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Evaluation of Radiation Indices and Yield Parameters of Cucumber/Okra Intercrop in a Screenhouse Environment

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ABSTRACT
Fruit vegetables such as okra and cucumber are very common crops largely grown and consumed in Nigeria and other parts of the sub-Saharan Africa owing to their medicinal properties. Growing competition for arable land, water, energy, and the degradation of the environment and seasonal variations, make these important crops very scarce and costly during dry seasons. This research was therefore conducted to investigate the yield response of sole planted and intercropped cucumber and okra under different moisture regimes in a screenhouse: 100% of soil field capacity (100% FC), 75% field capacity (75% FC), 50% field capacity (50% FC), and control (rain-fed condition). Yield indices which were investigated include land equivalent ratio (LER), relative crowding coefficient (K), aggressivity (A), competitive ratio (CR) and actual yield loss (AYL) following the standard methods. LER value of 1.10 under the 100% FC treatment indicated that the cucumber/okra intercrop used 10% more land efficiently than sole cropping. LER value of 0.72 of the intercrop of cucumber/okra under rain-fed condition indicated about 72% of the yield that would have been obtained with sole cropping of okra or cucumber was measured, indicating a disadvantage of intercropping under rain-fed condition. Aggressivity values obtained for all treatments indicated that the component crop, okra, was more competitive than the primary crop, cucumber during the crop growth stage. Crowding coefficient (k) values were 0.66 and 2.51 for cucumber and okra, respectively under the 100% FC treatment. Cucumber and okra had k values of 1.52 and 1.56, respectively under the 75% FC treatment. Productivity of cucumber was lower when compared with that of okra in the 100% FC, but higher productivity were recorded for both cucumber and okra under the 75% FC treatment. For the controlled experiment (rain-fed), cucumber produced lesser with a k value of 0.17, while okra produced more, having k value of 1.83.

Keywords: Crowding coefficient; Aggresivity; Competitive ratio; Okra; Cucumber.

I. INTRODUCTION

In vegetable species, intercropping conducted in greenhouses has been targeted to maximize the efficient use of this environment and be the most cost-effective with greater productivity in the same area. Intercropping is mainly used in the cultivation of vegetables due to fast growth and maturation, as well as high biomass productivity (Oliveira et al., 2010). However, the benefit of crop association requires that species not only have distinct but also complementary agronomic characteristics, which are key criteria in this type of cultivation system (Cecílio-Filho et al., 2013). In general, the main limiting factors for plant growth and development are related to the availability of water, nutrients, and light (Jose et al., 2006). In the case of intercropping, light intensity can be considered a limiting factor for plant growth because the canopy can shade the associated species (He et al., 2013). In low light, energy processes of plant metabolism will be reduced, such as ATP synthesis and carbohydrates, causing lower biomass production and decreased productivity (Su et al., 2014). As an acclimatization mechanism, fluctuations in ambient light availability make plants exhibit slower leaf area growth to maximize light absorption due to the reduced quantity and quality of light (Dai et al.,

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2009; Pacheco et al., 2013). Even with increased shading due to the growth of larger species, leaf thickness is reduced and there is higher biomass allocation to roots, higher chlorophyll a and b contents for leaf area, and higher ratio between chlorophyll b and a of shaded plants (Poorter et al., 2019; Mathur, Jain, & Jajoo, 2018; Yang, et al., 2019). Changes in the light environment influence leaf anatomy, physiology, and morphology (Hogewoning et al., 2010). Therefore, competition for resources needed for plant growth and eco-physiological implications of space-time interaction between plants with contrasting architecture and cultivated under intercropping system should be considered for the production of smaller species (Ghanbari et al., 2010). Studies have found that shading caused by intercropping reduces plant physiological responses, thus reduced growth and productivity (Su et al., 2014). Lettuce (Lactuca sativa L.) and Cucumber (Cucumis sativus L.) are crops of great economic interest; they have different agronomic characteristics, which allow exploration of spatial and temporal complementarity of the available resources in an intercropping agro-ecosystem. The coexistence period between intercropped species, which depends on the transplanting period of the secondary crop as related to the main crop, significantly changes the complementarity between species, thus the agro-economic viability of intercropping (Wu et al., 2012).

