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Growth and yield parameters of *Celosia argentea* in a greenhouse

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Abstract

Growth parameters and yield components of *Celosia argentea* cultivated in a greenhouse were investigated in order to establish its availability at all times of the season in South Africa. Three harvest periods at pre-flowering(PRE), flowering (FLW) and post-flowering (PST) stages of growth were investigated. Growth parameters were measured two weeks after transplanting (WAT) from five randomly selected pots in each row. Two separate pot experiments were conducted between October 2017- January 2018 and March- May 2018 respectively. Results revealed that the first trial had the highest values for all the growth parameters evaluated except the number of flowers and branches. Reduction in the number of leaves was observed for both trials at 10 WAT, while the post-flowering stage of growth had the highest values for fresh and dry yield. The study revealed that high yield of *C.argentea* could be expected around 7-9 weeks after transplanting and that planting in the field is to be encouraged during summer or late spring for best farm management.

Keywords:*Celosia argentea*, Greenhouse, Leafy vegetables**.**

Introduction

Leafy vegetables contribute significantly to food security and income generation for a large segment of the population. However, vegetable crop cultivation has been one of the least statistically explored sectors in many African countries. Additionally, the specificity of vegetable crops with regard to different methods of cultivation, growing cycle, time, frequency and different harvesting methods adopted by farmers pose certain challenges (Juma, 2015). This therefore calls for reliable and timely information on vegetable cultivation as this will play a crucial role in planning and allocating resources for the development of the agriculture sector and food security in Africa (Keita et al., 2010).

Celosia argentea (L.) Kuntze is one of the most popular, economically important vegetable crops cultivated in the tropical and sub-tropical regions of Africa,tropical America and Asia (Yarger, 2007). The species, also known as cockscomb, is an edible species of the Amaranthaceae family. Several nutritional studies have reported its richness in vitamins and mineral contents, as well as its high level of proteins and carbohydrates (Abdulmaliq et al., 2016). *Celosia* vegetables serve as a source of living for most rural vegetable farmers during the dry season in the south western parts of Nigeria, where it is known as Sokoyokoto (Akinfasoye et al., 2008*).* It is also used as livestock feed and as forage for poultry (Yarger, 2007). Traditionally, the plant is used for the treatment of diahorrea, inflammation, gynecological disorders and piles. *C. argentea* has also been recognized for pharmacological activities such as anti-bacterial, antinociceptive, antispasmodic,and anti-diabetic (Varadharaj and Muniyappan, 2017).

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Celosia argentea vegetable has a ridged stem with simple and alternate leaves which are without stipules, petiole indistinctly demarcated; blade ovate to lanceolate; narrowly linear tapering at base and pinnately veined. Inflorescences are usually conical with red, purple or pink colour for cultivated varieties (Gleason and Cronquist, 1991). The fruit is an ovoid to globose capsule, 3-4mm long and seeds are long (1-1.15 mm), shining, lenticular with shallowly reticulate shape. Propagation of *Celosia* is by seed; the seeds usually germinate between five-seven days after sowing and flowering occurs six - seven weeks after sowing (Grubben, 2004).

Cultivation of this vegetable has been reported during the rainy and dry seasons in some parts of West Africa. Although *C. argentea* grows in the wild in South Africa, due to the variation in the climatic conditions of the country, cultivation of this plant may require a controlled environment. Green houses are widely used to provide a controlled environment suitable for optimal production (Ayas et al., 2011). Most plants trials are conducted in regulated environments to enable a close monitoring of optimal conditions for increased yield. *C. argentea* is grown mainly under tropical to sub-tropical conditions. With modern greenhouse and controlled environment technologies, it is now possible to produce many tropical crops with increased yield and quality. It is important to know the growth efficiency of the crop under a controlled environment. Results from such a study can be adapted by farmers on a larger scale in the field.

The present study was therefore carried out to study the growth parameters and yield components of *C.argentea* cultivated in a greenhouse to advocate its domestication in SouthAfrica.

Material and Methods

Description of study area

The experiment was conducted in a greenhouse located at the Botany Department, University of Fort Hare, South Africa. Geographically, the site lies at latitude 32º 47'- 19º26' S, longitude 26º50'- 42º306'E and altitude of 514.70m above sea level.The experiment was carried out during spring (October 2017- January 2018) and winter (March-May 2018).

