Chapter 11
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Towards Understanding Nutrient Transport in *Celosia argentea* L.

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ABSTRACT

To better understand nutrient transport in vegetable, a pot experiment was carried out at the nursery site of the Department of Crop Production, Federal University of Technology, Minna (9°36' N, 6°33' E) Niger state, Nigeria. The study aimed at determining the effect of age of celosia plant at harvest on the yield and nutritional composition of the plant as well as the concentration of nutrients at different leaf positions. The experiment was a 3 x 3 factorial combination of three harvest periods (5, 7 and 9 weeks after sowing) and three leaf positions on the mother plant (upper, middle and basal) arranged in a completely randomized design. Harvested leaves were analysed for the nutritional composition. The results showed that the whole plant fresh weight, varied significantly ($p<0.05$) with the age of plant at harvest, having the maximum and the minimum values at 9 weeks after sowing (266.19 g/pot) and 5 weeks after sowing (96.12 g/pot) respectively. The leaf fresh weight and leaf dry weight followed the same trend with the whole plant fresh weight. Crude protein and Na reduced significantly ($p<0.05$) with the age of the plant with the highest values recorded at 5 weeks after sowing. Zn was highest at 7 weeks after sowing. K and Vit. C content were significantly higher at 9 weeks after sowing. Ca was highest at 9 weeks after sowing but there was no significant difference in the value obtained at 9 and 5 weeks after sowing. Higher values of Fe were obtained at 7 and 9 weeks after sowing. The Mg content was not significantly affected by the age at harvest. The middle leaves had significant higher content of Mg and Vit. C when compared to the basal leaves but there was no significant difference between the values obtained in upper and middle leaves. Significant ($p<0.05$) higher values of Ca, Fe, and crude protein were recorded in the basal leaves. There was no significant difference in the values of K, P, Na, Fat and Zn obtained at the different leaf positions.

Keywords: Celosia argentea; leaf positions; age at harvest; nutrients; yield.

1. INTRODUCTION

Organic materials are moved around the plant in the living cells by a process called translocation. The phloem tissue transports products of photosynthesis (sugars) from the leaves (source) to the sink. The xylem tissue equally transports water alongside with nutrients from the root to the upper parts of the plant. The mineral content in the different plant tissues is related to their mobility in the plant.

In conditions of mineral deficiency, some nutrients may be translocated from the mature leaves and fruits to the younger leaves [1]. Some nutrients are relatively immobile in plants and cannot be easily redistributed to younger leaves or other parts [2,3,4] thus: making the concentration of such nutrients higher in some plant part than the other. Based on the mobility in plant, elements are classified into three viz:

i. Mobile elements : N, K, P, S and Mg
ii. Immobile elements: Ca, Fe and B
iii. Intermediate: Zn, Mn, Cu, Mo

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Lagos spinach (*Celosia argentea* L.) is a tropical annual leafy vegetable, and a leading leafy vegetable in South Western Nigeria where it is known as 'Sokoyokoto'. The leaves and tender stems are cooked into soups. It is rich in protein, minerals and vitamins. Principal components of dry matter are cell wall polysaccharides and lignins, with protoplasmic components such as proteins, lipids, amino acids, organic acids and some other elements. It had been documented that the nutritional composition of *Celosia argentea* per 100 g edible portion is 83.8 g water; 185 kj energy; 4.7 g protein; 0.7 g fat; 7.3 g carbohydrate;1.8 g fibre; 260 mg Ca; 43 mg P and 7.8 mg Fe, respectively [5]. However, the composition of *Celosia argentea* is strongly influenced by environmental factors such as soil fertility, fertilizer application and age of the plant at harvest [5]. Various methods had been used to harvest vegetables; they could be uprooted or ratooned in such a way that the lower leaves are left unharvest. Even when the whole plant parts are harvested, some people do not consume the lower leaves (older leaves) believing that it is too fibrous and less nutritious when compared to the upper leaves (younger leaves). In view of the above, this research was carried out with the aim of determining the best age to harvest the plant to get the highest yield and optimum nutrients as well as the leaf position in which the derivable nutritional potential is highest.

