NIGERIAN AGRICULTURAL JOURNAL
ISSN: 0300-368X
Volume 53 Number 1, April 2022 Pg. 212-222
Available online at: http://www.ajol.info/index.php/naj
https://www.naj.asn.org.ng

Agronomic Performance and Nutritional Content of Okra [*Abelmoschus esculentus* (L.) Moench] as influenced by Plastic-Film Mulch Under *Elaeis guineensis* (Jacq.) Canopy

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Abstract

This study was conducted to compare the yield, agronomic characteristics, and nutritional composition of Okra (*Abelmoschus esculentus)* under *Elaeis guineensis* canopy without mulching (CNM), with the open field (C), and to determine if the use of plastic-film mulch under the canopy (CM) would improve the productivity of Okra. Our study shows that CNM and CM decreased the yield of Okra by 92% and 91% compared with C. The reduction in yield was a result of the decrease in chlorophyll content, total biomass, and harvest index caused by low light intensity and reduced soil temperature under CNM and CM. Like yield, nutritional (ash content, crude protein, carbohydrate) and phytochemical (glycoside, terpenes, saponin, phenol) contents of the fruit also decreased significantly at $p<0.05$ under the canopy (CNM, CM) with a high level of moisture in fruit compared with C. However, the results obtained in CNM and CM was comparable. The results indicate that the canopy of *E. guineensis* hinders the growth and yield responses of Okra. Moreover, the insignificant yield and nutritional contents of fruits obtained in CNM and CM show that the use of PFM under canopy is ineffective and unsuitable for yield improvement, agronomic attributes, and nutritional contents of Okra.

Keywords: Plastic-film mulch, canopy, agronomy, nutrition, okra

Introduction

The world population is expected to rise above 9 billion by 2050 (Ferroni and Zhou, 2012; Tilman *et al*., 2011). Nigeria is the most populated country in Africa with over 205 million people, and this number tends to double in the next 10 years (Worldometer, 2019). To feed the growing population, food production is required to increase by 60% by 2050 (FAO, 2000; Long *et al.,* 2015) and this might not be realistic through yields from existing agricultural land (Ray *et al*., 2013). The African continent has the largest area of arable land in the world and Nigeria with the largest among African countries (Mo Ibrahim Foundation, 2011). However, the rapid increase in urbanization and industrialization poses a threat to the availability of arable land for crop production (Satterthwaite *et al*., 2010). This has been exacerbated by increasing desertification and salinization. Therefore, to meet the food demand of the burgeoning population, agricultural practices that will promote land-use efficiency to ensure sustainable food production and biodiversity conservation is necessary for food security.

Tree plantations have been in existence for a very long time and the first woody plants to be domesticated were plant-yielding food (Turnbull, 2011). Oil palm tree [*Elaeis guineensis* (Jacq.)] is the fastest-growing monoculture plantation in the tropics (Gerber, 2011) and it dominates tree plantations in Nigeria because of its versatility, ability to stock carbon, and high economic values (Okolo *et al.,* 2019). Despite its huge advantage, 60 to 65% of the land under matured *E. guineensis* plantation remains unutilized (Dissanayake and Palihakkara, 2019). However, it remains unknown if the available spaces could be used for crop production under proper management practices to alleviate the problem of food insecurity. Previous reports on the effect of tree plantation on food crops have been controversial. Co-habitation of a tree with crops has been reported to promote the growth, and yield of wheat, maize, and barley (Dilla *et al.,* 2019; Sida *et al.,* 2018a; Tadesse *et al.,* 2021). Njoroge *et al.* (2020) also reported an increase in the yield of maize grown under *Cordia africana* in Kenya, whereas Sida *et al.* (2018b) reported a reduction in the yield of maize planted under *C. africana* tree in experiment conducted in Ethiopia. Although, previous research had documented the influence of tree plantation on crop production, however, the effect of *E. guineensis* canopy on the agro-

physiological characteristics of food crops had not been reported.

Soil temperature under tree plantations is an important factor to be considered for successful crop production. Soil temperature decreases under trees as a result of a large canopy that prevents direct sunlight (Kolstad *et al.,* 2019). The use of plastic-film-mulch has become increasingly popular for crop production worldwide (Fawibe *et al.,* 2020; Jabran *et al.,* 2016) due to its ability to increase soil moisture, soil temperature, and crop yield (Snyder *et al*., 2020; Gao *et al*., 2019). Previous studies have proven that plastic-film mulch (PFM) increases water-use and nutrient-use efficiencies by forming a barrier between the soil surface and the atmosphere, thereby, reducing direct evaporation (Adekalu *et al*., 2006; Keramat *et al.*, 2011). The successful cohabitation of trees and crops largely depends on the survival rate of the test crops under the shade of the canopy among other factors.

