



ISSN: 2455-0477

# Growth performance and nutritional quality of selected vegetables in response to organic and inorganic fertilizers under low and high irradiance

L. T. Olaokiki and S. A. Adejumo\*

Department of Crop Protection and Environmental Biology, Faculty of Agriculture, University of Ibadan, Ibadan, Nigeria

## ABSTRACT

Vegetables form major part of human dietary/nutritional needs. It provides the necessary vitamins and minerals as well as antioxidants to boost immunity. Different vegetables however have different benefits and require different growing conditions. This study investigated the effect of two growing conditions (Screen-house and open field) and soil amendments; Mexican sunflower compost (MSC; applied at 0, 5, 10 t/ha) and NPK 15:15:15 (applied at 0, 50 and 100 kg N/ha) on the growth performance, yield, and nutritional quality of five selected vegetables (*Amaranthus cruentus*, *Celosia argentea*, *Solanum macrocarpon*, *Solanum nigrum* and *Solanum incanum*). Each treatment was replicated three times and experiment arranged in completely randomized design, Compost was applied a week before seed sowing and NPK applied two weeks after sowing. Data were collected on growth, food quality and yield parameters as well as chlorophyll and micronutrient contents of each vegetable. At harvesting, proximate and nutrient analyses were carried out following standard procedures. Data were analysed using analysis of variance and means separated using Duncan Multiple Range Test (DMRT). The results showed that vegetables grown in the screen-house generally performed better than the open field in terms of leaf area and chlorophyll content. The response however varied based on the vegetable and the soil amendments. *Solanum* species, performed better than *Amaranthus* under screen-house than open field. Chlorophyll in the leaf responded positively to NPK fertiliser under screen-house conditions while growth parameters such as plant height, stem girth, number of leaves under screen-house and field conditions varied depending on the vegetables. The number of leaves and leaf area increased with soil amendments. Moisture, crude protein and ash contents were reduced under open field compared to screen-house. The zinc and iron contents of the vegetable leaves showed that addition of compost was superior to NPK and screen-house better than open field. It can be concluded that vegetables grown in the screen-house performed better in their respective growth parameters than vegetables grown under the open field.

Received: September 21, 2020  
Revised: February 27, 2021  
Accepted: March 13, 2021  
Published: April 01, 2021

\*Corresponding Author:

S. A. Adejumo

Email: nikade\_05@yahoo.com

**KEYWORDS:** Light intensity; Organic amendments; Vegetables; Secondary metabolites; Nutrients and Vitamins

## INTRODUCTION

Vegetables are the cheapest, available sources of important nutrients supply in daily diets (Akinfolarin & Gbarakoro, 2016). They provide the necessary vitamins and minerals as well as antioxidants. The antioxidants present in vegetables have been reported to prevent oxidative damage caused by reactive oxygen species which are generated in response to different stress factors (Halliwell & Gutteridge, 1989). The antioxidants also help in boosting immunity and induce resistance against sickness and diseases. They are also good sources of limiting micronutrients; iron and zinc thereby eliminating hidden

hunger (Kennedy *et al.*, 2003). They contain carbohydrates, carotene, protein, vitamins, other essential mineral elements (Barminas *et al.*, 1998). The edible part(s) of a vegetable could be stems, leaf, fruits/pods and stalk (celery) which can be eaten raw or cooked in a mixed dish as an appetizer or in a salad (Dhellit *et al.*, 2006). In addition, they serve as important source of income for farmers. Green leafy vegetables are also used in the diet of nursing mothers to aid the contraction of the uterus (Emebu & Anyika, 2011). Diets with high vegetable contents have been reported to have an ameliorative effect on hypertensive patients (Jerzykiewicz, 2007; Martirosyan *et al.*, 2007).

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Different vegetables however, have different benefits. For instance, the *Solanum species* in the family Solanaceae (night shadow plants) are reported to have high amount of secondary metabolites which are naturally produced as a defense against herbivores (Roberts & Wink, 1998). Similarly, Celosia vegetables, according to Asian Vegetable Research & Development Center (AVRDC), also have high antioxidant contents that bind free radicals in the bloodstream and render them harmless. Principal antioxidants in Celosia include carotenoid (beta-carotene) and vitamins C and E (Sato & Engle, 2002). Amaranthus vegetables are endowed with nutrients that are highly beneficial for reproductive health in both men and women. Research indicates that calcium that is present in amaranthus improves the ability of sperms to swim while calcium deficiency impairs that same ability (Chinoy *et al.*, 1983). Furthermore, vegetables influence the pH of the human body. Calcium in amaranth is said to help the body to achieve proper pH setting suitable for fertility and general reproductive function. Amaranth also has vitamin B9 or folate which is a major fertility booster. Folate deficiency is associated with anaemia and falling pregnancy and men's fertility is also positively influenced by foods rich in folate (Natural News, 2009).

Many vegetables are being cultivated by farmers while some still grow naturally in the wild. *A. cruentus*, *C. argentea*, *A. spinosus*, *S. macrocarpon*, *S. nigrum* and *S. incanum* are produced by vegetable growers (Assogba-Komlan *et al.*, 2007). *S. macrocarpon* is eaten in many countries of West Africa such as Togo, Ivory Coast and Nigeria (Sodipo *et al.*, 2012). It is found everywhere in non-arid hot zones in Africa and is an important vegetable because of its leaves and fruits (Schippers, 2000). Amaranth originated in America and is one of the oldest food crops in the world. The genus Amaranth consists of nearly 60 species, several of which are cultivated as leafy vegetables, grains or ornamental plants, while others are weeds. Grain amaranth species are important in different parts of the world. *A. cruentus* is one of the most important annual leafy vegetables in the tropics and it has a short growing period of four to six weeks (Makinde, 2007). It thrives well on soils with high organic matter. *S. nigrum* among the Black nightshade family is also found in many places.

Vegetable production, though, important for animal and human survival, but, good understanding of their climatic and nutrient requirements would help to improve their productivity. Meanwhile, crop production is continuously confronted with unfavorable climatic conditions and the prevailing environmental factors are the key determinants for agricultural productivity and sustainability (Ferdous *et al.*, 2011). The environmental factors are grouped into biotic and abiotic factors. Among the abiotic factors, light intensity, water and soil nutrients are very important factors that affect the vegetative and reproductive developments of vegetables (Xiao *et al.*, 2000). For instance, light intensity and duration control the plant-water relationships and influences leaf growth, photosynthetic rates, pollination and vegetable yield. Plants are dependent on solar radiation and water to produce food, complete their life cycle and for healthy growth and development but, excessive sunshine have negative effects on crops and causes temperature stress (Smestad, 2014).

Similarly, to achieve better growth and high yield, vegetables must be supplied with adequate nutrients through the use of fertilisers which could be organic or inorganic. The use of organic fertiliser is however preferred to inorganic fertilisers due to environmental and health implications apart from its availability and cost benefits ratio. This research work was carried out to determine the morphological, physiological and yield responses of the selected vegetables to Mexican sunflower compost and NPK fertiliser under Screen-house (low irradiance) and open field (high irradiance) conditions and to evaluate the nutritional compositions of each vegetable in response to fertiliser application and growing conditions.

## METHODOLOGY

### Soil Pre-treatment and Experimental Set-up

The experiment consisted of two trials (main and residual plantings). Top soil used for the experiment was collected at the depth of 0-15cm from the crop garden, air-dried, mixed thoroughly and sieved with 2 mm mesh before distributing into 5kg experimental pots and arranged inside the screen house and on the open field. The average relative humidity, temperature, and light intensity for the screen-house were 79 %, 33 °C and 710 lux, respectively, while that of the open-field were 63 %, 39.6 °C and 890.7 lux, respectively for the experimental period.