2. MATERIALS AND METHODS

The pot experiment was carried out at the Horticulture Nursery of Federal University of Technology Minna (9°36' N, 6°33' E), Niger state in the raining season of 2013. It was a 3 x 3 factorial experiment arranged in completely randomized design. The treatments were 3 harvest periods: 5, 7 and 9 weeks after sowing and 3 leaf positions (upper, middle and basal leaves). The treatments were replicated three times. Each pot was filled with 8 kg top soil. Four seeds of TLV8 variety were sown per pot and at two weeks after sowing, the seedlings were thinned to two per pot. NPK 20:10:10 fertilizer was applied at the rate of 80 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 40 kg K_2O ha^{-1} at two weeks after planting. Weeds were hand-picked whenever noticed. The plants were harvested at the sampling period stated above and fresh weights were taken after which they were separated into the upper, middle and the basal leaves. The leaves were dried in an oven at 65ºC till constant weight was obtained to get the leaf dry weight and were subsequently analyzed for protein, fat, carbohydrate, crude fibre, Vit. C and mineral elements (Fe, Mg, Zn, Ca, P, Na and K).

The mineral elements (Fe, Mg, Ca, Na and K) in the test samples were determined by digesting sample in mixture of concentrated HNO_3 and perchloric acid and read using atomic absorption 752 UVspectrophotometer (model-YM1208PTSI).

Flame photometer was used for Na and K only. The P was determined using the molybdate method and quantified using a spectrophotometer. The ascorbic acid concentration in the samples was determined by 2, 6-dichlorophenol indophenol titrimetric method. The crude protein was determined based on total N content by Kjeldahl method [6]. All the data collected were subjected to analysis of variance (ANOVA) using version 9.0 of SAS (GLM procedure). Treatment means were separated using the least significant difference where significant differences occurred at 5% level of probability.

3. RESULTS AND DISCUSSION

Table 1 reveals that the yield obtained (whole plant fresh weight, leaf fresh weight and leaf dry weight) increased with the plant age and the highest value was recorded at 9 weeks. This could be attributed to dry matter accumulation with increase in age. Several authors have reported that there is increase in dry matter yield as plant age [7,8]. However, the difference between the yield values obtained at 5 and 7 weeks after sowing were not statistically different.

The result of the effect of the age at harvest and leaf position on the nutritional content of celosia are presented in Tables 2 and 3. The result shows that there were significant differences in calcium content with respect to the plant age. The highest value of calcium was recorded at 9 weeks after sowing. This is in agreement with the result obtained in Amaranthus by [9] who recorded the highest amount of calcium at the highest sampling period (60 Days after planting). Calcium content was significantly higher in basal leaves than the other two leaf positions. This value (146.60 mg/100 g) obtained in *Celosia argentea* doubled the amount (42-62 mg/100 g) recorded for different *Amaranthus* species reported by [9]. This confirms the fact that *Celosia argentea* is rich in calcium [10]. The value obtained in this study is still far below the recommended dietary allowance of 1000-1200 mg/day [11]. [12] also observed that the highest amount of calcium was recorded in the basal leaves. This could be because calcium is immobile (non-translocatable) within plants and remains in the older tissue throughout the growing season. This is why the deficiency symptoms of Ca appears first in the young growing part of the plant [4]. There was no significant difference between the amounts of calcium recorded in upper and middle leaves.

The age of the plant at harvest did not contribute significantly to the variation in Magnesium content recorded in the leaves. The magnesium value of the upper and the middle leaves were at par and were both significantly higher than the value for the lower leaves. This confirms the fact that Mg is withdrawn from ageing leaves due to its highly mobile nature [3]. [13] observed no significant difference between the values of Magnesium obtained at the basal, middle and upper leaf position of *Hibiscus sabdariffa* plant.