Okra - *Abelmoschus esculentus* (L.) (Moench) is of African origin and widely cultivated around the world because of its nutritional and medicinal values (Abood *et al.,* 2019; Dada and Adejumo, 2015). However, it remains unknown if Okra could thrive under tree plantation. Also, the influence of PFM on the growth attributes and nutritional content of Okra under *E. guineensis* had not been reported. Therefore, this study aimed to examine the agronomical characteristics and nutritional composition of Okra and the influence of PFM on its productivity under *E. guineensis* plantation.

Materials and Methods

Experimental site

The experiment was conducted at the *E. guineensis* plantation site of the Federal University of Agriculture, Abeokuta, Nigeria (7.2437º N, 3.3433ºE) in 2021 cropping season. The climatic condition of the field is tropical with wet and dry seasons. Rainfall distribution is bimodal with a peak occurring in June/July to September and a period of lower precipitation mostly in August known as August break (Ogeh and Osiomwan, 2012). The average temperature during the experiment ranged between 28-31°C. The soil properties under the canopy were similar to that of the open field. The soil samples were randomly collected at 0-0.2m depth using a soil auger. The soil sample was air-dried at room temperature, crushed and sieved through < 2mm mesh. A sub-sample of the composite was analysed to determine soil organic carbon (SOC) content (Allison, 1965) and total N (Kjeldahl methods) and pH (1:2.5 water extraction) at the laboratory of the department of Chemistry, Federal University of Agriculture, Abeokuta. The pH and C:N of the soil were 8.0 and 4:1, respectively.

Experimental design and field management

The experiment was designed in a split-plot with tree canopy and mulching serving as the main and subplot, respectively. The treatments include: canopy with plastic-film mulch (CM), canopy without plastic-film mulch (CNM), and an open field without plastic-film serving as a control (C). The plot size of each treatment was 100m² (10m × 10m). On each plot, 10 beds of 1m × 0.9m were prepared with 0.2m as the distance between beds. Three seeds of Okra were sown at a distance of 0.5m and 1m intra and inter-row spacing and were thinned to 1 per stand at 14 days after sowing. However, in the CM plots, a plastic film of 1m wide was laid to cover each bed before planting. At the same planting distance, perforation was carried out manually.

Data collection

Agronomic data were collected at 20 days intervals for 100 days from the seedling stage until maturity. Plant height was measured using a meter rule. The leaf area was measured using a leaf area meter (Portable Leaf Area Meter, Hangzhou Mindfull Technology Co. Ltd, China). The number of leaves was counted on the day of each data collection. Fresh weight was measured using a weighing balance, while samples were oven-dried at 70°C until constant mass to determine dry mass. The three most expanded leaves were randomly selected and chlorophyll content measured using a chlorophyll meter (SPAD 502 PLUS, Minolta corporation, Ltd., Japan). At the base of each crop, moisture content and soil temperature were recorded at 0.05m soil depth using a portable moisture meter and temperature analyzer. The data were collected from each plot at 20, 40, 60, 80, and 100 days after planting. At physiological maturity stage, the fruits of Okra within 9m² were harvested every 5 days for yield estimation. The yield was calculated using the formula illustrated by Misganaw and Bayou (2020).

Yield per hectare (kg/ha) = (plot yield (kg) x 10,000)/plot size in square meter…..(i)

The Relative Growth Rate (RGR), Net Assimilation Rate (NAR), Leaf Area Ratio (LAR), and Harvest index (HI) were calculated using the equations below.

$$RGR = \frac{\text{Log } W^2 - \text{Log } W^1}{T^2 - T^1} \ldots\ldots \text{(ii)}$$

$$NAR = \frac{W^2 - W^1 \log A^2 - \log A^1}{T^2 - T^1 A^2 - A^1} \ldots\ldots \text{(iii)}$$

$$LAR = \frac{\text{Total leaf area}}{\text{Total plant biomass}} \ldots\ldots \text{(iv)}$$

$$\text{Harvest index (HI)} = \frac{\text{Economic yield}}{\text{Biomass}} \times 100 \ldots\ldots \text{(v)}$$

Where W^2 and W^1 are plant dry biomass at time T^2 and T^1 (days); A^2 and A^1 are leaf areas corresponding to time T^2 and T^1 (days), respectively.