Proper and adequate utilization of natural resources is the main item in practicing intercropping as the component crops are able to use natural resources to their ability differently and complementarily for the overall development of the two crops. Therefore, for success to be achieved, intercropping needs several considerations before and during cultivation. Intercropping systems according to (Tilman, et al., 2022) limits soil losses and run-off and provides a nearly continuous cover thus preventing soil from the direct impact of the rains, and that it produces a dense and diversified root system which reduces leaching of nutrients. Gosh et al. (2006) in their study found that intercropping was beneficial for the soil microbial community of sorghum, addition of nitrogen by fixation and transferring to the cereals, and soil fertility improvement. Legume crops in intercropping system support the growth of cereal crops by improving the organic matter content and physical characteristics of the soil like structure and texture of the soil (Zhang et al., 2022). Legume-cereal intercropping enhanced soil faunal activity resulting in more organic substrates accumulation in the soil; it could improve the soil fertility status of a less fertile soil by fixing atmospheric nitrogen and the intercrop legume will not compete with cereal crop for nitrogen resources (Gosh et al., 2006; Adu-Gyamfi et al., 2007). Dahmardeh et al. (2010) in Iran investigated the influence of maize-cowpea intercropping on soil chemical properties and found out that intercropping increased the amount of nitrogen (N), phosphorous (P), and potassium (K) content of the intercrop maize compared to the sole maize. According to (Belane, and Dakora, 2009), cowpea can fix up to 88 kgN/ha and in an effective cowpea rhizobium symbiosis more than 150 kgN/ha of N is fixed which can supply 80 to 90% of plants total nitrogen requirements. (Tilman, et al., 2022) found out that the combination of base-crops and legumes intercrop generally increased soil P, soil organic matter (SOM), and soil pH, while soil N and K were reduced. Okigbo and Lal (1979) reported that relatively simple intercropping system as maize/cassava can increase the cat-ion exchange capacity (CEC) and pH as well as increase in manganese (Mn) content in the soil. Intercropping of cotton and cowpea was found by Rusinamhodzi et al. (2006) as wonderful opportunity to improve carbon (C) sequestration and N-use efficiency in the short-term compared with monoculture. Vesterager et al. (1995) observed that maize and cowpea intercropping is beneficial in nitrogen poor soils. In pearl millet-cowpea intercrops, Bationo et al. (1996) reported low soil pH, K, calcium (Ca), magnesium (Mg), and CEC than the fallow system suggesting that the cropping system studied was mining the soil nutrients. Bationo et al. (1996) also reported in their studies with mucuna intercropped with maize showed positive impact on the chemical properties of soil, especially when it was introduced 6 weeks after planting (WAP) of maize and that clay, organic matter (OM), total N, P and CEC were improved by 8 - 14, 25 - 27, 43 - 50, 70 - 83, and 24 - 26%, respectively when compared with control. Despite the volume of work that had been done on sole and intercropped cucumber and okra, literatures on the radiation use parameters and yield response of their crop comparatively with sole cropping system. Therefore, the objective of this research is to determine some radiation indices and yield parameters of intercropped and sole planted cucumber and okra in a screenhouse environment.

II. METHODOLOGY

The experiment was conducted in the screenhouse of the Department of Agricultural and Environmental Engineering, Federal University of

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Technology, Akure between March and June, 2020. The site is located in Akure (latitude 7°14'N and longitude 5°08'E) which lies within the humid rainforest zone of Nigeria. The mean annual rainfall of Akure is between 1300 – 1600 mm with an average temperature of 27^0C (Fasinmirin and Oguntuase, 2008). This climate is influenced by the monsoons originating from the South Atlantic Ocean, which is brought into the country by the (maritime tropical) MT airmass. The Tropical rainforest has a small temperature range which are almost constant throughout the year. The southern part of Nigeria, experiences heavy and abundant rainfall, the storms are usually conventional in making, due to the region proximity to the equatorial belt. The relative humidity ranges between 85 and 100% during the rainy season and less than 60% during the dry season period. Akure is about 351m above the sea level. Akure is an area of about 2,303 sq/km situated within the western upland area (Fasinmirin and Oguntuase, 2008).