The amount of K recorded in plant harvested at 9 weeks after sowing was significantly higher than those obtained at 5 and 7 weeks after sowing which were at par. [14], recorded the highest amount of K at 6 weeks after sowing in Amaranthus. There was no significant difference between the values of K recorded at the different leaf positions.

The Fe content increased with the age of the plant. This is in agreement with the report of [15]. The highest value of Fe (38.98 mg/100 g) was obtained at 9 weeks after sowing but was statistically similar to the value obtained at 7 weeks after sowing. The basal leaves contained significantly more Fe than other leaf positions. This may be because Fe is relatively immobile in plant [3]. [16] also recorded the highest Fe content (27.53 mg/kg) in the basal leaves of *Amaranthus cruentus* and with no significant difference between the values recorded in the upper and middle leaves.

Phosphorus value significantly decreased with the age of the plant with 30.17 mg/100 g, 19.87 mg/100 g and 17.36 mg/100 g recorded at 5, 7 and 9 weeks after sowing respectively. [14] recorded the highest P content at 4 weeks after sowing (160 mg/100 g) beyond which the values declined in *Amaranthus cruentus.* There was no significant difference between the amounts of P recorded at the different leaf positions. This may be attributed to the fact that phosphate is easily redistributed in most plants from one organ to another [4].

Table 1. Yield values of *Celosia argentea* at different harvesting period

Age (Weeks)	Whole plant fresh weight (g/pot)	Leaf fresh weight (g/pot)	Leaf dry weight (g/pot)
5	96.12±8.04	36.18±5.03	3.03±0.05
7	173.94±15.08	56.94±8.83	3.93±0.10
9	266.19±38.16	58.83±8.62	5.71±0.16
LSD (0.05)	83.53	22.53	1.61

** LSD- Least significant difference (0.05)*

Significantly higher amount of Na was recorded at 5 weeks after sowing (18.90 mg/100 g) compared to the values obtained at 7 (16.74 mg/100 g) and 9 weeks after sowing (17.33 mg/100 g). There was no significant difference between the values obtained at 7 and 9 weeks after sowing. There was no significant difference in the amount of Na recorded in the three leaf positions. [12] also reported similar findings in *Telfaria occidentalis*. The basal leaves of *Hibiscus sabdariffa* were however reported by [13] to contain significantly higher value (3.38 mg/kg) of the mineral than the middle and the upper leaves. Though the values obtained in this study is low when compared with the recommended dietary allowance of 2300 mg/day [11] but table salt is the primary source of this mineral. Intake of a teaspoon of salt per day is capable of supplying the recommended rate of Na.

Table 2. Effect of the age at harvest on the nutritional content of *Celosia argentea*

Treatments	**Ca**	**Mg**	**K**	**Fe**	**PO_4**	**Na**	**C.P**	**Fat**	**Vit.C**	**Zn**
Weeks										
5	134.52±4.10	21.12±.15	79.74±3.83	26.68±1.47	30.17±1.01	18.90±0.35	3.20±0.11	2.70±0.07	27.92±1.34	3.13± 0.17
7	115.51±3.95	23.17±1.65	74.84±2.04	35.41±1.32	19.89±0.78	16.74±0.25	2.90±0.17	3.02±0.13	35.00±1.66	4.03±0.20
9	144.97±4.89	24.43±1.36	94.94±4.41	38.98±1.50	17.36±0.80	17.33±0.29	2.64±0.09	2.61±0.11	38.10±1.80	3.10±0.19
LSD	11.77	NS	10.19	4.05	2.37	1.10	0.30	NS	2.60	0.51

**C.P- Crude protein; LSD- Least significant difference (0.05); NS- Not significant.*
**All the parameters were measured in mg/100g except crude protein which was measured in g/100g*

Table 3. Effect of leaf position on the nutritional content of *Celosia argentea*