Nutritional composition and Phytochemical contents analyses of Okra (Abelmoschus esculentus) fruits

The harvested Okra fruits from each treatment (C, CM, CNM) were sliced, air-dried, and pulverized to obtain a fine dry powder. An aqueous extract of the sample was prepared by soaking 100g of the powdered samples in 200mL of distilled water for 12 hours. The extract was filtered using Whatman filter paper no 42. The moisture, fat, protein, and ash contents of the Okra fruit samples were determined using standard procedures described

by AOAC (2013). Moisture content was determined by oven-drying the samples at 80°C till a constant weight. Nitrogen content was analysed using the micro-Kjeldahl procedure. Protein content was computed as N multiply by 6.25. Samples were incinerated for at 550°C for 20hrs to determine the ash content. Fat content was determined using Soxhlet method as described by AOAC (2013). Total carbohydrate content was determined by difference as reported by Rachkeeree *et al*. (2018).Secondary metabolites such as alkaloids, glycoside, flavonoid, terpenes, saponin, and phenol were quantified in the fruit samples. Alkaloid was determined using the method of Harborne (1973). A total of 5g of fruit sample was weighed into a 250ml beaker and 200ml of 10% acetic acid in ethanol was added and left for 4hrs. The mixture was filtered and the filtrate concentrated on a water bath to one-quarter of the original volume. Concentrated ammonium hydroxide was added drop wise to the extract until the precipitation was complete. The whole solution was allowed to settle and the precipitate was collected and washed with dilute ammonium hydroxide and then filtered. The residue is the alkaloid, which was dried and weighed.

Saponin was determined using the method of Obadoni and Ochuko (2001). The samples were ground and 20g of each were put into a conical flask and 100cm^3 of 20% aqueous ethanol added. The samples were heated over a hot water bath for 4hrs with continuous stirring at about 55°C. The mixture was filtered and the residue re-extracted with another 200ml 20% ethanol. The combined extracts were reduced to 40ml over water bath at about 90°C. The concentrate was transferred into a 250ml funnel and 20ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered, while the ether layer was discarded. The purification process was repeated. Exactly 60ml of n-butanol was added. The combined n-butanol extracts were washed twice with 10ml of 5% aqueous sodium chloride. The remaining solution was heated in a waterbath. After evaporation, the samples were dried in the oven to a constant weight; the saponin content was calculated as percentage. Phenol was determined by spectrophotometric method. The fat free sample was boiled with 50ml of ether for the extraction of the phenolic component for 15mins. Exactly 5ml of the extract was pipetted into a 50ml flask, then 10ml of distilled water was added. Exactly 2 ml of ammonium hydroxide solution and 5ml of concentrated amyl alcohol were also added. The samples were made up to 50ml and left to react for 30mins for colour development. This was measured at 505nm wavelength.

Flavonoid was measured following the procedure of Bohm and KocipaiAbyazan (1994). Exactly 10g of okra fruit powder was extracted repetitively with 100mL of 80% aqueous methanol at room temperature. The whole solution was filtered through Whatman filter paper No 42 (125mm). The obtained filtrate was then transferred into a crucible and evaporated to dryness in a water bath and weighed to a constant weight. The weight obtained gave the estimation of flavonoids content in the fruit sample. Okra fruit powder 100mg (wi) was taken and soaked in 9mL of ethanol for 24hrs. The extract after filtration, was extracted with 10mL of petroleum ether using separating funnel. The ether extract was separated in pre-weighed glass vials and waited for its complete drying (wf). Ether was evaporated and the yield (%) of terpene was calculated with the formula (wi-wf/wi×100) (Indumathi *et al*., 2014). A total of 10g of okra fruit powder was extracted repetitively with 100mL of 80% aqueous methanol. Exactly 8mL of the extract was transferred to a 100mL volumetric flask and 60mL of H_2O and 8mL of 12.5% lead acetate were added, mixed and filtered. Exactly 50 mL of the filtrate was transferred into another 100mL flask and 8mL of 47% Na_2HPO_4 were added to precipitate excess Pb2+ ion. This was mixed and completed to volume with water. The mixture was filtered twice through same filter paper. Exactly 10mL of purified filtrate was transferred into clean Erlyn – Meyerflask and treated with 10mL freshly prepared Baljet's reagent (95mL of 1% picric acid + 5mL of 10% NaOH). After an hour, the mixture was diluted with 20mL distilled water and the absorbance was measured colorimetrically at 495nm.

