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LEAF YIELD AND NUTRITIVE VALUE OF BUNGU (*Ceratotheca sesamoides* Endl.) and BLACK SESAME (*Sesamum radiatum* Linn.) AS INFLUENCED BY AGE AT HARVEST IN THE SOUTHERN GUINEA SAVANNA ECOLOGICAL ZONE OF NIGERIA

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ABSTRACT

Overall yield and the nutritive value of harvested leaves of bungu and black sesame at weekly interval were determined. The objective was to provide useful information for market gardeners and consumers. Field experimental plots, each 1 x 2 m in size, were laid out using 2 x 4 factorial structure in split-plot design with four replications and data collected at 7, 8, 9, and 10 weeks after planting (WAP). Detached plant leaves were subjected to proximate analysis in the laboratory. Means of two years' results indicated that leaf and shoot yields per plant, and leaf-to-shoot ratio in the crop species were similar, but leaf and shoot yields per unit area of land were higher in black sesame (1.64kg and 5.35kg, respectively) than in bungu (0.97kg and 3.38kg, respectively). Generally, as age increased from 7 to 9 weeks, number and total length of branches, as well as number of leaves per plant also increased, and thereafter the increases were no longer significant. Leaf area per plant and leaf area index in the two crop species were similar between 7 and 9 weeks of age and thereafter declined. Based on the average of two years' results, the highest leaf and shoot yields per plant (5.48g and 18.73g, respectively) and per m^2 of land (1.49kg and 5.16kg, respectively) were obtained at 9 weeks of age. In terms of the nutritive value of the leaves, the levels of crude protein and total ash in black sesame and bungu leaves, respectively, were significantly higher at 7 weeks after planting (protein: 33.68%, 34.65%; ash: 10.75%, 13.00%) than at 8 weeks (protein: 28.55%, 28.50%; ash: 8.88%, 10.88%), 9 weeks (protein: 28.33%, 28.18%; ash: 8.88%, 10.00%), and 10 weeks (protein: 28.83%, 26.08%; ash: 9.00%, 10.63%). Considering both the quantity and nutritive value of leaf yield, 8 - 9 weeks after planting the crop appears to be the optimum age to harvest the leaves of the crop species for culinary use.

Keywords: Bungu; black sesame; age at harvest; leaf and shoot yields; nutritive value.

INTRODUCTION

The indigenous tribes of Nigeria's savanna ecological zones relish the leaves and tender shoot portions of *Ceratotheca sesamoides* Endl. (bungu) and *Sesamum radiatum* L. (black sesame); mainly for imparting a mucilaginous consistency to soup that is intended as accompaniment of starchy morsels prepared from cereals, cassava, and yam. *C. sesamoides* is cultivated to a considerable extent in the Dagomba area of northern Ghana, where it is called *bungu.* In southwest Nigeria (Yoruba land), it is called *eku pete*, while in northern Nigeria, it is called *karkashi* in Hausa, *gubu'do* in Fulani and *kawulubul* in Kanuri. *S. radiatum* is called *eku gogoro* in Yoruba. Both plant species, belonging to the family Pedaliaceae, are closely related indigenous leaf vegetables, naturally widely distributed in the savanna. Until relatively recently, they have been much neglected in research and little is known about in published literature, despite that both vegetables feature prominently in the 'swallow' dishes of natives in the localities where they are found and eaten. Although frequently intercropped with staple food crops in traditional savanna farming systems, they are more often harvested together or one as substitute for the other, from abandoned farms where they spring up as volunteer plants during both the rainy and dry seasons.

Indigenous African leaf vegetable species are inexpensive and, therefore, affordable rich natural sources of protein, dietary fiber, minerals, vitamins, antioxidants, and phytochemicals (flavonoids, phenols, saponins, alkaloids, tannins, and steroids) with medicinal properties (Chweya and Eyzaguirre, 1999; Nnamani et al., 2007; Masondo et al., 2015). Okigbo (1983) noted that research activities to improve the status of most of the African indigenous vegetable species have been grossly neglected. Despite the nutritional and economic importance of bungu and black sesame leaves and seeds in human diet, Masondo *et al*. (2015) observed that it is only in the recent past 20 years that research on them was initiated. These pioneering works indicated that edible leaf production and proximate composition in the crop species are profoundly influenced by crop management practices (Bakare, 1987; Fasakin, 1991, 2002; Egberongbe, 1995; Fasakin and Olofintoye, 2005).