2.1 Screenhouse and experimental design

The greenhouse that was used for the experiment was designed to the following specifications. The frame was made with galvanized iron rods with wood overlay which allowed the use of net to cover all sides of the greenhouse. Gable roofing was adopted while a transparent canopy made of plastic was used to roof the greenhouse so as to allow Sun rays into the greenhouse for photosynthesis to occur. The greenhouse measures 3.4m high, 4.6m long and 3.0m wide.

Cucumber (Cucumis sativus) seeds were planted in wooden boxes of 1m × 1m and filled with sandy loam soil obtained from the experimental field of the Agricultural and Environmental Engineering department. The wooden boxes were left open on both ends to allow for drainage of water. The experiment comprised of three different water applications levels (100%, 75% and 50% of the Field Capacity), and a control (rain-fed), all replicated three times following a Randomized Complete Block Design (RCBD) as shown in Table 3.1. Cucumber (Cucumis sativus) and Okra (Abelmoschus esculentus) were obtained from the NOSFORD Agricultural Institute, Osogbo, Osun State. Poultry manure at a rate of 1.75 kg/m^2 was applied to each plot on 20th March 2020, while seeds, (2 per hole) were planted 2.54 cm deep, at a spacing of 30 cm apart on 24th March, 2020. Three cropping systems which were sole planting of each crop and intercrop of both crops were adopted. Also, a drip irrigation system comprising of a 50 litre bucket, main pipes and sub-pipes, and drip lines were used to supply irrigation water to the crops in the screen-house. Three irrigation levels were adopted, which were 100% irrigation to field capacity to the first set of treatments, 75% FC to the second set of treatments and 50% FC to the third set of treatments. All treatments were irrigated on a daily basis. Both crops were harvested when fully matured. Intercultural operations such as weeding and thinning were done as at when necessary.

Table 1: Designation of plots of experiment

Plot number	Designation
Plot 1	100% FC Okra only
Plot 2	100% FC Cucumber only
Plot 3	100% FC Cucumber + Okra
Plot 4	75% FC Okra only
Plot 5	75% FC Cucumber + Okra
Plot 6	75% FC Cucumber only
Plot 7	50% FC Cucumber + Okra
Plot 8	50% FC Okra only
Plot 9	50% FC Cucumber only
Plot 10	Rain-fed Cucumber + Okra
Plot 11	Rain-fed Okra only
Plot 12	Rain-fed Cucumber only

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2.2 Field estimation of resource utilization

Radiation indices characteristics evaluated are the relative crowding coefficient, land equivalent ratio, aggressivity, and competitive ratio.

2.2.1 Relative crowding coefficient (K): This is a measure of the relative dominance of one species over another in an association (Cecilio-Filho 2013). The expression is given as:

$$K = Kc \times Ko, \quad [1]$$

$$Kc = \frac{Yco \times Zoc}{(Yc - Yco) \times Zco} \quad [2]$$

$$Ko = \frac{Yoc \times Zco}{(Yo - Yoc) \times Zoc} \quad [3]$$

where Kc and Ko are the relative crowding coefficients of cucumber and okra respectively, Yco and Yoc are the yields of cucumber and okra respectively, as intercrops, Yc and Yo are the yields of cucumber and okra, respectively, as individual crops. Zco is the sown proportion of cucumber intercropped with okra, and Zoc is the sown proportion of okra intercropped with cucumber.

2.2.2 Land equivalent ratio (LER):

LER is defined as the relative area of land under individual crop conditions required to provide the yield reached in intercropping. LER particularly indicates the biological efficiency of the intercropping in using the resources of the environment compared to individual crops. It is currently the most widely used index by researchers in evaluating the efficiency of intercropping systems (Federer, 2002; Cecilio Filho, 2013). LER is calculated as:

$$LER = LERc + LERo \quad [4]$$

where $LERc$ and $LERo$ represent the LER of the individual crops (cucumber and okra respectively, in the present work). Comparison of these individual indices can indicate the relative competitive ability between the component crops. Thus,