Seeds, pot preparation and experimental design

Mature seeds of *C. argentea* were obtained from an Agro shop in Nigeria and stored at room temperature in sealed bottles until use. Two separate pot experiments for the first and second trials were conducted between October 2017- January 2018 and March- May 2018 respectively. The experiment was laid out in Completely Randomized Design(CRD) with eight rows and nine columns under uniform temperature (25 ºC). Seeds were raised in rectangular seedling trays measuring 65×100 cm^2 with 200 bottom holes. The trays were filled with compost soil (Khanya Nursery, Alice Eastern Cape, South Africa). The concentrations of Ca, K, Mg, Na, P, Cu, Mn and Zn in the soil before and after planting were determined using the Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) as outlined by AGRILASA(2008). Seedling emergence was monitored and the pots were watered daily. Seedlings were transplanted singly at four leaf stage into 72 experimental pots measuring 25 cm in diameter and containing 5 kg of soil each (arranged in a completely randomized block design with eight rows and nine columns) on the10th of November 2017 and 7th of March 2018 for the first and second trials respectively. Growth parameters were recorded on a weekly basis throughout the experimental period.

Data collection

The week of transplanting was recorded as week 0. Five pots were selected randomly from each row for data collection and the growth parameters measured weekly were plant height, leaf length, leaf breadth, petiole length and stem girth (cm). Yield parameters measured were number of leaves, number of branches, leaf area (cm), number of flowers, plant fresh and dry weights (g) and number of days to emergence of the first flower. Readings were taken from week 0 to the 12th week after transplanting. Pots were kept free of weeds by weeding each pot frequently.

Harvesting

Observations were taken at three growth stages *viz.,*pre-flowering (PRE), flowering (FLW) and post-flowering (PST). Fresh leaf and stem was harvested when the first flower was observed (PRE), the second harvest was done when 50% of the plants had lowered (FLW), while the third harvest was done when the leaves and flowers were dropping (PST). Three plants were randomly selected from each row for harvest and destructive harvesting method was employed. Fresh and dry weight of the root, shoot and whole plant was determined at each harvest. For dry weight, the randomly selected plants for harvest were cut into root and shoots, the root and shoots were oven dried at 70 ºC for 72 h until constant weight was achieved. The fresh and dry weights of the plant were determined using digital weighing balance (Scout Pro SPU 6001, Pine Brook NJ, USA). Each trial was terminated on the 12th week when over 80% of the plants were seeding in both trials.

Statistical analysis

Data were subjected to one-way analysis of variance (ANOVA) and where significance was observed ($p<0.05$), means were separated using Fisher's (LSD) and GENSTAT or Minitab statistical package and significant correlation was determined using Pearson correlation.

Results and Discussion

Soil parameters

The physico-chemical properties of the soil before the experiment and the soil nutrient status after planting are presented in Table 1. The pH of the clayey loam soil was 4.92 for the first trial and 5.61 for the second trial. Growth media pH influences the availability and plant uptake of essential plant nutrients. Warneke and Krauskopf (1983) reported that pH greater than 6.5 increased the chances of nutrient deficiency in plants. The media pH for both trials before planting fell between the desirable ranges required for greenhouse growth as outlined by these researchers. The calcium (Ca), copper (Cu), magnesium (Mg), phosphorus (P), potassium (K) and zinc (Zn) contents of the soil used for the second trial were higher than that of the first trial. However, the manganese content of the soil used for first trial (77 mg/L) was higher, relative to the soil used for the second trial (3 mg/L) (Table 1). Out of all the essential elements in soil required by plants for growth and development, Ca, Mg, P and K are usually required in relatively large quantities (Adeyeye, 2005). In line with this fact, it could be deduced that the reduction in the level of K, Ca and Mg in the nutrient status of the soil after the experiment was as a result of the heavy uptake by the *C. argentea* plants. However, it appeared that the phosphorus level increased slightly.