In leaf vegetable production, the stage of plant growth at harvest is important in the overall yield of the edible portions of the vegetative shoot. The vegetative growth characters that contribute to quantity of leaf and shoot yields in this regard, otherwise known as components of leaf yield, are the shoot length, number of leaf nodes, the number and total length of branches, number of leaves, and aggregate area of the leaves (Olufolaji and Dinakin, 1988). Others are the shoot fresh weight (known as 'marketable yield') and the fresh weight of the edible leaves and tender apical shoot portions (known as 'edible yield'). It has also been asserted that age at harvest is an important agronomic factor influencing the palatability and nutritive value of leaf vegetables (Oyenuga, 1968; Taylor, 1988; Fasola and Ogunsola, 2014).

There is a dire need to conduct more research on African indigenous vegetable species, with emphasis on their agronomic characteristics, nutritional and phytochemical constituents, methods and extent of utilization (for culinary, medicinal, and other purposes), content of anti-nutritional factors, and genetic improvement. These studies will enhance their inclusion in regional and international gene banks for conservation purposes. The objective of this study, therefore, was to ascertain the effects of age at harvest on the vegetative characters that determine leaf and shoot yields in bungu and black sesame, as well as on the nutritive value of the leaves.

MATERIALS AND METHODS

Experimental Site

The study consisted of both field experiment and proximate analysis in the laboratory. The field experiment was conducted during the rainy season in each of 1996 and 1997 (August - November) at the University of Ilorin Teaching and Research Farm, located on latitude 08^0 26'N and longitude 04^0 29'E, about 345m above sea level in the southern Guinea savanna ecological zone of Nigeria. The climate of the study location is characterized by distinct wet and dry seasons. The wet season commences in March or April and terminates in October with a dry spell in August. The dry season starts in October and lasts till March or April. All weight determinations were carried out on a potable top-loading laboratory weighing scale model OHAUS-Traveller, while oven-drying of samples took place in GENLAB model laboratory oven set at 80^0C for 72 hours until constant weight was attained.

Planting Materials

Seeds of *C. sesamoides* and *S. radiatum* used for planting were those of locally grown cultivars in and around Ilorin, Kwara State, Nigeria. Seedlot of each of the two crop species, weighing about 1kg, was procured from the open market and meticulously cleaned by removing the admixtures in it, such as immature seeds, plant parts, sand, and seeds of other vegetables. Afterwards, a working sample of the seedlot of each species was drawn using the 'pie method' described by Copeland (1976). 1,000 seeds were counted from the working sample of each seedlot, replicated 10 times and their weights taken. Also, because of the informal source of the seeds, replicated germination test was carried out in the laboratory, on moistened Whatman 12.5cm filter papers in covered petridishes. The average 1000-seed weight and germination test results, respectively, were for *C. sesamoides* 1.25g and 64.50%, and for *S. radiatum* 1.92g and 45.00%.

Experimental Design, Field Layout and Cultural Practices

The field trial was laid out in a 2 x 4 factorial structure in split-plot design with four replications. Each plot was 1m x 2m in size with species completely randomized in the main plots and ages at harvest in the subplots. Weighed quantities of available seeds, at the rate of 9kg/ha, were direct-drilled 2cm deep in 30cm-spaced rows (Fasakin, 1991). Fertilizer was applied banded per row at 3 weeks after planting (WAP) using 100g NPK 20-10-10 per plot, which was the equivalent of 100kg N/ha, 50kg P/ha, and 50kg K/ha recommended for the crop (Bakare, 1987). To forestall activity of leaf-eating insect pests and seedling damping-off disease, Karate 2.5EC insecticide and the broad-spectrum Kaptaf 75SD fungicide, respectively, were applied as foliar spray also at 3 WAP. Weed control in the plots was by hoeing, supplemented with hand pulling within the rows.