Results and Discussion

Results

The average soil moisture during the experiment under *E. guineensis canopy* increased by 6% and 7% in the CNM and CM treatments, respectively compared with C (Figure 1). The increase in soil moisture at CNM and CM plots could be attributed to the shading effect of *E. guineensis* canopy which reduced evapo-transpiration. The average soil moisture content under the CNM is similar to that in the CM; however, the difference between plots under canopy and C plots increased significantly ($p < 0.001$). The average soil temperature across all the sampling days decreased by 11% and 8% in the CNM and CM plots, respectively compared with the control (Figure 2). Though the plastic film increased the soil temperature under the canopy; however, its effect was not significant. The height of Okra ranged from 10.4 to 33.5cm, 8.4 to 20.3cm, and 10.4 to 14cm under C, CNM and CM, respectively (Figure 3). Maximum height was attained under C and CNM at 80, and 100 days after planting (DAP), respectively; however, maximum height was attained at 60 days under CM after which constant heights were maintained (Figure 3). The average height of Okra at 80 DAP under C was 61.7% and 162% higher than under CNM and CM, respectively (Figure 3).

The total number of leaves of Okra at different stages of growth was higher under the C plot compared with the treatments under the canopy (Figure 4). At the vegetative and fruiting stage, the number of leaves of Okra increased significantly ($p < 0.05$) by 28.6% and 71.4%, and 17.4% and 26.3% under C compared with CNM and CM, respectively. Across all growth stages, the number of leaves produced under CNM and CM were comparable. The total leaf area at different growth stages was higher under the control treatment (C)

compared with CNM and CM. At the flowering stage, leaf area increased significantly ($p < 0.05$) by 86% and 108% under the C treatment compared with the CNM and CM, respectively. Across the growth stages, there were no significant differences in the leaf area of Okra under CNM and CM (Figure 5). At different growth (vegetative, flowering, fruiting) stages, the chlorophyll contents of Okra under varying treatments (C, CM, and CNM) were similar; however, the average chlorophyll content of Okra across growth stages under C increased by 7% compared with each of CNM and CM, respectively (Figure 6). Across all treatments, the chlorophyll contents of Okra decreased as the growth increased.

The total biomass of Okra decreased by 72.7% and 81.8% under CNM and CM, respectively compared with the open plot (Table 1). Moreover, the RGR and NAR of Okra also decreased significantly by 76.3% and 86.8% under CNM and 65.7% and 78.8% under CM compared with the control. However, there was no significant difference in the LAR of Okra in response to the varying treatments. *E guineensis* canopy had a significant influence on the harvest index and yield of Okra compared with the open field. The harvest index of Okra decreased by 65% and 47% under CNM and CM, respectively compared with C (Figure 7). The yield of Okra under *E. guineensis* canopy with or without plastic film ranged between 59.6 - 66.8kg/ha. The yield of Okra under the open field (C) was 12 times and 11 times greater than those under CNM and CM, respectively (Figure 8). However, the use of plastic-film mulch under *E. guineensis* canopy had no significant influence on the yield and harvest index of Okra.

The nutritional composition of Okra varied considerably under the different treatments. The fruit crude protein significantly decreased by 4.2% and 4.7% under CNM and CM, respectively compared with the control (Table 2). Although, the ash content and carbohydrate of Okra fruit were comparable in both open field and under canopy; however, the use of plastic-film mulch under canopy significantly reduced ash content and carbohydrate by 22.4% and 49.7%, respectively compared with CNM. Furthermore, the result shows that the use of plastic-film mulch increased the moisture and fat contents of Okra fruit by 101% and 17.8%, respectively compared with the open field (Table 2). The quantity of phytochemicals in Okra significantly decreased under canopy compared with the open field. Among the phytochemicals studied, glycosides, terpene, saponin, and phenol were highly present in the Okra fruits cultivated on C plots compared with CNM and CM. On average, glycoside, terpene, saponin, and phenol decreased by 26%, 19%, 44%, and 15%, respectively under CNM compared with the open field (Table 3). The use of plastic-film mulch under the canopy further decreased glycosides, terpene, and phenol but increased alkaloids and flavonoids.

