t/ha at pop I > 20 t/ha at pop II higher than 20 t/ha at No CE. The influence of 20 t/ha was followed by 5 t/ha which had a trend of 5 t/ha at pop I > 5 t/ha at pop II and III (**Table 3** & **Table 8**). The male flowers regarded as an indicator for stress in plants showed a general increase along the increase in manure rates and a general increase also along the increase in plant population (**Table 3** & **Table 8**). In fruit yield, there was a general increase in yield along increase in manure rate and a general decrease in yield along increase in intercrop population levels (**Table 3** & **Table 8**).

3.4.4. Season × Intercrop Population × Manure Rates Interaction Effect

Significant season × intercrop population × manure rates interaction effects was observed in male flowers production and in fruit yield (**Table 3** & **Table 9**). In TMF, while there was no significant difference along increase in manure rate or population level for year II, the year I produced a different trend with a general increase with a gradient higher along population levels and along the increase in manure rates (**Table 3** & **Table 9**). In fruit yield, although year I and II had different trend in response to increased manure rate and intercrop population levels, in year I higher intercrop population had higher retardation effect on fruit yield compared with lower plant population levels while higher manure rate resulted in increased nutrient uptake and hence increased fruit yield (**Table 3** & **Table 9**).

4. Discussion

4.1. Environmental Condition of the Experimental Site

The snake tomato crop described as drought hardy but easily hampered by the effect of high relative humidity and high soil moisture content which was personally observed can therefore be an exacting crop in terms of crop requirements. Maintaining an optimum environmental condition will therefore be a key to obtaining high crop yield and for better crop productivity. The environmental condition obtained during the study period showed significant differences in the crop responses obtained for both years. The observed year I condition which was lower in both the moisture availability and in the maximum/minimum temperatures compared to higher values in year II probably accounted for the seasonal variation to which the component crops responded. The higher moisture content obtained in the year II environmental condition had more influence on crop responses compared to the temperature effects. Thus the higher moisture content which resulted in the luxuriant vine growth was more detrimental to snake tomato crop performance which resulted in reduced reproductive growth responses compared to obtainable in year I. This is corroborated by the significant positive correlation relationship between season and vine length indicating that higher moisture content coupled with a higher maximum temperature could have resulted in longer vine length, but which caused retardation effects in the number of male flowers. Nonetheless the seasonal variation effects in crop mixture resulted in better crop productivity in year II. This is indicated by the higher snake tomato RYTa and ATER and improved crop aggressivity, although with lower relative crowding coefficient (RCC) while higher intercrop population levels were detrimental to the celosia relative yield total RYTb (partial LER of celosia).

4.2. Vegetative and Reproductive Growth Responses

The observed higher rainfall and higher maximum/minimum temperature in year II favoured better vegetative growth, while the corresponding lower rainfall coupled with lower maximum/minimum temperature in year I favoured better reproduction growth responses. The celosia that is purely vegetative required only soil moisture and uptake of nutrient element for good vegetative growth. Moreover, year I resulted in plants with more leaf production when treated with 20 t/ha compared to lower responses obtained with those under lower manure rates, while compared to response in year II could be due to the better mineral element available in the 20 t/ha application compared to lower manure rates or could be due to an improvement in soil physical structure resulting in higher responses under the higher application rates despite the slow mineralization. The snake tomato plants in intercropped plots produced thicker girth, more leaves and more side-vines which also indicated that intercropping induced earlier and more flower production (TMF/TFF) and thicker fruits in snake tomato but retarded fruit

Table 8. Intercrop population × manure rates interaction effects on growth and yield of snake tomato.