Data Collection and Analysis

In the field experiment, data collection was at weekly interval beginning at 7 WAP. At each sampling, all plants in two randomly selected rows per designated plot were uprooted, counted, and the following measurements (expressed as mean/plant) taken on a subsample of 10 randomly drawn plants: number and total length of the primary branches; number of leaves; area of the leaves. Area of leaves was determined with DELTA-T MK.2 model automatic leaf area meter. Fresh leaf and stem weights, separately, were measured per plant and per plot. Shoot yield was the addition of leaf and stem fresh weights. Leaf area index (LAI) was the product of leaf area per plant and number of plants per m^2 of a plot.

For proximate analysis, the detached leaves of harvested plants at each sampling date in the field experiment were bulked for each species. Thus, four leaf samples of each species (at 7, 8, 9, and 10 WAP) were available for analysis. Leaves were oven-dried at 80^0C to a constant weight, finely ground in an electric grinder and passed through a 2mm-sieve. Crude protein, crude fat or ether extract (EE), crude fiber, and total ash contents were determined using the methods described by the Association of Official Analytical Chemists (2008). Carbohydrate or nitrogen-free extract (NFE) was determined by difference, calcium by the EDTA titration method (Hildebrand and Reilley, 1957), and phosphorus by the Ascorbic acid method (Jackson, 1969; Aldrich, 1986).

Data collected were subjected to analysis of variance, using SAS package. Significantly different treatment means were determined and compared at 5% level of the Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

The results in Table 1 indicated that the number of established plants per m^2 of land generally decreased as age increased from 7 to 10 weeks. Between the two species, the decrease was significantly higher in black sesame than bungu in the two years trial. The 1996 trial showed that plant population densities at 7 and 8 weeks were not significantly different but higher than at 9 and 10 weeks, contrary to the 1997 trial, which showed small insignificant differences between the four ages. The unequal reduction in plant population density between the two years suggested that a definite pattern is yet to be established for these crop species.

Species and age effects on development of components of leaf and shoot yields are also indicated in Table 1. Between the two species, black sesame had less number of leaves but larger leaf area per plant (in 1996 but not in 1997) as well as LAI. In turn, bungu was more profusely branched and with higher number of leaves per plant. These data suggest that the observed yield components are attributes developed in response to pattern and proportion of the plant's total dry matter partitioned to the main stem, branches, and leaves in the two species.

Table 1 also shows that as age increased from 7 to 10 weeks, number of branches, total length of branches, and number of leaves per plant in the two species increased up to 9 weeks and thereafter the increases were no longer significant. Leaf area per plant, in turn, was similar at 7 and 8 weeks in 1996 and between 7 and 9 weeks in 1997, the mean values declining thereafter. These effects of age on the development of components of leaf yield in the two crop species may be attributed to increased dry matter production with age and the preferential partitioning of relatively high proportion of it to the reproductive organs, which have become prominent at 9 weeks of age. The decrease in leaf area per plant after 8 and 9 weeks in 1996 and 1997, respectively, despite the continuous increase in number of leaves per plant could be as a result of reduction in the sizes of both earlier and newly formed leaves. LAI followed the same trend as leaf area per plant due to the combined effects of the significant reduction in plant population density and individual leaf size.

Mean values of leaf and shoot yields with age and between the two crop species are presented in Table 2. Overall individual plant productivity between the two species, including leaf-to-shoot ratio, was similar despite differences in their vegetative characters. However, leaf and shoot yields per unit area of land in black sesame were higher than in bungu, probably due to the higher plant population density and LAI in the former. The table further shows that the highest leaf and shoot yields per plant and per unit area of land were observed at 9 weeks, beyond which yields declined. This trend suggests that although number of leaves per plant increased with age but their individual size and weight have reduced due to re-ordering of dry matter partitioning in the plant in favour of the reproductive organs at this age (Hewitt and Marrush, 1986). It could also be due to reduction in plant population density, as indicated in Table 1.