The treatments used were: Mexican sunflower compost and NPK fertiliser (15:15:15). Compost was applied at 0, 5 and 10 tt/ha and NPK at 0, 50 and 100 kg N/ha. The experimental design was Completely Randomized Design (CRD) in a factorial arrangement with three replicates. Compost was added to the soils receiving compost treatments at different rates, mixed thoroughly, watered and left for two weeks before the vegetable seeds were sown. The seeds of *A. cruentus*, *C. argentea*, *A. spinosus*, *S. macrocarpon*, *S. nigrum* and *S. incanum* were sown directly into the pots using broadcast method. Thinning was done two weeks after sowing to 2 plants per pot and watering was done regularly. NPK fertiliser was added two weeks after sowing. Data were collected on the growth, chlorophyll and yield parameters. Data collected on growth parameters include: plant height, leaf area and number of leaves. Leaf area (cm<sup>2</sup>) was determined by measuring the leaf length and breadth of each vegetable using measuring tape. *A. cruentus*, and *A. spinosus* leaf areas were determined by multiplying L X B with 0.64 (Kolawole & Sarah, 2009). *C. argentea* had calibration factor of 0.75 according to Agbogidi *et al.* (2005). *S. macrocarpon*, *S. nigrum*, *S. incanum* according to Flavio and Marcos (2003) had calibration factors: Length × breadth × 0.89. Chlorophyll content was determined fortnightly using a hand-held SPAD-502 meter. At 8 weeks after sowing, the vegetables were gently uprooted from each pot. The roots were rinsed to wash the adhering soils back into the pots for the residual planting. They were partitioned into shoot and root, properly tagged for easy identification and carried to the laboratory. In the laboratory, they were weighed to determine the fresh weights using Metler sensitive weighing scale. They were then enveloped and labelled properly before oven drying for 72 hrs at 60 °C and weighed again to determine their dry weights.

Before oven drying, leaf samples were taken for the determination of the moisture content. Samples for proximate analysis were taken from the treatments that performed well with regards to growth and yield parameters. One (1) gram each was taken from each vegetable and oven dried at 105°C for two hours until a constant weight was achieved. After drying, the moisture content was computed on wet basis:  $\text{Weight of the sample before drying} / \text{Weight of the sample after drying} \times 100$ .

After oven drying, for the determination of ash content, 1g each of the ground vegetable samples was ashed in a Gallenkamp Muffle Furnace, FR 612 model, at a temperature of 550°C for 4 hours. Crucibles were first weighed before ashing and 1g of the samples was weighed into each crucible and arranged into the furnace. After cooling, the ash was weighed again together with the crucibles and percent ash was calculated for each sample as:  $\text{WC} + \text{SB} - \text{WC} + \text{SA} / \text{WC} + \text{SA} \times 100$ . Where, WC = Weight of the crucible, SB = Weight of the sample before ashing and SA = Weight of the sample after ashing. Zinc and Iron were then determined in the ash following the procedure described by Ogundiran, (2007) using dry ashing method.

## RESULTS

### Effects of Compost and NPK on the Growth Parameters of the Vegetables Under the Screen-house and Field Conditions.

Generally, there was an increase in all the growth parameters as the week progressed. The response under screen-house and open field however varied based on the type of vegetables and the fertiliser application. However, for *Amaranthus* and *Celosia* species, some growth parameters were better under open field than screen house. On the number of leaves, *A. cruentus* in the screen-house was not different from those in the open field. At 2WAS control plant had the highest number of leaves and the trend continued till 6WAS. Under open field, addition of soil amendments enhanced leaf formation and at 6 WAS, the number of leaves of treated plants were more compared to control. *C. argentea* behaved differently. The number of leaves at 6WAS showed that in the screen-house, soil amendment with NPK at 100kgN/ha gave the highest number of leaves. Meanwhile, under the open field conditions, the highest number of leaves was recorded in plants grown in the soil amended with MSC at 10 t/ha but not different from control. Compared to other vegetables, Solanum varieties (*S. macrocarpon*, *S. incanum* and *S. nigrum*) responded better in the soils treated with soil amendments both in the screen-house and under the open-field. *S. macrocarpon* especially had the highest number of leaves across all the treatments, followed by *S. nigrum*, and *S. incanum*. There was significant difference in the number of leaves of the Solanum varieties grown under screen-house and open-field. They also responded well to MSC than NPK at 6WAP (Table 1). For the plant height, *A. cruentus* performed better in the open field than screen-house and fertiliser application had no significant effect on plant height under the two conditions compared to control. *C. argentea* responded the same way as *A. cruentus* and the plant height was more on the field than screen-house at 2, 4 and 6 WAS tallest plant was produced in

MSC (5 t/ha) treatment under the open field at 4 and 6 WAS. Plant height was generally enhanced in the Solanum varieties grown in the screen-house compared to open field. At the end of 4 and 6 WAS, especially in the screen-house, *S. incanum* treated with 50 Kg N/ha had the tallest plant while control gave the tallest plants under the open field. *S. nigrum* performed better in soil treated with 10 t/ha MSC under both conditions at 4 and 6 WAS. *S. macrocarpon* also had the tallest plants in 10 t/ha MSC treatment in the screen-house and open field except at 6 WAS in the open field when 100 Kg N/ha gave the tallest plant (Table 2). However, with regards to stem girth, *A. cruentus* responded well under screen-house conditions than open field. Application of compost enhanced stem girth in the screen-house and NPK at 50 kgN/ha gave wide stem girths at 6WAP in the open field. The stem girth of *C. argentea* was not significantly different under both conditions at 6 WAS and in response to the fertilizer application compared to control. Solanum vegetables also responded better under screen-house compared to open field and the stem girth was wider in the screen-house than open field. The response to fertilisers however differs. Application of 10 t/ha MSC and 50 Kg N/ha increased the stem girth under screen house and field conditions (Table 3). In the case of leaf area, all the vegetables especially, Solanum vegetables, responded better under screenhouse than open field. *A. cruentus* grown under screen-house performed better than open field and recorded the highest value in MSC treatment at 10 t/ha. On the field, application of NPK at 100 Kg N/ha gave the highest leaf area. In *C. argentea*, leaf area was also enhanced under screen

**Table 1: Effects of compost and NPK fertilizer on the number of leaves of the vegetables under the two experimental conditions.**