$$LERc = \frac{Yco}{Yc} \quad [5]$$

$$LERo = \frac{Yoc}{Yo} \quad [6]$$

2.2.3 Aggressivity (A): A is an index that indicates how much the relative increase in yield of the component crop (okra in this case) is greater than that of the dominant crop (cucumber) in an intercropping system. It was proposed by (Cecilio-Filho, 2013) to measure the dominance of one crop over another. It is illustrated by the expression in equation 7:

$$Ac = \frac{Yco}{YcZco} - \frac{Yoc}{YoZoc} \quad [7]$$

and $$Ao = \frac{Yoc}{YcZoc} - \frac{Yco}{YcZco} \quad [8]$$

2.2.4 Competitive ratio (CR)

CR simply represents the ratio of the individual LERs of the two component crops and takes into account the proportion of the crops in which they are initially sown (Cecilio-Filho, 2013). CR is another method of evaluating competition between different crops. This index gives a better measure of competitiveness of the component crop. In an intercropping system, the crop presenting the higher CR is better able to use the environment resources when compared to the other component crop and estimated using the equation 9:

$$CR = CRc + CRo \quad [9]$$

$$CRc = \frac{LERc}{LERo} \times \frac{Zoc}{Zco} \quad [10]$$

$$CRo = \frac{LERo}{LERc} \times \frac{Zco}{Zoc} \quad [11]$$

where CR is the competitive ratio for intercropped cucumber, CRo is the competitive ratio for intercropped okra and CR is the competitive ratio for the intercropping system.

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2.3 Data Analysis

Crop data recorded from the field was subjected to descriptive statistical analysis such as mean, standard deviation and coefficient of variation. Analysis of variance (One-way ANOVA) and post hoc comparison were conducted to test if the difference among treatments is significant ($P \leq 0.05$). Homogeneity of means at $P \leq 0.05$) was tested using the Duncan Multiple Range test. Statistical analysis was carried out using MINITAB 17. The existence of inter-relationships between data set was tested by linear correlation and the correlation coefficients determined at 1 and 5% levels of significance.

III. RESULTS AND DISCUSSION

3.1 Ratio of below and above canopy photosynthetic active radiation (τ)

Sole okra treatments (consisting of 100% FC, 75% FC and 50% FC) had a mean PAR ratio of 0.7587±0.031. Sole cucumber treatments (consisting of 100% FC, 75% FC and 50% FC) had a mean PAR ratio of 0.7338±0.034, while cucumber and okra intercrop treatments (consisting of 100% FC, 75% FC and 50% FC) had a mean PAR ratio of 0.7608±0.034. The cucumber and okra intercrop plots have a higher PAR ratio than sole cucumber and sole okra. This may be attributed to the fact that the cucumber vines climbed on ropes which were used to stake the crops, and on the walls of the screen house. This created a vertical canopy stratification thereby allowing more PAR to pass through to the ground. This is similar to the findings of John et al. (2005), who documented that vertical stratification of leaf area could change light penetration dynamics and increase light availability to the soil.

Table 2: Ratio of below and above canopy photosynthetic active radiation (τ)

Treatments	Ratio of below and above canopy photosynthetic active radiation (τ)
Cucumber only	0.7338±0.03422[a]
Okra + Cucumber	0.7608±0.03426[a]
Okra only	0.7587±0.03068[a]

*different superscript in a column means there is significant difference

3.2 Resource utilization

Parameters used to estimate resource utilization between the dominant crop (cucumber) and the component crop (okra) include: relative coefficient, land equivalent ratio, aggressivity, competitive ratio and actual yield loss. The 100%, 75%, and 50% water treatments had LER of 1.10, 1.13 and 1.03, respectively (Table 3). For the 100% treatment, LER value of 1.10 indicates that the cucumber/okra intercrop used land 10% more efficiently than sole cropping; i.e. cucumber/okra intercrop is 10% more efficient than sole cropping. In the same vein, for 75% FC, LER value of 1.13 indicated that intercropping is more beneficial than sole cropping by 13%, while for 50% FC treatment, an LER value of 1.03 indicated intercropping was 3% more beneficial than sole cropping. This shows that intercropping was more beneficial than mono-cropping for these treatments since LER > 1 was obtained (Mohammed et al., 2007). The rain-fed treatment had an LER value of 0.72, which means the intercrop only produced about 72% of the yield that would have been obtained with sole cropping of both okra and cucumber, indicating a disadvantage of intercropping under rain-fed condition. This low LER value could have been due to irregular rainfall during the course of the experiment. The results are presented in the Table 3.