Parameters	Season Effect	Intercrop Population Levels			
		No CE	CE Pop I	CE Pop II	CE Pop III
No of Leaves	No CE	38.0^{h}	39.3^{h}	48.3^{fg}	47.5^{g}
	CE Pop I	49.8^{f}	61.8^{c}	51.8^{ef}	76.3^{a}
	CE Pop II	52.0^{ef}	55.2^{de}	51.7^{ef}	64.3^{b}
	CE Pop III	55.8^{d}	53.3^{e}	51.8^{ef}	51.8^{ef}
No of Male Flowers	No CE	7.2^{h}	8.5^{h}	14.8^{g}	33.7^{d}
	CE Pop I	14.7^{g}	18.2^{f}	19.5^{f}	7.2^{h}
	CE Pop II	14.2^{g}	45.5^{c}	44.0^{c}	35.2^{d}
	CE Pop III	26.5^{e}	34.2^{d}	51.0^{b}	57.0^{a}
Fruit Yield	No CE	0.4^{i}	0.9^{e}	1.3^{b}	2.6^{a}
	CE Pop I	0.3^{j}	0.5^{h}	1.0^{d}	1.1^{c}
	CE Pop II	0.3^{j}	0.4^{i}	0.6^{g}	0.7^{f}
	CE Pop III	0.2^{k}	0.4^{i}	0.5^{h}	1.1^{c}

Means of data across rows and columns followed by same letters are not significantly different by Fisher's test.

Table 9. Season, manure rate, intercrop population interaction effects on yield and yield determinants of snake tomato.

Parameter	Season	Intercrop Population	Manure Rates (t/ha)			
			0	5	10	20
No of Male Flowers	First Year	No CE	13.3^{f}	16.3^{e}	28.0^{e}	63.3^{c}
		CE Pop I	23.0^{e}	29.7^{e}	33.0^{e}	11.3^{f}
		CE Pop II	16.3^{e}	80.0^{c}	83.0^{c}	68.7^{c}
		CE Pop III	45.0^{d}	60.0^{d}	96.0^{a}	106.3^{a}
	Second Year	No CE	1.0^{f}	0.7^{f}	1.7^{f}	4.0^{f}
		CE Pop I	6.3^{f}	6.7^{f}	6.0^{f}	3.0^{f}
		CE Pop II	12.0^{f}	11.0^{f}	5.0^{f}	1.7^{f}
		CE Pop III	8.0^{f}	8.3^{f}	6.0^{f}	7.7^{f}
Fruit Yield	First Year	No CE	0.4^{d}	1.4^{c}	2.2^{b}	4.9^{a}
		CE Pop I	0.3^{d}	0.7^{d}	1.6^{b}	1.9^{b}
		CE Pop II	0.3^{d}	0.5^{d}	0.9^{c}	1.1^{c}
		CE Pop III	0.0^{e}	0.4^{d}	0.6^{d}	1.9^{b}
	Second Year	No CE	0.3^{d}	0.4^{d}	0.4^{d}	0.3^{d}
		CE Pop I	0.4^{d}	0.4^{d}	0.4^{d}	0.3^{d}
		CE Pop II	0.3^{d}	0.4^{d}	0.3^{d}	0.4^{d}
		CE Pop III	0.3^{d}	0.4^{d}	0.4^{d}	0.4^{d}

Means of data across rows and columns followed by same letters are not significantly different by Fisher's test.

yield. [61] had reported that intercrops are most productive when their component crops differ greatly in growth duration so that their maximum requirements for growth resources occur at different times. However, intercropping results generally in yield reduction of intercrops compared with the same crops grown sole [22] [62].

In this study, higher plant population in year II did not retard vine length increase but vine length decreased with increased plant population in year I. Hence etiolation had support from higher moisture and temperature but was retarded in the presence of lower moisture and lower temperature. The generally more leaf production obtained for intercropped plots compared to the control at the different manure rates (0, 5, 10 and 20 t/ha) showed the effect of etiolation where plants in the bid to catch sunlight exert greater growth vigour compared to those in control plots that were not intercropped. Earlier reports by [63] and [64] had reported that intercropped okra was taller than the sole crop and that the taller okra plants obtained when intercropped with maize was a growth response for better uptake of the limiting solar radiation. [65], also reported that intercropping generally increased okra plant height, while intercropping with sweet potato which had higher tuber yield also resulted in significantly higher increase in the number of pods per plant of okra.