The results showed that the first trial soil had high organic carbon, while the soil used for the second trial had low organic carbon. Low soil fertility has been identified as a critical constraint to agricultural productivity in Africa, where the use of organic fertilizer among small scale farmers is usually restricted to only cash crops (Fanadzo et al., 2010). The soil analysis indicated that the soil samples used for the first and second trial cultivation were free of heavy metals such as chromium (Cr), arsenic (As) and cadmium (Cd) and contained high amounts of

*Table 1***.** Physio-chemical properties of the soil before and after planting in the first and second trial

Samples	Sample density g/mL	P mg/L	K mg/L	Ca mg/L	Mg mg/L	Exch. Acidity cmol/L	Total cmol/L	AcidSat. cationic%	pH (KCL)	Zn mg/L	Mn mg/L	Cu mg/L
First trial pre planting soil	0.71	90	736	3057	783	0.05	23.63	0	4.92	25.7	77	5.2
First trial post planting soil	0.70	130	270	2880	650	0.13	25.53	1	6.42	34.9	14	2.0
Second trial pre planting soil	0.80	140	1626	4272	976	0.11	33.62	0	5.61	27.5	3	6.2
Second trial post planting soil	0.87	150	1356	3039	642	0.09	24.01	0	6.71	31.1	4	4.8

essential mineral nutrients. Although, Mn and Cu are sometimes considered as heavy metals, their values in the media for both trials were not above the required level. *Celosia argentea* adapts to different soil conditions; however, various studies have revealed that a well-drained fertile soil with plenty of organic matter is required for its growth and development (Norman et al., 2009; Akinfasoye et al., 2008; Zuck, 2015). Soil moisture is also an important factor for optimum growth of this species, as water stress can result in premature flowering (Sakata, 2015). This implied that for domestication purposes, the specificity of *C. argentea* vegetable as far as soil was concerned was met by the soil used in this study.

Plant height

The outcome of the growth and yield parameters are shown in Figure 1. The plant height increased steadily after transplanting (week 0) till the time of final harvest. There was an initial lag growth phase,with a characteristics low increase in height from 0 to 4 weeks after transplanting. At this time, the plant increased by a few centimeters from 2.97 ± 0.64cm to 8.70 ± 1.89 cm in the first trial and 2.34 ± 0.50 cm to 8.52 ± 2.13cm in the second trial. From 5 - 12 weeks after transplanting, the plant had a log growth phase with an almost exponential increase in height (Figures 1&2). The first trial however had significant increased height than the second trial. The difference in plant height in both trials is represented in Figure 2.The number of weeks required for significant increase of most of the growth parameters of *C. argentea* was similar for both trials. The height of a plant is directly linked

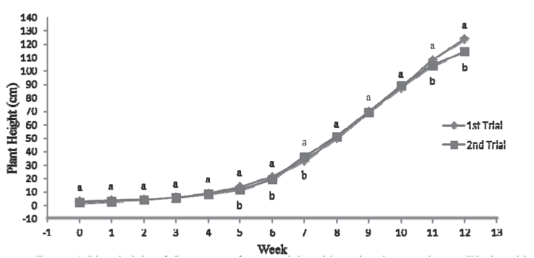

Figure 1. Plant height of *C. argentea* for two trials cultivated at the greenhouse. Weeks with different letters are significantly different at $p < 0.05$ levels. n=40.

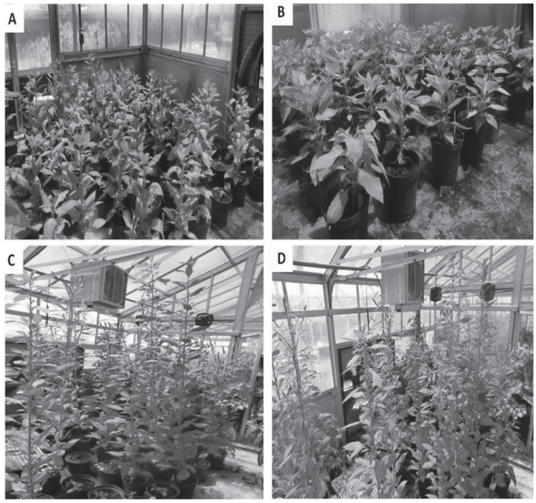

Figure 2. Plant height difference between two trials of cultivated *C. argentea* at 5 weeks after transplanting (**A**)first trial (**B**) second trial. Plant height at 11 weeks after transplanting (**C**) first trial (**D**) second trial