Treatments	Screen house			Open field		
	2WAS	4WAS	6WAS	2WAS	4WAS	6WAS
A. C Control	10.3a	12.3a	17.0a	6.66bc	10.3abc	13.0ab
A. C+MSC (5ton/ha)	6.66bc	8.66bc	13.6a	8.00a	11.0ab	14.3ab
A. C+MSC (10ton/ha)	9.00ab	10.0b	14.3a	7.00abc	11.3a	15.0ab
A. C+NPK (50kgN/ha)	9.33ab	11.3ab	14.6a	8.00a	11.3a	15.3a
A. C+NPK (100kgN/ha)	8.00ab	11.0ab	13.6a	7.66ab	11.0ab	15.3a
C. A Control	7.66a	12.6a	14.3a	10.6a	12.0a	14.0a
C. A+MSC (5ton/ha)	6.33abc	12.6a	14.6a	9.00ab	10.0b	12.0bc
C. A+MSC (10ton/ha)	6.66ab	11.6ab	14.6a	11.0a	13.0a	14.6a
C. A+NPK (50kgN/ha)	5.33bc	12.3ab	14.0a	9.33ab	10.3ab	13.0ab
C. A+NPK (100kgN/ha)	7.00a	14.0a	15.3a	7.66bc	10.6ab	13.3ab
S. I Control	3.33b	6.00b	8.00b	1.33bc	3.66ab	7.66ab
S. I+MSC (5ton/ha)	3.66a	6.00b	8.33a	1.66a	4.00a	7.66ab
S. I+MSC (10ton/ha)	3.33b	6.66a	7.33b	2.00a	3.33abc	8.6a
S. I NPK (50kgN/ha)	3.66a	5.33bc	8.66a	1.66b	3.00bc	7.00bc
S. I NPK (100kgN/ha)	3.33b	6.00b	7.66b	1.66b	3.66ab	7.00bc
S. M Control	4.33a	5.66a	7.00b	2.66b	5.00b	6.00b
S. M+MSC (5ton/ha)	4.33a	5.33b	6.66bc	3.33b	6.66a	8.00a
S. M+MSC (10ton/ha)	4.66a	6.00a	7.33a	3.66a	5.66b	7.66a
S. M NPK (50kgN/ha)	4.00b	6.00a	7.00b	3.66a	6.66a	7.66a
S. M NPK (100kgN/ha)	4.00b	5.00bc	7.33a	3.33b	7.66a	8.33a
S. N Control	3.00b	4.33bc	7.33b	1.33b	3.66b	7.66a
S. N+MSC (5ton/ha)	3.00b	5.33b	8.33b	1.66a	4.00a	7.66a
S. N+MSC (10ton/ha)	4.33a	7.00a	8.66b	2.00a	4.00a	8.66a
S. N NPK (50kgN/ha)	4.33a	7.00a	8.66b	1.66a	3.33bc	7.00b
S. N NPK (100kgN/ha)	4.00a	6.66a	8.66b	1.66a	3.66b	7.00b

Means followed by the same letter in a column are not significantly different from each other at  $P < 0.05$  by DMRT. A.C= *Amaranthus cruentus*, C.A= *Celosia argentea*, S.M= *Solanum macrocarpon*, S.I= *Solanum incanum*, S.N= *Solanum nigrum*, MSC = Mexican Sunflower Compost

**Table 2. Effects of compost and NPK fertilizer on the Plant Height (cm) of the vegetables under the two experimental conditions.**

Treatments	Screen house			Open field		
	2WAS	4WAS	6WAS	2WAS	4WAS	6WAS
A. C Control	16.4a	20.1a	29.2a	19.2a	23.0a	31.5a
A. C+Sunflower (5ton/ha)	14.9ab	21.0a	28.6a	16.5ab	22.6a	30.5b
A. C+Sunflower (10ton/ha)	11.4b	15.4b	30.3a	14.8ab	23.5a	33.1a
A. C+NPK (50kgN/ha)	11.7b	14.8b	27.3a	18.2ab	22.8a	31.8a
A. C+NPK( 100kgN/ha)	12.7b	15.3b	24.8b	15.5ab	24.6a	33.7a
C. A Control	10.3ab	22.9a	35.1a	13.1a	18.4bc	31.5abc
C. A+Sunflower (5ton/ha)	12.4a	18.8ab	29.3a	12.3ab	31.1a	39.1a
C. A+Sunflower (10ton/ha)	9.00b	15.7b	23.1b	12.5ab	28.9ab	34.5abc
C. A+NPK (50kgN/ha)	7.23bc	19.3a	27.3ab	12.4ab	28.6ab	36.1abc
C. A+NPK (100kgN/ha)	9.40b	17.6ab	25.7ab	13.2a	29.8a	38.7ab
S. I Control	4.66b	7.83b	9.23a	2.7a	9.00a	11.7a
S. I+Sunflower (5ton/ha)	5.50ab	7.73b	9.03ab	2.5a	4.86bc	7.00bc
S. I+Sunflower (10ton/ha)	5.83ab	7.93b	9.03ab	2.8a	5.03b	7.00bc
S. I NPK ( 50kgN/ha)	6.16a	8.16a	9.83a	2.8a	5.53b	8.13b
S. I NPK (100kgN/ha)	5.06b	8.43a	8.90b	2.6a	5.60b	8.36b
S. M Control	5.00b	7.89b	10.9a	2.9a	5.88a	8.22a
S. M+Sunflower (5ton/ha)	5.16ab	8.45a	11.5a	2.5ab	4.86b	7.03bc
S. M+Sunflower (10ton/ha)	6.26a	9.42a	10.4a	2.8a	5.03a	7.03bc
S. M+NPK (50kgN/ha)	4.52bc	7.88b	8.45b	2.2ab	4.86b	7.89b
S. M NPK (100kgN/ha)	4.83b	8.22ab	8.73b	2.6a	5.53a	8.36a
S.N Control	7.22bc	10.5b	11.9bc	4.81b	9.86b	11.9b
S. N+Sunflower (5ton/ha)	7.16b	11.1b	11.9bc	5.08b	10.3ab	12.5ab
S.N+Sunflower (10ton/ha)	9.82a	13.9a	15.2a	5.99a	11.9a	13.6a
S. N+NPK (50kgN/ha)	8.16ab	12.4a	14.4a	5.30ab	10.8ab	11.8b
S.N+NPK (100KgN/ha)	8.09ab	11.9a	12.7b	5.22ab	11.4a	12.2ab

Means followed by the same letter in a column are not significantly different from each other at P < 0.05 by DMRT. A.C=*Amaranthus cruentus*, C.A=*Celosia argentea*, S.M= *Solanum macrocarpon*, S.I=*Solanum incanum*, S.N=*Solanum nigrum*, MSC = Mexican Sunflower Compost.

house conditions but application of 100 Kg N/ha gave the highest value at 4 and 6 WAS. Though, slow growing vegetable, there was exponential and considerable increase in the leaf area of all the *Solanum* varieties in the screen house compared to open field and was more than double the values obtained in the open field especially at 6 WAS. Leaf area production was enhanced in the amended soils compared to the control both in the screen-house and the open field conditions. The least value for leaf area was recorded in the control treatments. *S. nigrum* in comparison with the other *S.* species had the highest mean value for leaf area under screen-house in response to MSC at 10t/ha and NPK at 100 KgN/ha. Generally, the leaf areas of all the vegetables increased across all the treatments at 6WAP under both experimental conditions (Table 4).