The aggressivity values obtained for each treatment indicated that the component crop, okra, was more competitive than the primary crop, cucumber in the experiment. For 100% FC treatment, okra had an aggressivity value of 0.90, while cucumber had an aggressivity value of -0.90. For 75% FC treatment, cucumber had an aggressivity value of -0.29, while okra had a value of 0.29. For the 50% FC treatment, cucumber had an aggressivity value of -0.43, while okra had an aggressivity value of 0.43 (Table 3). The rain-fed treatment showed cucumber had an aggressivity value of -1.06, while okra had an aggressivity value of 1.06. All these values indicate that okra was more aggressive than cucumber in this experiment.

For the 100% FC treatment, cucumber had a crowding coefficient (K) value of 0.66 which shows that it produced less yield than expected. Okra on the other hand had a (K) value of 2.51

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(Table 4), which shows that okra overproduced for this treatment. For 75% water treatment, cucumber had a K value of 1.52 which shows it overproduced while okra with a K value of 1.56 also overproduced than expected (Table 4). For the 50% water treatment, cucumber and okra had K values of 0.73 and 1.56, respectively, which indicated that cucumber underproduced, while okra overproduced for this treatment. In summary, okra had a higher crowding coefficient than cucumber in this experiment. This may be because okra requires less water than cucumber to produce fruits, so the okra plants could compete and get enough water to produce fruits more than cucumber plants. For the rain-fed treatment, cucumber underproduced with a K value of 0.17, while okra overproduced, having K value of 1.83.

Table 3: Land equivalent ratio and aggressivity

Treatment	Land equivalent ratio			Aggressivity	
	Cucumber	Okra	Sum	Cucumber	Okra
100% FC	0.58	0.52	1.10	-0.90	0.90
75% FC	0.73	0.40	1.13	-0.29	0.29
50% FC	0.63	0.40	1.03	-0.43	0.43
Rain fed	0.28	0.44	0.72	-1.06	1.06

Table 4: Relative crowding coefficient and Competitive ratio

Treatment	Relative crowding coefficient (K)			Competitive ratio		
	Cucumber	Okra	Total K	Cucumber	Okra	Sum
100% FC	0.66	2.51	3.17	0.48	2.09	2.57
75% FC	1.52	1.56	3.08	0.78	1.28	2.06
50% FC	0.73	1.56	2.29	0.68	1.48	2.16
Rain fed	0.17	1.83	2.00	0.27	3.66	3.93

3.3 Agronomic Measurements

3.3.1 Effect of water treatments on Plant Height

Plant height was higher in the treatments carried out inside the greenhouse than those that were rain fed. For the 100% FC treatment, the tallest plant was cucumber in plot 2 (sole cucumber) which had a height of 232 cm while the shortest plant in this treatment was okra in plot 1 (sole okra) which had a height of 128cm (Figure 1). For the 75% FC treatment, cucumber from plot 5 (cucumber and okra intercrop) had a height of 229 cm making it the tallest plant in this treatment, while okra in plot 4 (sole okra) was the shortest plant, having a height of 78 cm. In the 50% FC treatment, cucumber in plot 9 (sole cucumber) was the tallest plant, with a height of 242 cm, while the shortest plant in this treatment was okra in plot 8 (sole okra), which had a height of 130 cm. The difference in the height of cucumber vine under the sole cucumber and 100% FC treatment and intercropped cucumber and okra under the 75% FC treatment are significantly different (P>0.05). This observation may have been caused by the fact that the two crops are of slightly different growth rates and canopy structures. This spatial and temporal complementarity may have led to a more efficient overall use of light, water, and nutrients in the intercrop system (Brooker et al., 2014). Cucumber are natural climbers. In a sole cropping system without a trellis, they grow as a ground vine. However, the okra plant act as living trellis, providing physical support for cucumber tendrils (Oluwole et al., 2020). This support allows cucumber to direct energy into vertical growth rather than lateral spreading. For the rain-fed treatment, cucumber in plot 10 (cucumber and okra intercrop) was the tallest plant, having a height of 143cm, while the shortest plant was okra in plot 10 (cucumber and okra intercrop), with a height of 32 cm. In the cucumber-okra intercrop system, the cucumber plant perceives the adjacent okra plant as a competitor. This triggers its shade avoidance syndrome (SAR**),** leading to significant energy utilization in stem elongation, resulting in taller plant compared to a sole crop environment where the competitive signals are more diffuse and overwhelming