to its productive potential interms of herbage (Gasta and Lemaire, 2015). Although plant height increased with plant age, significant increase in the plant height was observed at six weeks after transplanting in both trials.This was similar to the findings of Law-Ogbomo and Ekunwe (2011) for the same species after six weeks of planting *C. argentea* in the field. This was an indication that exponential increase in the height of *C. argentea* plant should be expected after six weeks of planting. Worthy of note is the greatest plant height obtained in this study (136cm). Nagashima and Hikosaka (2011) reported that plants in a crowded stand regulate their height.This was an indication that *C. argentea* had the potential of growing taller if cultivated in the open field.

Stem girth

The stem girth of the plants (Figure 3) increased at as low initial rate from one to two weeks after transplanting in both trials. Thereafter, there was a significant increase from 3 – 9 weeks after transplanting in both trials. The rate at which the stem girth increased was greatly reduced at nine weeks after transplanting and stopped completely in the second trial (Figure 3). Plant stem is one of the key role players in plant growth and development. It plays a decisive role in maintaining desirable water balance between the plant and soil, by remobilizing as similates from root to shoot, thereby contributing towards drought resistance

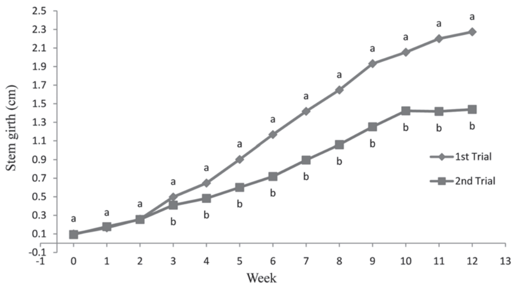

Figure 3. Comparison of stem girth of two trials of *C. argentea* cultivated at the greenhouse. Weeks with different letters are significantly different.

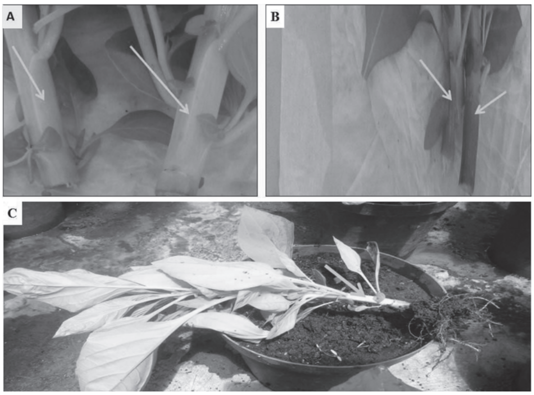

Figure 4. (**A**) stem girth in first trial; (**B**) stem girth in second trial; (**C**) Stem girth after 5 weeks in the second trial.

(Kulkarni and Deshpande, 2006). Plants generally undergo primary (taller/longer) and secondary (wider) growth during their development (Kerr and Garton, 2018). However, herbaceous (non-woody) plants such as *C. argentea* mostly undergo primary growth,with very little secondary growth or increase in thickness in stem. As observed with the plant height, the stem girth of the first trial was significantly greater than that of the second trial (Figure 4). The low increase in stem girth recorded for both trials at nine weeks after transplanting could be attributed to the herbaceous nature of *C. argentea.* This observation was supported by the reports of Law-Ogbomo and Ekunwe (2011) who also observed as low stem girth increase of *C.argentea* between six to ten weeks after sowing on 0 kg NPK ha^{-1} soil.

Number of leaves

The number of leaves recorded for both trials are represented in Figure 5. The number of leaves only increased by a few numbers from 0-3 weeks after transplanting (2.19 ± 0.38 to 9.33 ± 1.79 cm) in the first trial and (2.08± 0.28 to 8.27±1.46 cm) in the second trial. A log phase increase in leaf number was observed at 4 - 9 weeks after transplanting,while the last three weeks(10-12weeks) showed a stationary increase in the first trial and in week 12 an actual decrease in number was observed in the second trial (Figure 5). Again, the number of leaves in the first trial was significantly higher than for the second trial. Leaves are the primary site for photosynthesis and are produced in abundance as plant develops into vegetative stage for more efficient light harvesting, which in turn leads to faster growth rate and increased yield (Mathan et al., 2016). Both trials revealed the leaf number increased with plant age. The slow increase in the