**Effects of Mexican Sunflower Compost and NPK Fertiliser on the Chlorophyll Contents of the Vegetables Under the Two Experimental Conditions**

Chlorophyll production was enhanced in the screen-house conditions compared to the open field. It also increased as the plant ages. In *A. cruentus*, at 4 and 6 WAS, under screen-house, control performed better than fertiliser treatments except at 6 WAS under open field when MSC treatment at 5 t/ha gave the highest value but not significantly different from other treatments. Screen-house conditions also increased

**Table 3. Effects of compost and NPK fertilizer on the Stem Girth (cm) of the vegetables under the two experimental conditions.**

Treatments	Screen house			Open field		
	2WAS	4WAS	6WAS	2WAS	4WAS	6WAS
A. C Control	0.63ab	2.30ab	3.30ab	0.46ab	2.23ab	3.16a
A. C+Sunflower (5ton/ha)	0.73ab	2.63a	3.53a	0.50ab	2.30ab	2.96ab
A. C+Sunflower (10ton/ha)	0.60b	2.76a	3.53a	0.63a	2.36a	3.20a
A. C+NPK (50kgN/ha)	0.83a	2.56a	3.50a	0.63a	2.36a	3.43a
A. C+NPK( 100kgN/ha)	0.86a	2.73a	3.30ab	0.63a	2.43a	3.30a
C. A Control	0.43a	2.36a	3.06ab	0.66b	2.43a	3.06ab
C. A+Sunflower (5ton/ha)	0.20b	2.56a	3.03ab	1.46a	2.56a	3.16a
C. A+Sunflower (10ton/ha)	0.33ab	2.30ab	2.96b	0.93ab	2.43a	3.10a
C. A+NPK (50kgN/ha)	0.36ab	1.93b	3.12a	0.90ab	2.23ab	3.10a
C. A+NPK (100kgN/ha)	0.36ab	2.03ab	3.16a	1.53a	2.50a	2.86b
S. I Control	0.46b	0.96b	2.20ab	0.13ab	0.60ab	1.80ab
S. I+Sunflower (5ton/ha)	0.36bc	0.86b	1.96b	0.20a	0.63ab	1.80ab
S. I+Sunflower (10ton/ha)	0.93a	1.46a	2.60a	0.13ab	0.70a	2.06a
S. I NPK (50kgN/ha)	0.30bc	1.13ab	2.30ab	0.13ab	0.73a	2.03a
S. I NPK (100kgN/ha)	0.66ab	1.20ab	2.26ab	0.16a	0.56ab	1.80ab
S. M+Control	0.13ab	0.60ab	1.80ab	0.16ab	0.53b	1.63ab
S. M+Sunflower (5ton/ha)	0.20a	0.63ab	1.80ab	0.13b	0.56b	1.46b
S. M+Sunflower (10ton/ha)	0.13ab	0.70a	2.06a	0.20ab	0.83a	1.73a
S. M+NPK (50kgN/ha)	0.13ab	0.73a	2.03a	0.13b	0.63ab	1.66ab
S. M+NPK (100kgN/ha)	0.16a	0.56b	1.80ab	0.26a	0.66ab	1.56ab
S. N+Control	0.56a	0.96ab	2.30a	0.16b	0.46b	1.63b
S. N+Sunflower (5ton/ha)	0.46b	0.86ab	1.86b	0.20ab	0.50ab	1.83ab
S. N+Sunflower (10ton/ha)	0.54a	2.46a	2.70a	0.23a	0.50ab	2.06a
S. N+NPK (50kgN/ha)	0.33b	1.33ab	2.50a	0.20ab	0.43b	1.60b
S. N+NPK (100kgN/ha)	0.68a	1.40ab	2.46a	0.26a	0.56a	1.96ab

Means followed by the same letter in a column are not significantly different from each other at P < 0.05 by DMRT. A.C=*Amaranthus cruentus*, C.A=*Celosia argentea*, S.M= *Solanum macrocarpon*, S.I=*Solanum incanum*, S.N=*Solanum nigrum*, MSC = Mexican Sunflower Compost.

the chlorophyll contents of *C. argentea* compared to open field. *C. argentea* treated with NPK 50kgN/ha in the screen-house had the highest amount of chlorophyll compared to other treatments at 6 WAS while, control plants had the highest chlorophyll concentration in the open field at 6 WAS. In terms of chlorophyll production, the *S.* varieties also showed higher chlorophyll concentrations in the screen-house compared to open field across all the treatments and in comparison to the other vegetables. Specifically, *S. macrocarpon* grown in the screen-house with NPK had the highest mean value, followed by the control which had no soil amendment, but on the field, application of MSC at 5t/ha gave the highest value of chlorophyll. *S. incanum* also responded positively to NPK fertiliser and had the highest chlorophyll concentration in this treatment (Table 6).

**Total Fresh and Dry Weight of the Harvested Vegetables**

The total fresh and dry weights recorded for all the vegetables at harvesting showed that growing vegetables under screen-house conditions favours biomass accumulation compared to open field. The total fresh and dry weights recorded for *C. argentea* showed that it had more weight in the screen-house than open-field. In the screen-house, the fresh weight was 110g, and its dry weight was 58 g, while in the open-field its fresh weight was 78 g and its dry weight was 26 g. *A. cruentus* also had fresh and dry weights of 107 and 44 g, respectively in the screen-house, while

Table 4. Effects of compost and NPK fertilizer on the leaf area (cm<sup>2</sup>) of the vegetables under the two experimental conditions.

Treatments	Screen house			Open field		
	2WAS	4WAS	6WAS	2WAS	4WAS	6WAS
A. C Control	9.56b	24.0ab	38.6b	10.2ab	21.0ab	29.9b
A. C+Sunflower (5ton/ha)	16.3a	26.5a	39.1b	10.0ab	20.4ab	31.4a
A. C+Sunflower (10ton/ha)	10.8b	28.7a	48.5a	14.9a	23.5a	30.8ab
A. C+NPK (50kgN/ha)	12.8ab	23.5ab	42.7ab	10.8ab	23.3a	30.0ab
A. C+NPK(100kgN/ha)	12.0ab	20.7b	44.1ab	13.5a	22.7ab	34.3a
C. A Control	8.06b	26.8ab	48.6ab	7.49ab	18.4b	31.5ab
C. A+Sunflower (5ton/ha)	9.88ab	21.8ab	41.6ab	8.75ab	31.0a	39.1a
C. A+Sunflower (10ton/ha)	8.48ab	22.8ab	33.0b	7.50ab	28.9ab	34.5ab
C. A+NPK(50kgN/ha)	8.17b	38.6a	40.2ab	9.42a	28.6ab	36.1ab
C. A+NPK(100kgN/ha)	13.5a	33.5a	53.2a	9.11a	29.8ab	38.7a
S. I Control	5.27b	15.3bc	78.1b	5.29a	15.3ab	24.1b
S. I+Sunflower (5ton/ha)	4.05c	13.6bc	86.3ab	4.73ab	13.6b	27.7ab
S. I+Sunflower (10ton/ha)	5.14b	17.2b	85.2ab	4.97ab	17.2ab	21.7b
S. I NPK (50kgN/ha)	10.0a	20.9a	89.7a	4.21a	15.4ab	24.8ab
S. I NPK (100kgN/ha)	5.32b	20.7a	92.4a	5.32a	20.5a	32.5a
S. M Control	10.3ab	34.1a	68.4b	13.5ab	35.0ab	52.1ab
S. M+Sunflower (5ton/ha)	13.4a	38.4a	89.3ab	16.2a	29.4ab	46.7ab
S. M+Sunflower (10ton/ha)	11.2a	39.6a	77.3b	11.1b	35.6a	56.0ab
S. M NPK (50kgN/ha)	11.6a	38.6a	91.8a	14.0ab	33.1ab	61.3a
S. M NPK (100kgN/ha)	10.4ab	34.4a	88.6ab	13.9ab	28.8b	50.6ab
S. N Control	19.9b	28.5d	34.6c	5.80a	16.7ab	36.8ab
S. N+Sunflower (5ton/ha)	24.1ab	61.1bcd	78.0b	4.73ab	15.5ab	38.5ab
S. N+Sunflower (10ton/ha)	27.9ab	92.9ab	103.6a	5.02a	16.4ab	40.9a
S. N NPK (50kgN/ha)	33.0a	80.6bc	97.8ab	4.62ab	15.5ab	38.5ab
S. N NPK (100kgN/ha)	39.1a	134.0a	159.0a	4.63ab	17.7a	44.4a