Discussion

The successful co-habitation of trees and crops such as wheat, maize, and barley has been reported (Dilla *et al.,* 2019; Sida *et al.,* 2018a; Tadesse *et al.,* 2021). However, Muthuri *et al.* (2005) explained that trees could have a complimentary, neutral, or competitive effect on resources available for the growth and development of crops under their canopy. The result of this study showed that Okra could thrive under the *E. guineensis* canopy, however, the yield decreased compared with the open field. The underlying factors for the reduced yield under the canopy are discussed below. The utilization of photosynthetically active radiation during photosynthesis is essential for the synthesis of assimilates, biomass build-up, and, economic yield outcome. The decreased total biomass and harvest index of Okra under CNM and CM compared with C can be attributed to the availability of low light intensity reaching the surface of the understorey plant. The canopy of *E. guineensis* intercepted the light energy from the sun thereby reducing the production of organic carbon by the plant which in turn affected biomass accumulation and partitioning of photoassimilate. Also, the effect of low light energy available to drive the process of photosynthesis is evident in the decreased chlorophyll content of Okra cultivated under the canopy compared with the open field. Li *et al.* (2018) reported that the reduction of chlorophyll content in leaves under shade signifies an adaptive mechanism of crops to ensure optimal growth. It is presumed in this study that Okra reduced the chlorophyll content of the photosynthetic tissues to increase their light absorption capacity (Li *et al*., 2018; Ort *et al*., 2011). The increased RGR and NAR in Okra grown in C than those grown under CNM and CM further indicate high biomass accumulation under C as a result of high photosynthetic ability. However, to improve light intensity under the canopy, practices such as foliage pruning of *E. guineensis* and appropriate planting distance of crop to the tree could be considered.

The availability of soil moisture is necessary for the physiological processes associated with crop growth and development (Fang and Xiong, 2015). However, an optimum temperature is required for cell metabolic activities involved in water and mineral nutrients uptake by the plant. Low-temperature stress especially at the reproductive stage can cause a considerable decline in crop yield (Wang *et al*., 2013). Under the canopy, the average soil temperature decreased by 11% compared with the open field. The low temperature possibly resulted in the permeability reduction of water and solutes as a result of membrane structure tightening (Mckersie and Lesheim., 2013) that probably affected the uptake of water and mineral nutrients under the canopy. The use of PFM for crop production has been considered an excellent mulching practice with the advantages of saving water and preserving soil moisture compared to no-film mulch (Berger *et al.,* 2013). However, the result of this study shows that PFM had no significant influence on the soil moisture under the

canopy. This could be attributed to the double-shade effect, that is, the effect of the plastic film and that of the tree canopy on the soil. Therefore, the presence of the canopy nullifies the effect of the PFM by serving as a barrier between the atmosphere and the soil surface thereby conserving soil moisture. The insignificant yield outcome obtained between treatments under canopy shows that the use of PFM under canopy is ineffective and unsuitable for the improvement of yield and agro-physiological characteristics of Okra. The use of PFM under *E. guineensis* plantation could reduce water and nutrient uptake by hindering root growth and water movement in the soil (Dong *et al.,* 2017), thereby lowering the yield of the tree and that of the crop. Furthermore, the decreased yield under the *E. guineensis* canopy could be a result of insufficient nutrient availability as a result of zero fertilizer application; therefore, creating competition between the *E. guineensis* tree and Okra for nutrients. Under the open field, there was less competition which possibly led to sufficient nutrients available to Okra*;* hence, the highest yield was obtained.

Plant survival is determined by their ability to produce antioxidants and secondary metabolites under varying environmental conditions to protect themselves from microbial attack and predators (Cox-Georgian *et al.,* 2019; Rajashekar *et al*., 2009). Terpenes are the most common type of essential oil found in plants. The increased concentration of terpenes in the C plot might be a result of the exposure of the plant to the open which makes it prone to pathogenic and microbial attacks. However, under shade, terpenes in Okra were reduced by 19% and were further reduced by 87% using PFM under the canopy.Previous studies have demonstrated that phenolic chemicals help to extend the shelf life and improve the quality of fresh fruits by delaying the oxidative degeneration that causes senescence (Khanizadeh *et al*., 2009; Rekika *et al*., 2005). The increase in the phenolic content of fruits from the C plot might be a result of the sun's irradiation. Oh *et al.* (2009) reported that the phenolic content of lettuce increased by three folds after a brief exposure to high light. Moreover, phenolic compounds were also found to decrease in lettuce when plastic-film mulch was used to protect the crop against ultra-violet (UV) light irradiation. The results of this study indicate that the fruit of Okra under the control contains more nutrients and active secondary metabolites compared to those produced under the canopy.

Conclusion

This study shows that yield, and nutritional composition of Okra cultivated under *E. guineensis* canopy decreased remarkably compared with that on the open field. The reduction in yield was a result of the decrease in chlorophyll content, total biomass, and harvest index caused by low light intensity and reduced soil temperature. In addition, the use of PFM under *E. guineensis* canopy had no significant influence on the nutrient contents and agro-physiological characteristics of Okra*;* hence not suitable for its cultivation under a canopy.