Table 3 shows the proximate composition of bungu and black sesame leaves determined at various stages of growth. Water and dry matter contents are given as net weights while the other nutrients are given as percentage of dry matter. The results show that, comparatively between *C. sesamoides* and *S. radiatum*, leaf water content and dry matter yield were similar at the four growth stages tested. Also, the levels of crude protein, crude fat, and total ash in the leaves of the two crop species were significantly higher at 7 than 8, 9, and 10 weeks while dry matter, soluble carbohydrates, crude fiber, calcium, and phosphorus contents increased with age. These observed variations in the levels of nutrients at different growth stages are in agreement with the findings of Fasola and Ogunsola (2014) on *Ceratotheca sesamoides* and *Sesamum indicum* and of Bamishaiye *et al*. (2011) on *Moringa oleifera.* Their results showed that the proximate and mineral nutrients, as well as phytochemical constituents of leaf vegetables increase with age of the plant up to the onset of flowering and fruiting, and thereafter start to decline.

According to Hewitt and Marrush (1986), the decline in the levels of certain nutrients (majorly protein and minerals) in the plant leaf with age is probably due to their remobilization from the leaf preferentially to the reproductive organs during flowering and fruiting. In the current studies on *C. sesamoides* and *S. radiatum*, flowering in the two crop species was observed to start at about 8 WAP and reached 50% stage at 9 - 10 WAP.

CONCLUSION

In order to derive maximum nutritive benefits in terms of protein and the elemental nutrients, bungu and black sesame leaves for culinary use should ideally be harvested at 7 - 8 weeks of age; i.e. shortly before the appearance of flowers. When this age range is considered vis-à-vis the age of optimum leaf yield (9 weeks) and leaf-to-shoot ratio (7 - 8 weeks), it appears that 8 - 9 weeks is the optimum age to harvest the crop species, in terms of both quantity and nutritive value of leaf yield.

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Table 1: Effect of age at harvest on components of leaf and shoot yields in Bungu and black sesame

Treatment	Established plants m^{-2} of land		No. of Branches $plant^{-1}$		Length of Branches (cm) $plant^{-1}$		No. of Leaves $plant^{-1}$		Leaf Area (m^2) $plant^{-1}$		LAI	
	1996	1997	1996	1997	1996	1997	1996	1997	1996	1997	1996	1997
Species*												
Black sesame	484^{a}	296^{a}	4.54^{b}	3.22^{b}	15.05^{b}	11.36^{b}	30.34^{b}	25.59^{b}	118.64	148.29^{a}	5.71^{a}	4.16^{a}
Bungu	260^{b}	219^{b}	10.06^{a}	8.91^{a}	96.73^{a}	84.70^{a}	62.62^{a}	54.48^{a}	123.25	128.67^{b}	2.93^{b}	2.50^{b}
S. E.	16.39	11.25	0.19	0.27	3.85	4.64	1.63	1.73	5.08	6.20	0.27	0.13
Age at Harvest* (weeks)												
7	483^{a}	267	6.27^{b}	4.42^{b}	30.68^{c}	12.34^{c}	29.62^{c}	25.54^{c}	151.97^{a}	137.55^{a}	6.61^{a}	3.50^{a}
8	401^{a}	259	7.24^{a}	4.65^{b}	45.61^{b}	32.41^{b}	41.88^{b}	38.25^{b}	146.50^{a}	149.61^{a}	5.22^{a}	3.57^{a}
9	314^{b}	270	7.74a	7.45^{a}	71.01^{a}	65.09^{a}	55.13^{a}	44.79^{ab}	113.25^{b}	149.00^{a}	3.47^{ab}	3.75^{a}
10	291^{b}	233	7.94a	7.75a	76.28a	82.29a	59.29^{a}	51.57^{a}	$72.07b^{c}$	117.77^{b}	1.98^{c}	2.49^{b}
S. E.	25.40	20.73	0.21	0.26	4.47	5.43	1.85	2.24	9.34	7.50	0.36	0.30

S. E. = Standard Error; * Species and age at harvest means in the same column followed by at least one common letter are not significantly different at 5% level of the DMRT