The year II condition and intercropping generally depressed female flower production, while in year I there was no significant difference among intercrop population levels and the control. The higher female flower in year I was therefore due to flower induction mechanism from lower temperatures while female flower induction in year II was mainly due to the soil moisture stress under higher intercrop population levels. Nonetheless, there was a progressive increase in male flowers production obtained with increase in intercrop population level compared to control in year I indicating that stress under high population levels induced higher male flower responses, while in year II stress applied by higher population were not different in effect on male flowers. Thus there was a difference observed in male and female flower induction mechanisms, while the female flower responded solely to the available lower temperatures with or without moisture stress effects and were depressed by higher intercrop population, the male which appeared to be a stress indicator not controlled by temperature was triggered mainly by stress factors obtainable under higher intercrop population levels and the response increased as the stress level increased.

Although water stress as an important flower bud induction mechanism in most tropical crops requires perhaps 2 - 3 months of stress for economic levels of flower bud induction [66] [67], but despite the role water stress can play, drought conditions is not as beneficial for flowering as cool weather [68]. Even though lower temperature can induce female flower in snake tomato, it could be retarded or promoted by absence or presence of moisture, while for male flower induction continuous flowering was the case irrespective of temperature while it could be accentuated by moisture stress condition. The difference in behaviour of flower sex types therefore indicated a higher nutrient support required for TFF compared to TMF. Although the TFF response in year I compared to year II indicated the influence of synergy between lower temperature and moisture stress, but the excessive response of TMF in year I compared to year II indicated that other factors apart from lower temperature and moisture stress were involved. The higher crop yield value obtained for the control plots compared to intercropped plots indicated yield retardation effect by the presence of the celosia component crop. The higher yield obtained for snake tomato at lower intercrop population could be due to lesser inter-plant competitive effect at lower intercrop population while the heavier celosia crop yield at higher intercrop population despite increasing intra-plant competition could be due to cumulative effect of higher plant biomass at higher intercrop population compared to obtainable at lower intercrop population.

The increase in fruit yield with a trend of 20 t/ha > 10 t/ha > 5 t/ha > 0 t/ha manure rates on the one hand, and the general retardation in fruit yield along the increase in intercrop population on the other hand revealed that more nutrient release occurred with increase in manure rate albeit with greater exhaustion of nutrient at higher intercrop population levels. Nonetheless the fewer number of leaves with a trend of pop I > pop II > pop III at the 5 t/ha and 20 t/ha indicated progressive retardation effect at higher intercrop population. This could be due to a progressive exhaustion in the available nutrient at higher intercrop plant population. Contrariwise, the more leaves obtained for plant at higher pop III > pop II > pop I at the 0 t/ha indicated a greater pull on the inherent soil fertility by higher intercrop population compared to lower plant population. At the 10 t/ha, the no significant difference among intercrop population levels indicated probably a crop adjustment between the component crops where the main crop and intercrop explored different niche in the soil.

Although there was a growth and yield retardation effects at higher intercrop population levels, the effect of higher nutrient uptake at higher plant population could have triggered a higher mineralization process at higher manure rates compared to obtainable at lower manure rates leading to eventual higher fruit yield. [68] had stated that the net release of nutrients from organic matter is a function of decomposition ratios of the different organic matter fractions and of the uptake of nutrients by the growing biomas, hence higher mineralization is subject to higher nutrient uptake. The application of 20 t/ha PM manure rate thus obtained significantly longer vine length, more leaves and more side-vines in snake tomato, while both 5 and 20 t/ha had significantly thicker stem girth compared to other rates. Although higher rainfall should favour nutrient uptake, the thicker stem girth of plants treated with 5 t/ha in year II indicated that the higher maximum temperature was not limiting as major requirement for faster rate of manure mineralization, but higher rainfall was detrimental to snake tomato growth, while higher response in year I where the lower maximum temperature should necessarily be the limiting factor for manure mineralization in the bulkier 20 t/ha compared to the lower rates indicated that the 20 t/ha had advantage over other applied rates. This probably could not be due only to the relative higher content of readily available mineral element compared to lower manure rates but rather more due to the highly improved soil physical structure which influenced crops to better growth and yield responses.