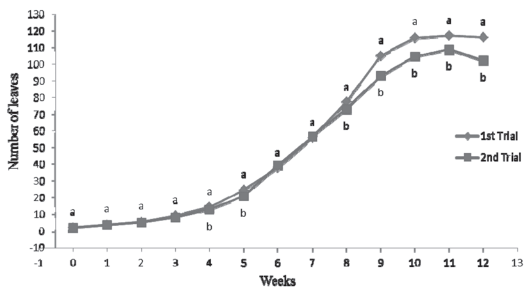

Figure 5. Leaf count of *C. argentea* (two trials) cultivated at the greenhouse. Weeks with different letters are significantly different.

number of leaves between 0 - 3 weeks after transplanting was in accordance to the reports of Ravindra et al. (2008) and Tchoundjeu and Atangana (2011), who reported slow vegetative growth for this species at the initial stage. The significant increase in the number of leaves recorded from 4 - 9 weeks after transplanting in both trials showed that the vegetative period of *C.argentea* begins at four weeks after transplanting. The stationary increase at 10- 12 weeks after transplanting conforms to the reports of Ravindra et al. (2008) of a negligible increase in the number of leaves of *C. argentea* at 60 to 80 days after sowing. The highest number of leaves recorded in the first trial (116.1) at 12 WAT was higher than the number recorded by Law- Ogbomo and Ekunwe (2011) (108.40) for *C. argentea* at 10 weeks after sowing on soil amended with 400 kg ha^{-1} NPK fertilizer at 250,000 plants ha^{-1}.

Number of branches

The number of branches of *C. argentea* from the two trials is as shown in Figure 6. The initiation of branches was observed at sixth week after transplanting in the first trial and thereafter, the plant continued to produce branches till last week of the experiment. For the second trial, the initiation of branches was observed at five weeks after transplanting and increased till 11 weeks after transplanting. Decrease in the number of branches was observed at 12 weeks after transplanting. Unlike for the previous parameters, the second trial showed a significantly higher number of branches compared to the first trial. Figure 7 is a representation of number of leaves and branches produced by *C. argentea* at both trials. Our findings indicated that for *C. argentea*, branching should be expected 5 weeks after transplanting, which is in concurrence with the findings of Akinfasoye et al. (2008).

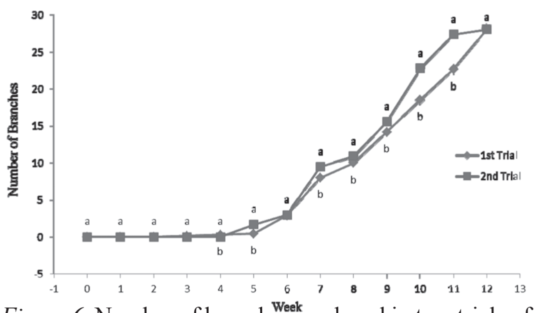

Figure 6. Number of branches produced in two trials of *C. argentea* cultivated at the greenhouse. Weeks with different letters are significantly different.

Figure 7. Leaves and branches produced by *C. argentea* in two trials. **A**- 10 weeks after transplanting in the first trial; **B**- 10 weeks after transplanting in the second trial

Number of flowers

Figure 8 shows the number of flowers produced by *C. argentea* cultivated in the greenhouse. The first flower appeared at the ninth week after transplanting in the first trial while for the second trial, flower emergence started at the fifth week. After the emergence of the first flower in both trials, the number steadily increased weekly till termination of the experiment (Figure 8). As observed with the number of leaves, the number of flowers in the second trial was significantly higher than that observed for the first trial. *C. argentea* is a facultative short-day plant (Warner, 2009). Premature flowering in greenhouses during winter and early spring has been reported for this species,when the natural photo period is short (Warner, 2009; Kieft-ProSeeds, 2010). Flower initiation is a photo period sensitive stage of