Means followed by the same letter in a column are not significantly different from each other at  $P < 0.05$  by DMRT. A.C=*Amaranthus cruentus*, C.A=*Celosia aregentea*, S.M=*Solanum macrocarpon*, S.I=*Solanum incanum*, S.N=*Solanum nigrum*, MSC = Mexican Sunflower Compost.

in the open-field, it had fresh weight of 54 g and dry weight of 19 g. *A. spinosus* followed next with fresh weight of 92 g and dry weight of 30 g in the screen-house while in the open-field it had fresh weight of 48g and dry weight of 18 g. *S. macrocarpon* followed the same trend and had fresh weight of 59g and dry weight of 28 g in the screen-house while in the open-field, it recorded fresh weight of 25 g and dry weight of 12 g. Then *S. incanum* in the screen-house recorded fresh weight of 42 g and dry weight of 19 g, while in the open-field, it had fresh weight of 14 g and dry weight of 9 g. *S. nigrum* also had more of fresh and dry weights in the screen-house compared to open-field which were 38 g and 20 g in the screen-house and in the open-field, fresh weight of 25 g and dry weight of 12 g (Figure 1).

### Effects of Mexican Sunflower Compost and NPK Fertiliser on the Moisture and Ash Contents of the Vegetables Under Both Experimental Conditions

Mexican sunflower compost increased the moisture contents of *Solanum* vegetables both in the screen-house and open field compared to NPK fertiliser, while, application of 100 kgN/ha of NPK fertiliser to both *C. argentea* and *A. cruentus* gave the highest moisture content. There was no significant difference in the moisture contents of *S. incanum* at 100 kgN/ha and control (Figure 2). *Celosia argentea* grown on the open field with the

Table 5. Effects of compost and NPK fertilizer on the chlorophyll content ( $\mu\text{g/g}$  FW) of the vegetables under the two experimental conditions.

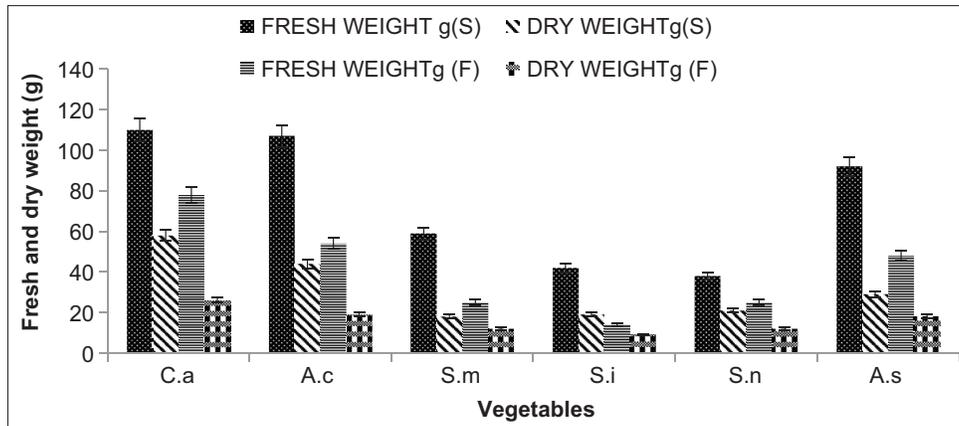
Treatments	Screen house			Open field		
	2WAS	4WAS	6WAS	2WAS	4WAS	6WAS
A. C Control	26.8ab	40.5a	47.9a	21.9a	33.2ab	35.4ab
A. C+Sunflower (5ton/ha)	24.8b	35.0ab	44.7ab	19.3ab	32.0ab	38.5a
A. C+Sunflower (10ton/ha)	27.4a	36.9a	44.8ab	22.1a	31.5ab	29.9b
A. C+NPK (50kgN/ha)	26.8ab	37.7a	43.1ab	21.1a	33.9a	37.5a
A. C+NPK(100kgN/ha)	27.9a	35.1ab	44.2ab	20.8a	32.1ab	35.5ab
C. A Control	41.2a	41.3a	44.5ab	34.1a	35.4ab	42.9a
C. A+Sunflower (5ton/ha)	35.1ab	35.5ab	43.4ab	30.0a	36.8a	40.7a
C. A+Sunflower (10ton/ha)	38.2a	39.5a	41.9b	23.6c	33.5ab	37.2ab
C. A+NPK (50kgN/ha)	29.3b	39.8a	44.9a	26.1b	35.4ab	38.0ab
C. A+NPK (100kgN/ha)	29.4b	39.5a	42.3ab	28.8b	36.0a	38.7ab
S. I Control	25.5a	37.1a	52.1ab	22.4ab	25.1b	41.6a
S. I+Sunflower (5ton/ha)	26.5a	35.1ab	48.9b	21.7b	27.9a	39.8ab
S. I+Sunflower (10ton/ha)	25.7a	35.1ab	49.8b	22.8ab	27.4a	38.9ab
S. I NPK (50kgN/ha)	27.4a	35.4ab	52.5ab	25.4a	27.5a	34.3ab
S. I NPK (100kgN/ha)	28.0a	35.8ab	53.5a	25.0a	27.5a	31.5b
S. M Control	45.3ab	49.0a	51.1ab	36.6ab	37.3ab	42.6ab
S. M+Sunflower (5ton/ha)	49.9a	48.7ab	49.2ab	37.0ab	44.2a	47.5a
S. M+Sunflower (10ton/ha)	45.6ab	46.6ab	51.1ab	37.2ab	38.1ab	43.4ab
S. M NPK (50kgN/ha)	45.9ab	47.5ab	52.6a	33.8ab	38.8ab	43.4ab
S. M NPK (100kgN/ha)	50.0a	49.9a	52.3ab	39.8a	32.1bc	42.6ab
S. N Control	25.3ab	45.9a	52.3a	21.4a	32.6ab	32.6ab
S. N+Sunflower (5ton/ha)	28.8a	40.9ab	50.0ab	24.1a	36.8a	36.2a
S. N+Sunflower (10ton/ha)	25.1ab	42.1ab	50.0ab	21.4a	31.2ab	31.5ab
S. N NPK (50kgN/ha)	25.8ab	41.3ab	48.8ab	21.6a	32.9ab	32.1b
S. N NPK (100kgN/ha)	26.8ab	41.3ab	50.0ab	23.1a	32.5ab	29.8c

Means followed by the same letter in a column are not significantly different from each other at  $P < 0.05$  by DMRT. A.C=*Amaranthus cruentus*, C.A=*Celosia aregentea*, S.M=*Solanum macrocarpon*, S.I=*Solanum incanum*, S.N=*Solanum nigrum*, MSC = Mexican Sunflower Compost.