Table 2: Effect of age at harvest on leaf and shoot yields in Bungu and black sesame

Treatment	Leaf Yield (g) plant-1		Leaf Yield (kg) m-2 land		Shoot Yield (g) plant-1		Shoot Yield (kg) m-2 land		Leaf-to-Shoot Ratio	
	1996	1997	1996	1997	1996	1997	1996	1997	1996	1997
Species*										
Black sesame	4.40	4.50	2.03^{a}	1.25^{a}	16.00	13.44	6.96^{a}	3.74^{a}	0.29	0.33
Bungu	5.16	4.17	1.19^{b}	0.75^{b}	18.15	13.71	4.17^{b}	2.59^{b}	0.29	0.29
S. E.	0.26	0.24	0.12	0.04	0.73	0.66	0.38	0.14	0.01	0.02
Age at Harvest* (weeks)										
7	4.47^{b}	3.10^{c}	1.91^{a}	0.77^{b}	12.33^{b}	7.77^{c}	5.18	1.94^{c}	0.36^{a}	0.40^{a}
8	5.03^{ab}	4.78^{ab}	1.78^{ab}	1.07^{ab}	15.11^{b}	13.28^{b}	5.31	3.12^{b}	0.33^{a}	0.38^{a}
9	5.39^{a}	5.57^{a}	1.62^{b}	1.36^{a}	19.91^{a}	17.55^{a}	5.94	4.37^{a}	0.28^{b}	0.32^{b}
10	4.22^{b}	3.90b^{c}	1.14^{c}	0.80^{b}	20.96^{a}	15.69^{ab}	5.82	3.25^{b}	0.20^{c}	0.26^{c}
S. E.	0.25	0.30	0.08	0.09	0.97	0.93	0.25	0.30	0.01	0.01

S. E. = Standard Error; * Species and age at harvest means in the same column followed by at least one common letter are not significantly different at 5% level of the DMRT

Table 3: Variation in percent proximate composition of the edible leaves of Bungu and black sesame with age

Nutrients Analyzed	BLACK SESAME Ages at Harvest * (weeks after planting)				BUNGU Ages at Harvest * (weeks after planting)				
	7	8	9	10	7	8	9	10	S. E.
Water	83.08^{a}	81.28^{a}	79.23^{b}	78.23^{b}	82.63^{a}	80.78^{a}	78.55^{b}	79.28^{b}	0.58
Dry Matter	16.93^{c}	18.73^{b}	20.78^{a}	21.78^{a}	17.38^{c}	19.23^{b}	21.45^{a}	20.73^{a}	0.58
% of Dry Matter									
Soluble Carbohydrates (NFE)	39.95^{b}	50.58^{a}	51.05^{a}	49.68^{a}	37.60^{b}	50.13^{a}	49.58^{a}	51.30^{a}	0.88
Crude Protein	33.68^{a}	28.55^{b}	28.33^{b}	28.83^{b}	34.65^{a}	28.50^{b}	28.18^{b}	26.08^{b}	0.72
Crude Fat (EE)	5.25^{a}	4.00^{b}	4.50^{b}	4.50^{b}	5.63^{a}	4.25^{b}	4.50^{b}	4.00^{b}	0.26
Crude Fiber	7.00^{b}	7.25^{b}	8.00^{b}	10.38^{a}	8.00^{b}	7.75^{b}	6.75^{b}	9.13^{a}	0.42
Total Ash	10.75^{a}	8.88^{b}	8.88^{b}	9.00^{b}	13.00^{a}	10.88^{b}	10.00^{b}	10.63^{b}	0.57
Calcium	1.93^{c}	2.35b^{c}	2.75^{b}	3.35^{a}	1.83^{c}	2.20^{bc}	2.55^{b}	3.90^{a}	0.22
Phosphorus	0.17^{b}	0.24^{b}	0.21^{b}	0.39^{a}	0.18^{b}	0.24^{b}	0.22^{b}	0.44^{a}	0.03

S. E. = Standard Error; * Values in a row under each species followed by at least one common letter are not significantly different at 5% level of the DMRT