Treatments	**Ca**	**Mg**	**K**	**Fe**	**PO_4**	**Na**	**C.P**	**Fat**	**Vit.C**	**Zn**
Upper leaves	132.04±4.84	24.33±1.32	90.65±4.82	30.78±1.12	23.76±1.07	17.94±0.96	2.66±0.14	2.61±0.33	34.44±1.57	3.72±0.21
Middle leaves	123.31±3.93	24.41±1.22	80.52±3.79	29.20±1.14	21.77±0.99	18.32±1.07	2.81±0.11	3.06±0.60	35.89±1.38	3.63±0.32
Basal leaves	146.60±5.01	20.69± 1.01	81.44±4.01	38.38±1.67	23.18±1.11	17.38±0.99	3.34±0.19	3.06±0.58	29.67±1.11	3.81±0.28
LSD(0.05)	13.59	3.50	NS	4.67	NS	NS	0.34	NS	3.01	NS
Interaction										
(Age x position)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

**C.P- Crude protein; LSD- Least significant difference (0.05); NS- Not significant.*
**All the parameters were measured in mg/100g except crude protein which was measured in g/100g*

Crude protein reduced with the age of the plant. The value obtained (3.2 g/100 g) at 5 weeks after sowing was significantly higher than at 7 and 9 weeks after sowing. There was no significant difference between the values obtained at 7 and 9 weeks after sowing. This concurs with the reports of [7,14,17]. [18] observed that crude protein content increased from 4 weeks after sowing till 7 weeks after sowing in *Sesamum radiatum* leaves after which there was a decline in amount till 10 weeks after sowing. The basal leaves had the highest crude protein content (3.34 g/100 g) which was significantly higher than the other positions which were at par. The highest value of crude protein obtained in the basal leaves (3.34 g/100 g) in this study is lower than the values obtained in *Amaranthus cruentus* leaves (23%) as reported by [19]. This confirms the assertion of [9] that *Amaranthus* is higher in protein than Celosia. [5] reported that the amount of protein found in Celosia was 4.7 g/100 g. Varietal factors and the environment could also contribute to the variation in the value of crude protein obtained.

There was no significant difference between the fats amount obtained at the different harvesting periods and the different leaf positions. This is in line with the report of [18] who reported that the age of plant did not have any effect on the fat content of *Sesamum radiatum* leaves.

Vitamin C (Ascorbic acid) content increased progressively and significantly with age. The values recorded at 5, 7 and 9 weeks after sowing were 27.92 mg/100 g, 35.00 mg/100 g and 38.10 mg/100 g respectively. The values obtained for both upper and middle leaves were statistically similar but significantly higher than the value for basal leaves. [13] recorded the highest Vit. C content in the middle leaves of *Hibiscus sabdariffa*. The value of Vit. C obtained implies that if 200 g of *Celosia* is eaten, it could supply the recommended daily allowance of 75 mg/day [11] if minimally processed. This confirms the assertion of [10] and [20] that *Celosia* is a good source of Vit. C.

The value of zinc (4.03 mg/100 g) recorded at 7 weeks after sowing was significantly higher than those at 5 and 9 weeks after sowing which were similar statistically. There was no significant difference between the values of zinc obtained at the different leaf position. This could be because the mineral is highly mobile and is found in every part of the plant [2]. [1] also observed that leaf position had no significant effect on the zinc content of *Hibiscus sabdariffa*. However, in *Amaranthus cruentus*, [16] recorded the highest value (0.11 mg/kg) in the middle leaves. This value obtained in *Amaranthus cruentus* is low compared to the value obtained in *Celosia argentea*. This suggests that *Celosia argentea* is a moderately rich source of zinc. Deficiency of this mineral could cause growth retardation and poor sexual development in animal [11].

4. CONCLUSION

Consumption of Celosia at a younger age (5 weeks after sowing) seems better as P, Na, Ca and Crude Protein values were significantly higher in leaves harvested at this age. However, for higher yield, harvesting at 9 weeks after sowing can be considered. The value of K, Fe and Vit. C were higher in leaves harvested at 9 weeks after sowing. The lower leaves have significant higher levels of Ca, Fe and crude protein.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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