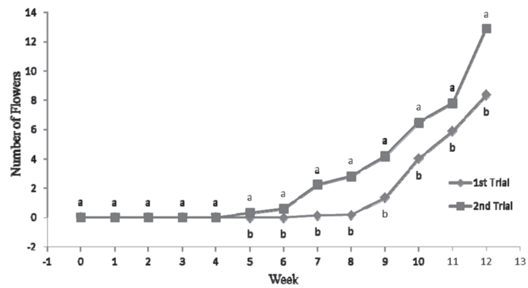

Figure 8. Number of flower of two trials of *C. argentea* cultivated at the greenhouse. Week with different lettersare significantly different.

development for *C.argentea.* The early flowering observed at five weeks after transplanting in the second trial (March–April 2018) could be as a result of photo periodism, i.e., floral inducing short days of the winter period. Flower initiation at nine weeks after transplanting in first trial is in accordance with the report of Zuck (2015). A positive correlation between the number of branches and the number of flowers was observed in this study. Increased number of branches in the second trial translated into higher number of flowers observed.

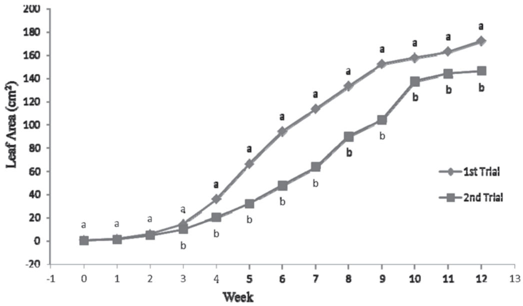

Figure 9. Leaf area of *C. argentea* cultivated at the greenhouse. Week with different letters are significantly different.

Leaf area

Leaf area of samples from the two trials of *C. argentea* is depicted in Figure 9. The leaf area increased slowly at one - three weeks after transplanting in both trials, however, from four weeks after transplanting, significantly rapid expansion of the leaves was observed up to nine weeks after transplanting of the first trial and 10 weeks after transplanting of the second trial. The late growth phases (10-12 weeks of the first trial and 11-12 weeks of the second trial), showed a minimal leaf expansion rate. Statistically, the first trial exhibited significantly higher leaf area than the second trial. Leaf area of *C. argentea* increased as the plant advanced in age. The stagnancy in the leaf area at 10 weeks after transplanting is closely related to the findings of Ravindra et al. (2008) who reported that *C.argentea* leaf area stopped increasing at 70 days after sowing. All the parameters measured showed a positive significant correlation with one another in both trials except in the first trial where the leaf area and number of flowers had a negative low correlation of -0.117** (Table 2). The implication of the overall results is that, as a determinant parameter increases, it translates to an increase in another parameter. For example, as the number of branches increases, the number of leaves, flowers and even leaf area also increased

*Table 2.*Pearson correlation of the growth parameters of *C. argentea* cultivated at the greenhouse from October 2017 to January 2018 (first trial)

Week	1						
Height	.901**	1					
Girth	.898**	.849**	1				
Leaf Number	.915**	.911**	.863**	1			
Branch Number	.810**	.839**	.732**	.834**	1		
Flower Number	.228**	.138**	.218**	.182**	.162**	1	
Leaf Area	.855**	.847**	.815**	.874**	.706**	-.117**	1
	Week	Height	Girth	Leaf Number	Branch Number	Flower Number	Leaf Area

** Correlation is significant at the 0.01 level (2-tailed).

Table 3. Pearson correlation of the growth parameters of *C. argentea* cultivated at the greenhouse from March to May 2018 (second trial).

Week	1						
Height	.899**	1					
Girth	.907**	.848**	1				
Leaf Number	.863**	.855**	.819**	1			
Branch Number	.799**	.886**	.773**	.884**	1		
Flower Number	.606**	.668**	.520**	.477**	.580**	1	
Leaf Area	.901**	.887**	.912**	.825**	.798**	.594**	1
	Week	Height	Girth	Leaf Number	Branch Number	Flower Number	Leaf Area

** Correlation is significant at the 0.01 level (2-tailed).

significantly (Tables 2 &3). This explains the positive correlation observed between number of leaves and leaf area for both trials (for first trial 0.874**; for second trial 0.825**). Increase in the number of leaves and leaf area automatically led to higher yield. Hence positive correlations existed between number of leaves and leaf area with yield.

Table 2 and 3 represent the correlation of all the growth parameters in relation to themselves for both trials. All the parameters increased with age in both trials.