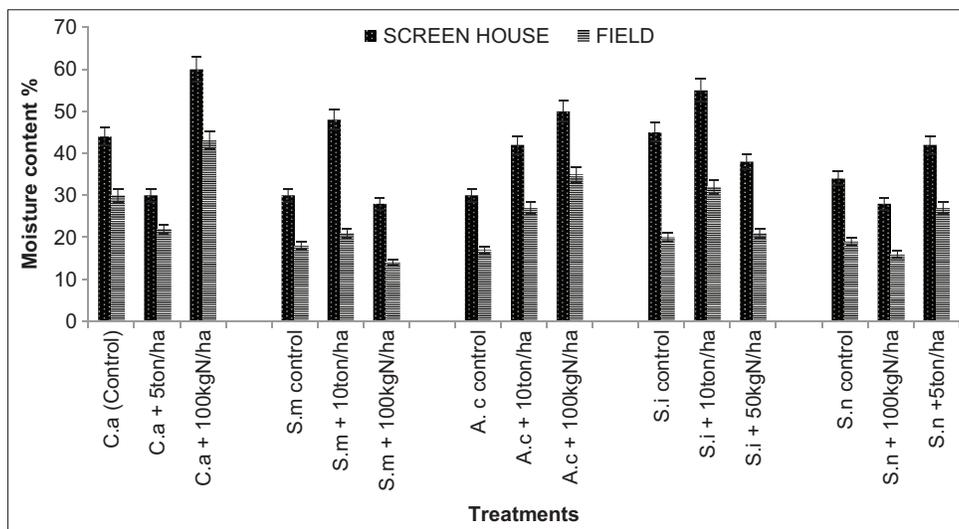
application of 100 kgN/ha NPK fertiliser had the highest ash content, while control had the highest ash content in the screen-house. *S. macrocarpon* had the least ash content with the application of 100 kgN/ha under both experimental conditions. *S. nigrum* and *S. macrocarpon* at 10 t/ha compost had higher ash contents than with the application of NPK. It was observed that the *Solanum* varieties grown on soil without amendments also had higher ash contents than those treated with NPK. *A. cruentus* was observed to have the highest ash contents with the application of 100 kgN/ha both in the screen-house and open field while control had the least ash content only on the field. Meanwhile at 10 t/ha, compost application to *A. cruentus* gave the least ash content in the screen-house. Generally, the ash contents of the *Solanum* vegetables was enhanced in the screenhouse more than open field and with the application of compost (Figure 3).

### Effects of Mexican Sunflower Compost and NPK Fertiliser on the Crude Protein Contents of the Vegetables Under Both Experimental Conditions

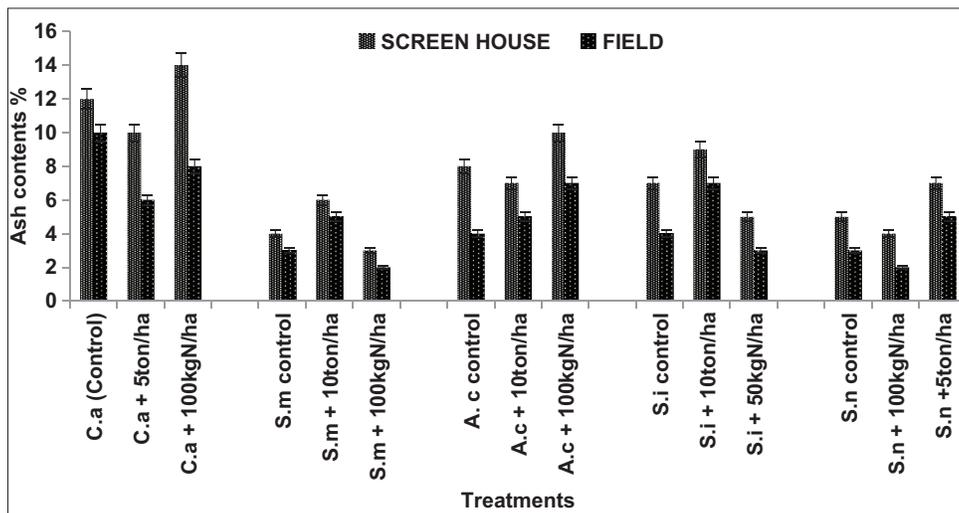
As observed for the moisture and ash content, crude protein content was also enhanced under screen-house than open field. The result showed that soil amendments with NPK fertiliser at 100 kgN/ha increased the crude protein content of *C. argentea* vegetable on the field, while in the screen-house, soil



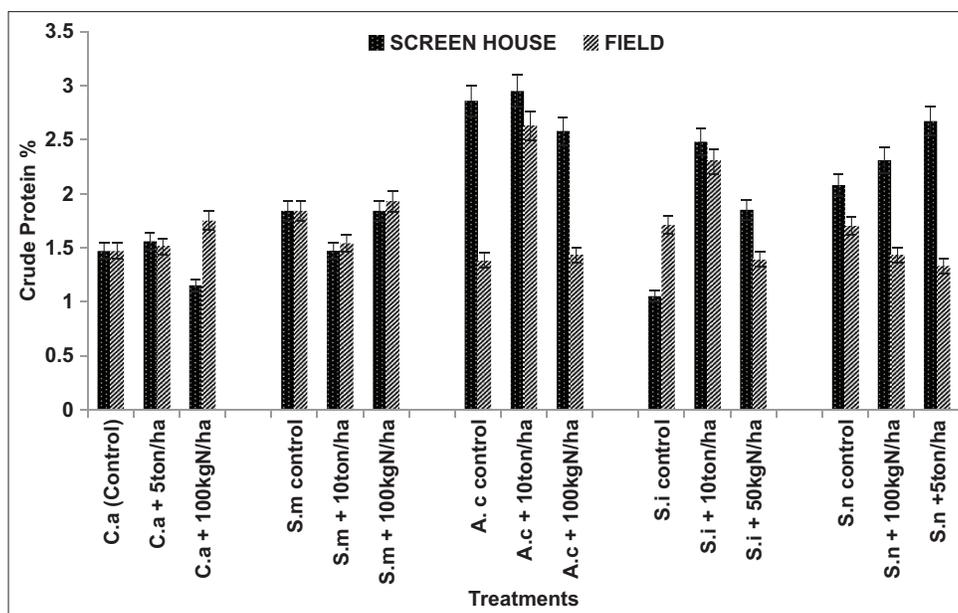
**Figure 1:** Total fresh and dry weights of the harvested vegetables. (C.a, A.c, S.m, S.i and S.n denote *Celosia aregentea*, *Amaranthus cruentus*, *Solanum macrocarpon*, *Solanum incanum* and *Solanum nigrum* respectively (Bars of chart represent 5% Standard Error)



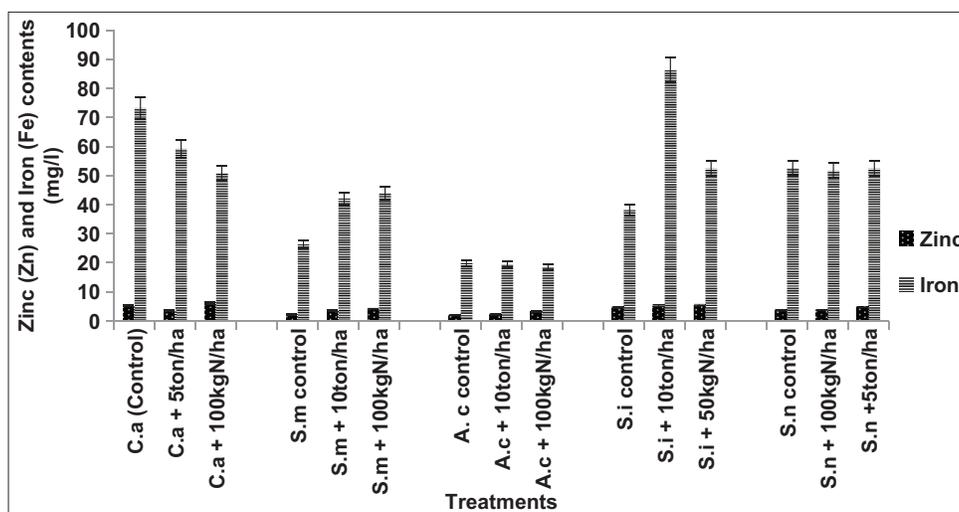
**Figure 2:** Effects of the treatments on the moisture contents of the vegetables under the two experimental conditions. (C.a, A.c, S.m, S.i and S.n denote *Celosia aregentea*, *Amaranthus cruentus*, *Solanum macrocarpon*, *Solanum incanum* and *Solanum nigrum* respectively (Bars of chart represent 5% Standard Error)