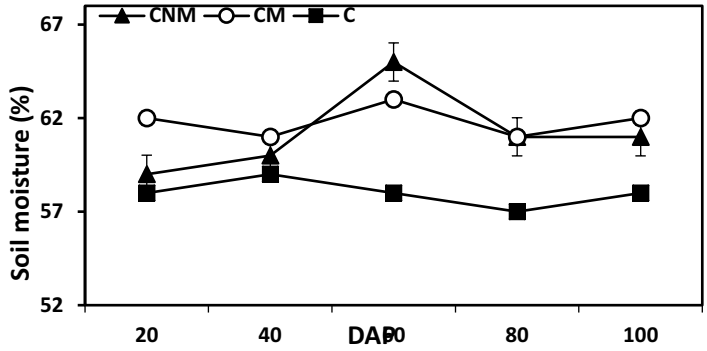

Figure 1: Average moisture content under varying treatments on each data collection day after planting (DAP). CNM denotes canopy without plastic film mulch; CM, canopy with plastic film mulch; C, open plot without plastic film mulch

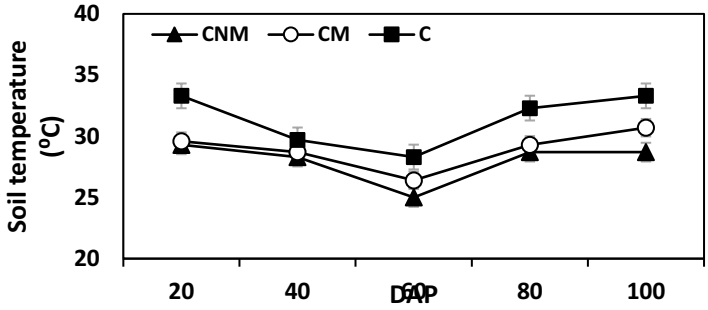

Figure 2: Average soil temperature under varying treatments on each data collection day after planting (DAP). CNM denotes canopy without plastic film mulch; CM, canopy with plastic film mulch; C, open plot without plastic film mulch

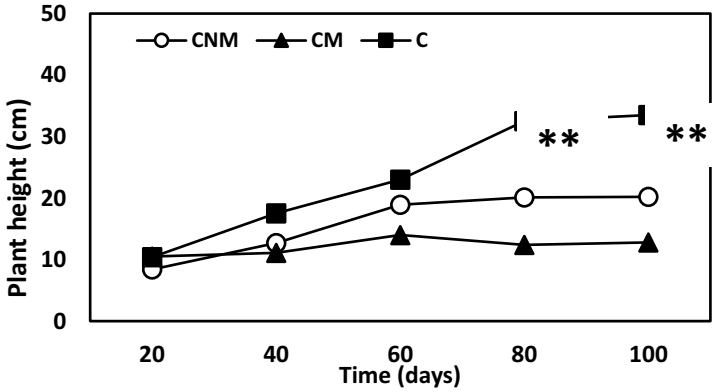

*Figure 3: Plant height of Okra as influenced by E. guineensis canopy and plastic-film mulch. CNM denotes canopy without plastic film mulch; CM, canopy with plastic film mulch; C, open plot without plastic film mulch. ** indicates significant difference at p<0.01*

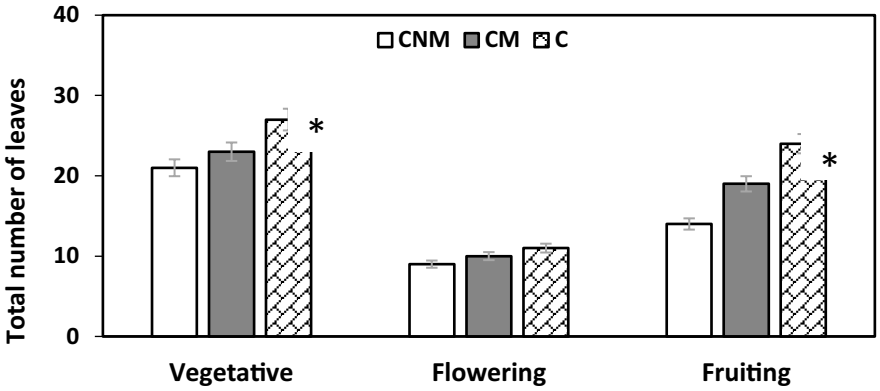

*Figure 4: The total number of leaves of Okra as influenced by E. guineensis canopy and plastic-film mulch at different growth stages. CNM denotes canopy without plastic film mulch; CM, canopy with plastic film mulch; C, open plot without plastic film mulch. * indicates significant difference at p<0.05*