All manure rates had significant influence on male flowers and fruit length while the trend of responses in fruit circumference and fruit yield described the nutrient dynamics in both the availability and uptake by plants which was better in fruit yield than in fruit circumference. The higher male flowers with 10 t/ha and 20 t/ha, more female flowers with 20 t/ha, heavier fruit yield with 10 and 20 t/ha and thicker fruit girth (FRC) with 20 t/ha indicated that while lower minimum temperature induced flowering, but prolific flowering, fruit set and fruit development were sustained better at the higher manure rate. The no significant difference in number of fruits despite significant difference obtained in fruit yield could mean that better fruit size was obtained with higher manure rates as confirmed by the trend in the fruit circumference. Nonetheless, fruit sizes had no influence on fruit internal content. Moreover, the observed fruit yield in year I and II did not correspond with fruit size responses, hence significant differences in fruit sizes did not result in significant fruit yield in snake tomato.

4.3. Productivity Indices in Responses to Intercrop Population Levels

The year II environmental condition contributed better to productivity with above unit (>1.0) values for LER (1.44) and ATER (1.16) thus demonstrating yield advantages for the intercropped snake tomato compared to obtainable in sole plants [33]. Although the relative crowding coefficient (RCC) indicated a lesser competing crops in year II compared to obtainable in year I, nevertheless contribution to productivity was more from celosia in year I, while snake tomato contributed more in year II. The crop response indicated that intercropping snake tomato with celosia retarded snake tomato in the productivity responses compared to the sole. The sole cropping with lesser competing crops had lower negative aggressivity value compared to intercrop population I which had higher aggressivity compared to the other population levels. Hence the longer vine length and higher intercrop population conferred better aggressivity to the snake tomato compared to celosia. The negative correlation between male flower and RYTa indicated that male flower compared to female flower was a drain on the productivity indices while the male flower being positively correlated with RCC indicated that higher male flower a stress indicator could be a resultant effect of higher competing crops thereby causing retardation in snake tomato yield and productivity.

Thus the plants with 10 t/ha PM had better influence on snake tomato productivity while celosia productivity was best at 20 t/ha. This indicates a higher nutrient requirement to maintain celosia compared to snake tomato which confirm the higher aggressivity of snake tomato compare to celosia. The 10 and 20 t/ha PM were better in the influence on LER and aggressivity, the 20 t/ha although not different from 0 t/ha and 5 t/ha had better influence on LEC, while the least response in RCC obtained for 0 t/ha indicated that less competing crops were supported by 0 t/ha. The lower ATER obtained for plants treated with 5 t/ha compared to those with 10 and 20 t/ha on the one hand and compared to those with 0 t/ha on the other hand indicated that the manure rates generally had no significant influence on crop growth and yield which was corroborated by the no correlation relationship obtained between manure and crop growth responses hence plants responded not to nutrient uptake per se but probably more to the relative physical structure improvement which at higher manure rate could have had significant influence to produce better crop growth, while plants treated with 0 t/ha relies mainly on inherent soil fertility of the soil. The higher crop yield value for snake tomato indicated that snake tomato with a deeper root explored plant growth resources' better compared to the shallow rooted celosia component which could have contributed to the better LER values obtained for the crop mixture compared to the sole crop of each crop component.

5. Conclusion

In conclusion, the higher moisture in the environment caused luxuriant growth at the expense of reproductive growth. The crop mixture at intercrop population I was better compared to either II or III in growth while population II or III influenced plants to produce more male flowers which was regarded as a drain on crop growth resources, but all intercropped plots had more female flowers compared to control. Although intercropping retarded growth and yield but it produced better crop productivity. Alongside the available higher nutrient in applied manure rates coupled with higher nutrient uptake observed in crop growth responses, the increased manure rates assisted in male flower production, however, the more obvious increase in male flower production observed across increase in intercrop population indicated a greater stress on plants at higher plant population. Plants treated with 20 t/ha poultry manure probably due to better improvement in soil physical structure had better influence on crop growth and yield responses, but for 10 t/ha probably due to crop adjustment between the component crops exploring different niche in the soil was best in productivity indices. Although in the crop mixture, snake tomato performed best with 10 t/ha while celosia was best with 20 t/ha PM, nonetheless productivity indices of aggressivity and relative crowding coefficient showed that snake tomato vine length conferred aggressivity on the crop compared to celosia while crowding coefficient was improved with manure rate.

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