The shoot and root are the determinants of the whole plant growth rate and as such, they maintain a dynamic balance in biomass.The shoot reflects the relative abundance of above-ground resources (light and CO_2) while the root reflects the below ground resources (water and nutrients) (Robinson et al., 2010). The overall health of the plant and environmental influences can be assessed through the shoot and root. The higher shoot and root yield reported in the first trial when compared to the second trial could be as a result of decrease in day length and temperatures in the green house in the second trial (10 h, 20- 23°C). This result conformed to the report that a decrease in photoperiod resulted in less shoots and lower shoot weights (Marcelis et al., 2005).

The fresh and dry weight of shoot, root and whole plant of *C. argentea* measured at the three different growth phases (pre-flowering, flowering and post-flowering stages) are shown in Figures 10 & 11. The post-flowering phase yield of the shoot and root was significantly higher than the pre-flowering and flowering stages of both trials. The dry weights for the whole plant in the first trial were13.93 ± 5.06 g, 44.31 ± 18.24 g and 225.65 ± 18.55 g for the pre-flowering, flowering and post-flowering stages. In the second trial, the weights recorded respectively for the pre-flowering, flowering and post-flowering stages were 17.69 ± 7.28 g, 30.19 ± 13.00g and 70.6 ± 20.85 g.

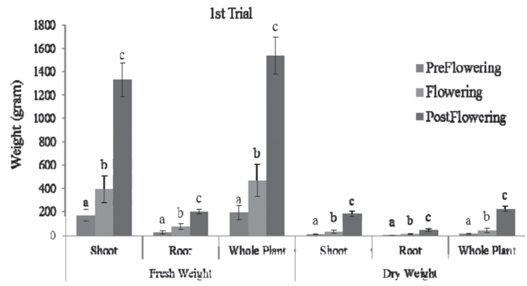

Figure 10. Fresh and dried weight yields of shoot, root and whole plant of the three growth phases of *C. argentea* cultivated at the greenhouse. Values are mean ± SD (n=40). Bars with different letters within the same set are significantly different.

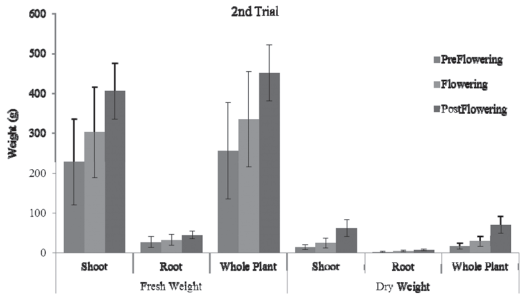

Figure 11. Fresh and dried weight yields of shoot, root and whole plant of the three growth phases of *C.argentea* cultivated at the greenhouse. Values are mean ± SD (n=40). Bars with different letters within the same set are significantly different.

The significantly higher values obtained for the fresh and dry yield of post-flowering growth phase of both trials corroborates the observation of Adediran et al. (2015) and Adeyeye et al. (2013), who reported highest values for fresh and dry yield of *C. argentea* at seven and nine weeks after planting respectively. This could be ascribed to dry matter accumulation as the plant approached maturation. Similarly, Warkentin et al. (2007) reported an increase in biomass accumulation during the post-flowering period of chickpea under long-day conditions. The high values recorded for leaf area at 11-12 weeks after transplanting at both trials might also have been responsible for the high values of the fresh and dry yield at the post-flowering growth phase. Akinfasoye et al. (2008) reported that larger leaf area reduced stem girth and number of leaves but produced higher yield through photosynthesis.

This study evaluated the growth characteristics and yield potential of *C.argentea* cultivated in the green house. Results showed that all the assessed growth and yield parameters of *C.argentea* were interdependent. Increase in one parameter led to increase in another. *C. argentea* could continue to increase in height under favourable climatic conditions until it was harvested. This study also revealed that despite the fact that both trials were carried out in the greenhouse, the relative effect of short day photoperiod and low temperatures in winter influenced early flower initiation and shoot yield reduction of the second trial. For agricultural practices in the field, increase in plant height, stem girth, number of leaves, leaf area and higher yield should be expected around four to five weeks after transplanting. Lighting in the greenhouse or planting in the field is encouraged during summer or late spring for best farm management.

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