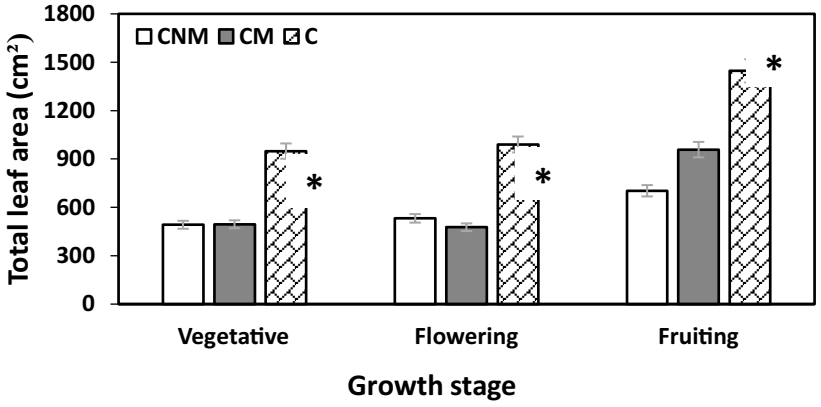

*Figure 5: The total leaf area of Okra at different growth stages as influenced by E. guineensis canopy structure and plastic-film mulch. CNM denotes canopy without plastic film mulch; CM, canopy with plastic film mulch; C, open plot without plastic film mulch. * indicates significant difference at p<0.05*

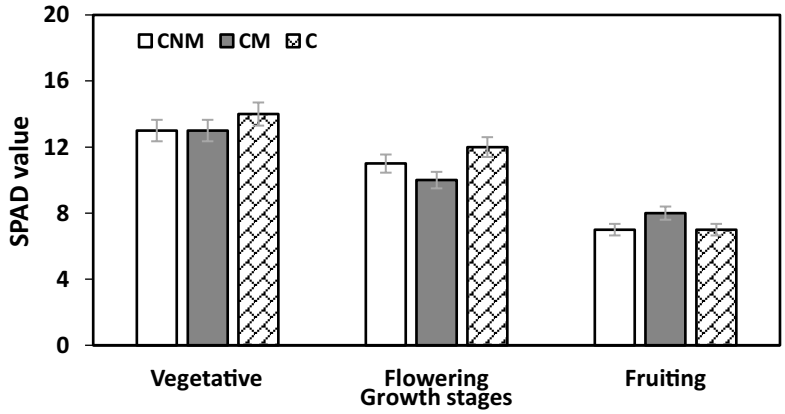

Figure 6: Average chlorophyll content of Okra as influenced by E. guineensis canopy and plastic-film mulch. CNM denotes canopy without plastic film mulch; CM, canopy with plastic film mulch; C, open plot without plastic film mulch

Table 1: Dry matter (DM), relative growth rate (RGR), leaf area ratio (LAR), and net assimilation rate (NAR) of Okra as influenced by *E. guineensis* canopy and plastic-film mulch

Plot	DM (gm^{-2})	RGR (d^{-1})	LAR ($m^{-2}g^{-1}$)	NAR ($gm^{-2}d^{-1}$)
CNM	0.3 ± 0.03^{b}	0.009 ± 0.01^{a}	371 ± 43^{a}	$2.1\times10^{-5} \pm 0.00^{a}$
CM	0.2 ± 0.03^{b}	0.013 ± 0.01^{a}	446 ± 49^{a}	$3.4\times10^{-5} \pm 0.00^{a}$
C	1.1 ± 0.35^{a}	0.038 ± 0.01^{a}	366 ± 66^{a}	$1.6\times10^{-4} \pm 0.00^{a}$
	*	ns	ns	ns

Data indicate the mean ± SE of three replications. Values within a column followed by different superscript letters are significantly different at p < 0.05 by Duncan's multiple range test. * denotes significant difference at p < 0.05, ns means non-significant

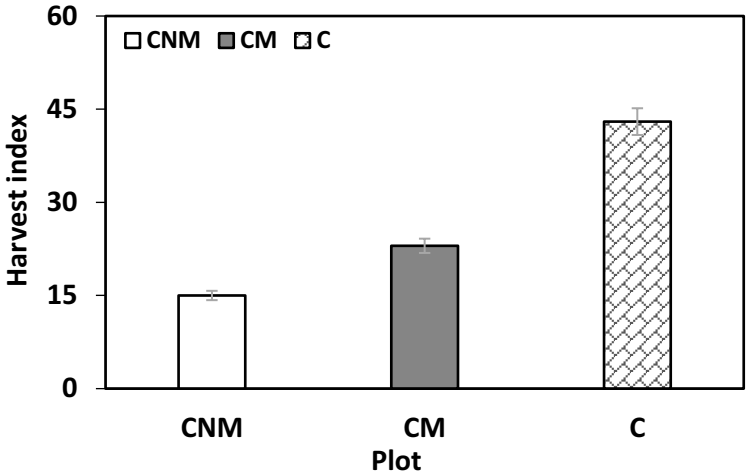

Figure 7: Harvest index of Okra as influenced by E. guineensis canopy structure and plastic-film mulch.CNM denotes canopy without plastic film mulch; CM, canopy with plastic film mulch; C, open plot without plastic film mulch