**Figure 3:** Effects of the treatments on the ash contents of the vegetables under both experimental conditions. (C.a, A.c, S.m, S.i and S.n denote *Celosia aregentea*, *Amaranthus cruentus*, *Solanum macrocarpon*, *Solanum incanum* and *Solanum nigrum* respectively (Bars of chart represent 5% Standard Error)



**Figure 4:** Effects of the treatments on the crude protein contents of the vegetables under both experimental conditions. (C.a, A.c, S.m, S.i and S.n denote *Celosia aregetea*, *Amaranthus cruentus* *Solanum macrocarpon*, *Solanum incanum* and *Solanum nigrum* respectively (Bars of chart represent 5% Standard Error).



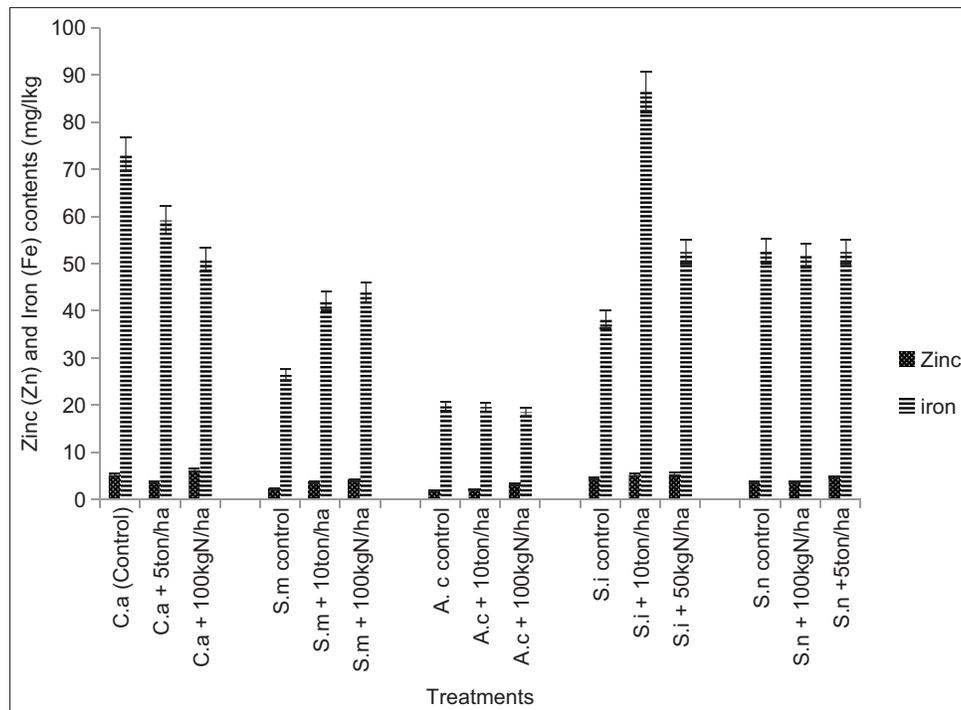
**Figure 5:** Effects of Mexican sunflower compost and NPK fertilizer on the Zinc and Iron concentrations of the vegetables in the screen-house (C.a, A.c, S.m, S.i and S.n denote *Celosia aregetea*, *Amaranthus cruentus* *Solanum macrocarpon*, *Solanum incanum* and *Solanum nigrum* respectively (Bars of chart represent 5% Standard Error)

amendment with compost at 5 t/ha increased the crude protein. In both experimental conditions, there was no significant difference in soils without amendments. The crude protein was significantly enhanced by compost at 10 t/ha for *A. cruentus* both in the screen-house and on the field. *S. incanum* grown on soil without amendment had the least crude protein produced, while 10 t/ha sunflower compost gave the highest crude protein production. On the other hand, 100 kgN/ha significantly increased the crude protein of *S. macrocarpon* and there was no significant difference in the control. The application of 10 t/ha sunflower compost, gave the least crude protein mean values. Organic amendment at 5 t/ha gave a significantly high crude protein in *S. nigrum* vegetable grown in the screen-house, while

in the open-field, control which is the soil without amendment had the highest value (Fig 4).

#### Effects of Mexican Sunflower Compost and NPK fertiliser on the zinc and iron contents of the vegetables in the screen-house

*Celosia aregetea* with the application of 50 kgN/ha NPK had the highest iron and zinc contents, while soil with the application of 5 t/ha compost gave the lowest zinc and iron contents. *S. macrocarpon* grown on the soil without amendments had the highest iron contents, and there was no significant difference in the zinc concentrations across all the treatments. Meanwhile,



**Figure 6:** Effects of Mexican sunflower compost and NPK fertilizer on the Zinc and Iron concentrations of the vegetables under the open-field. (C.a, A.c, S.m, S.i and S.n denote *Celosia argentea*, *Amaranthus cruentus*, *Solanum macrocarpon*, *Solanum incanum* and *Solanum nigrum* respectively (Bars of chart represent 5% Standard Error)

with the application of 10 t/ha compost to *A. cruentus*, iron content was enhanced while control had the lowest, and there was no significant difference in the zinc contents across all the treatments. Soil without amendment for both *S. incanum* and *S. nigrum* vegetables had the highest iron concentrations, followed by soil with the application of 10 t/ha compost. There were no significant differences in the zinc contents of both *S. incanum* and *S. nigrum* vegetables across all the treatments (Fig 5). Application of 100 kgN/ha to *Celosia* vegetable gave the least iron content and highest zinc content, while the control had the highest iron content, followed by the soil with the application of 5 t/ha. *S. macrocarpon* treated with the application of 100kgN/ha NPK had the highest iron content while the control had the lowest, but there were no significant difference in the zinc content across the treatments. Similarly, there were no significant difference in both the zinc and iron contents across all the treatments of *A. cruentus*. With the application of 10 t/ha compost gave the highest iron content, while the control plant had the least iron content. There were no significant difference in the zinc content across all the treatments. No significant difference in both the zinc and iron contents of *S. nigrum* (Fig 6).

## DISCUSSION

The environmental factors such as relative humidity, temperature and light intensity are known for controlling plant evapo-transpiration and this has significant effect on crop growth and development. Light intensity determines the relative humidity, temperature and plant transpiration rate. The result of this study showed clearly the importance

of reduced light intensity on vegetable production and the potential of fertilisers especially the Mexican sunflower compost in improving vegetable production under different growing conditions. The relative humidity in the screen-house was more than that of the open-field because there was less exposure to direct sunlight. Lower temperature value was also recorded in the screen-house compared to the open field. These were responsible for the performance of the selected vegetables that was generally better in the screenhouse than open field. This was because screen-house created a modified microclimate in which radiation and wind movement were lowered but relative air humidity was higher than in the open field, resulting in reduction in evapo-transpiration.