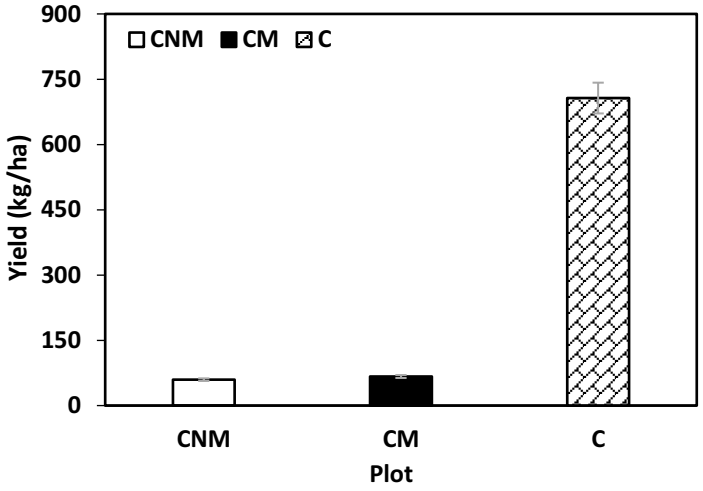

Figure 8: The yield of Okra as influenced by E. guineensis canopy structure and plastic-film mulch. CNM denotes canopy without plastic film mulch; CM, canopy with plastic film mulch; C, open plot without plastic film mulch

Table 2: Proximate and nutritional composition of Okra fruits as influenced by *E. guineensis* canopy and plastic-film mulch

	Proximate and nutritional composition						
Plot	**Moisture (%)**	**Dry matter (%)**	**Fat (%)**	**Ash content (%)**	**Crude fibre (%)**	**Crude protein (%)**	**Carbohydrate (%)**
CNM	17.21 ± 0.3^{b}	83.03 ± 0.2^{b}	1.95 ± 0.04^{b}	8.12 ± 0.00^{a}	20.27 ± 0.04^{b}	15.84 ± 0.05^{b}	37.29 ± 0.09^{a}
CM	23.63 ± 1.5^{a}	73.37 ± 1.5^{c}	2.58 ± 0.17^{a}	6.30 ± 0.15^{b}	33.01 ± 1.31^{a}	15.76 ± 0.19^{b}	18.72 ± 0.48^{b}
C	11.77 ± 0.2^{c}	88.81 ± 0.3^{a}	2.19 ± 0.03^{b}	9.60 ± 008^{a}	22.30 ± 0.09^{b}	16.54 ± 0.05^{a}	38.17 ± 0.16^{a}
	***	***	**	***	***	**	***

Data indicate the mean ± SE of three replications. Values within a column followed by different superscript letters are significantly different at $p < 0.05$ by Duncan's multiple range test. ** and *** denote significant differences at $p < 0.01$ and $p < 0.001$, respectively

Table 3: Phytochemical contents of Okra fruits as influenced by *E. guineensis* canopy and plastic-film mulch

	Phytochemical content					
Plot	**Alkaloids (%)**	**Glycosides (%)**	**Flavonoids (%)**	**Terpenes (%)**	**Saponin (%)**	**Phenol (%)**
CNM	0.61 ± 0.04^{b}	1.03 ± 0.01^{b}	0.6 ± 0.04^{b}	0.47 ± 0.03^{b}	0.55 ± 0.04^{b}	0.88 ± 0.04^{b}
CM	1.94 ± 0.11^{a}	0.02 ± 0.00^{c}	1.9 ± 0.11^{a}	0.06 ± 0.00^{c}	0.49 ± 0.04^{b}	0.04 ± 0.00^{c}
C	0.57 ± 0.02^{b}	1.39 ± 0.04^{a}	0.6 ± 0.02^{b}	0.58 ± 0.02^{a}	0.99 ± 0.02^{a}	1.04 ± 0.04^{a}
	***	***	***	***	***	***

Data indicate the mean ± SE of three replications. Values within a column followed by different superscript letters are significantly different at $p<0.05$ by Duncan's multiple range test. ** and *** denote significant differences at $p<0.01$ and $p<0.001$, respectively

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