Variations that were observed in the response of different vegetables to organic and inorganic fertilisers were due to the nature of the two types of fertilizer and the growing pattern of these vegetables. Addition of NPK fertiliser gave the highest plant height at 6 WAS especially for *A. cruentus* and *C. argentea* vegetables compared to compost both in the screen house and open field. Compost is known for slow rate of mineralization by releasing its nutrients slowly to the soil unlike NPK fertiliser. These nutrients were however, made available to the *Solanum* varieties (*S. incanum*, *S. macrocarpon*, and *S. nigrum*) being slow-growing plants and their growth rates synchronized with the rate of nutrient release in compost at which time the NPK would have been leached out as at the time the *S.* varieties were just coming up. This therefore explained the positive response of *Solanum* species to compost more than other vegetables. This coupled with the availability of essential nutrients in compost accounted for the better performance of *Solanum* vegetables in

compost amended soils under both conditions of open field and screen-house. This was also in accordance with earlier reports that organic amended soil supplies twice the essential nutrients than inorganic fertilizer.

Generally, it was observed that the leaf area of the different vegetables increased under the screenhouse conditions compared to the open-field. This might be attributed to increase in the activities of metabolic enzymes under reduced temperature in the screen-house, the condition that will support the synthesis of proteins needed for structural buildup. High temperature induced by high light intensity has been implicated in the increase in evapotranspiration, leaf/canopy temperature and disruption of physiological processes. Addition of fertilizer, especially, compost reduced the effect of the temperature on the open-field grown vegetables better than NPK fertilizer due to the water retaining ability of organic fertilizer. Nutrient availability in sufficient amount has been reported to improve plant leaf area development. Furthermore, there was a significant increase in the growth parameters of *S. nigrum*, *S. macrocarpon* and *S. incanum* under the screen-house condition in combination with compost amendment due to reduction in water loss which in turn enhances chlorophyll formation, photosynthesis and biomass accumulation in the screenhouse more than the open field. In search for light, the solanum species grown in the screenhouse also had taller stems compared to those grown on the open field. The increase in plant height under shade has also been reported to be due to removal of the light induced inhibition of gibberellic acid which is known to be responsible for stem elongation.

Light however, enhances leaf formation in the open field where higher number of leaves was recorded. The reason given for this was that under high light intensity, the increase in leaf transpiration rates could facilitate the efficient uptake of water and nutrient from the soil which in turn could have increased the rate of photosynthesis and leaf production. The Amaranthus species that out-performed other vegetables under the open field condition belongs to the plant species that make use of carbon four photosynthetic pathway and these plants have been reported to have high photosynthetic efficiency under high light intensity due to their high water use efficiency coupled with reduction in photorespiration process; a wasteful physiological process. Meanwhile, other vegetables that did not perform well under high light intensity belong to the carbon three plant species that follow Carbon three photosynthetic pathway. The physiological processes of these plant species are usually affected by high light intensity due to the increase in photorespiration and water loss. This probably was responsible for poor growth of these vegetables and low biomass accumulation under open field.

Low-light intensities in the screen-house also improved the chlorophyll pigments formation of the leaves compared to open field conditions. The Solanum varieties which are always rich in chlorophyll concentrations had more chlorophyll in the screen-house than the open-field. The increase in chlorophyll concentration could also be attributed to low temperature and water availability, all of which results in increase in physiological

and biochemical processes. Chlorophyll production has been reported to decrease under high light intensity due to impairment in enzymatic activities as a result of increase in temperature. Besides, degradation of chlorophyll has also been reported under severe stress like drought and high light intensity (Arnao and Hernandez-Ruiz, 2009). The degradation might have been caused by increase in the production of reactive oxygen species under high light intensity/temperature (Siddiqi *et al.*, 2009; Jalal *et al.*, 2012). The increase in transpiration rate under high light intensity might have also reduced the available water for physiological processes like chlorophyll synthesis.

It has been reported that leafy vegetables have high moisture content ranging from 72.93% to 91.83% (Kwenin *et al.*, 2011). George (2003) stated that moisture content makes an important contribution on the texture of the leaves and helps in maintaining the protoplasmic content of the cells. In this study, the significant difference observed may be due to the cultivation conditions that influenced the water level of vegetables (Florkowski *et al.*, 2009). Screen-house conditions increased the biomass accumulation and leaf area development and, it also increased the moisture content of the tested vegetables more than those grown under the open field probably due to reduction in transpiration and ability to retain water in the protoplasm for a longer period of time. The ash content of any sample is also the measure of the mineral contents present in such sample. The result of the ash content revealed that fertilizer application and growing environment have significant effects on ash contents of the vegetables. With fertilizer, nutrients are made available and with the provision of shade in the screen-house there was efficient conversion of the absorbed nutrients to food which in turn results in high ash contents. Not only the ash content was enhanced, the crude protein production was also positively affected due to reduction in temperature and consequent increase in protein synthesis and enzymatic activities under optimum temperature. Meanwhile, leafy vegetables, though are good sources of protein and they help in building, and maintaining plant tissues, but depending on the species and type of vegetable, the ash and crude protein contents varied. The crude protein content of *A. cruentus* vegetable was the highest, while *S. incanum* vegetable showed the least crude protein content. The level of protein in the vegetables generally indicates that they are very important for human health and are good supplements for humans.

The differences in the micronutrient contents of the tested vegetables may be attributed to their differences in type of fertiliser, availability and absorption efficiencies. Nutrient concentrations in foods depend largely on the quality of soil in which the crops are grown. Soil fertility management practices were reported to affect zinc and iron concentrations in vegetables and there was a direct association between soil chemical properties and vegetable mineral concentrations (Amuri *et al.*, 2017). Mexican sunflower compost is a good source of necessary nutrients which is an indicative that the materials are good sources of plant nutrients for maximum production of vegetables. This is in agreement with Atayese and Liasu (2001) that Mexican sunflower compost contained arbuscular mycorrhizal fungi spore which enhanced absorption

of nutrients from soil to biomass. Different plant varieties also have different root system and hence different efficiency in exploiting and taking up nutrients from the soil. Zinc content in *C. argentea* at 100 kgN/ha was significantly higher than what was reported in other commonly grown vegetables (Kamga *et al.*, 2013). There was no significant difference in the Zinc contents of the *S.* varieties which may be attributed to the diversion of minerals towards plant development and possibly antioxidant production.

Under both conditions however, Mexican sunflower compost treated soils performed better than inorganic fertilizers and this could be attributed to the nutrient availability as earlier reported for compost (Qureshi, 1990, Adejumo *et al.*, 2011). High level of nutrient has also been reported in Mexican sunflower and this contributed to its acceptability by soil fertility scientists as a good source of plant nutrients (Sacred Africa, 2007). *Vegetables* had the highest fresh and dry weight yield in response to compost application especially in the screen-house conditions which confirms the findings of Ganunga *et al.* (1998) and Adejumo (2010) who reported the effectiveness of Mexican sunflower in soil fertility improvement.

## CONCLUSION AND RECOMMENDATION

This study showed that for the *S.* varieties, Mexican sunflower at 10 t/ha performed well in all growth parameters especially under low irradiance. Leafy vegetables grown inside screen-houses, shades or low light intensities also performed excellently well than the ones grown under direct sunlight. It is therefore recommended that leafy vegetables should be grown under shade using Mexican sunflower compost at 10t/ha as this increased the growth and yield of the vegetables.

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