In general, at 10 WAP, the 100% FC treatment had an average height of 126.22 ± 13.13cm (under which cropping system), 75% FC treatment had an average height 115.071 ± 12.57 cm(under which cropping system) and 50% FC treatment had an average height of 112.85 ± 12.69

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cm. This shows that the plots with 100% FC (plots 1, 2 and 3) had highest mean plant height than other treatments (75% and 50% FC). This is consistent with (Omotade and Babalola, 2015) who reported that cucumber height and vine decreased significantly as irrigation levels reduced. The rain-fed treatment had an average height of 45.11 ± 3.29 cm (Table 5). This might be due to the lack of consistent rainfall coupled with high temperature recorded during the course of the experiment. Figure 1 shows the plant height between one week after planting and ten weeks after planting.

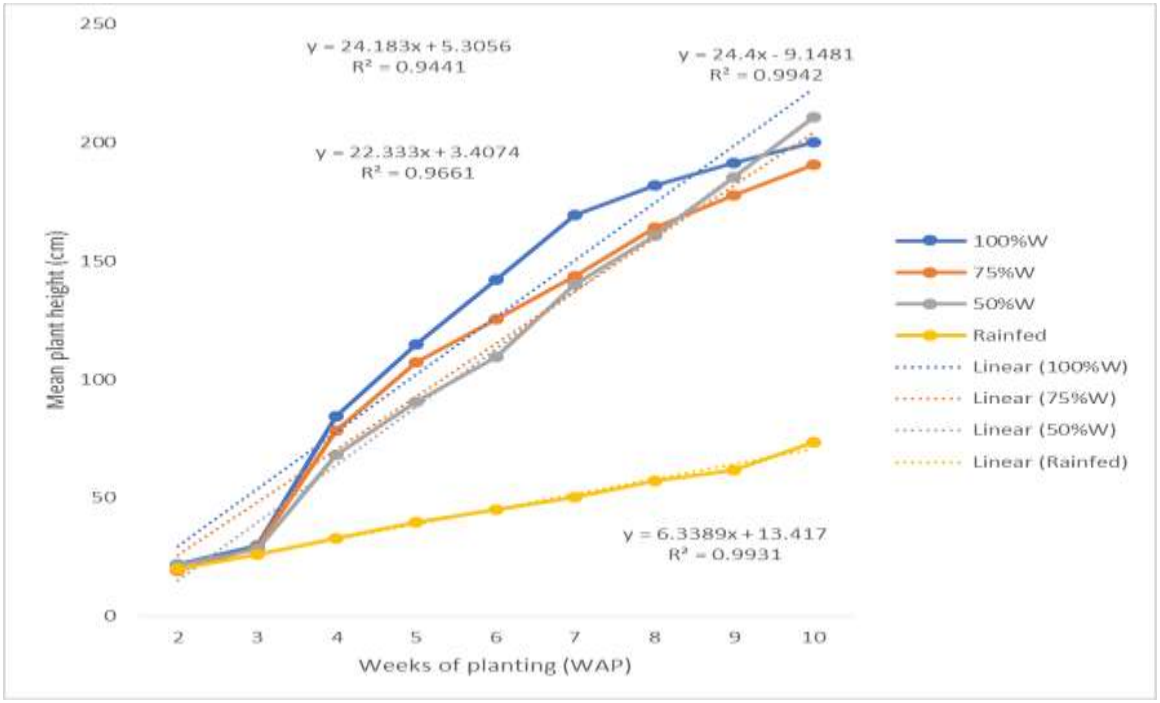

Figure 1: Mean Plant Height (cm) against weeks of planting

Table 5: Mean plant heights (Standard Deviation) of the different treatment plots

S/N	Treatments	Mean plant height
I	100% FC	126.22±13.13[a]
ii	75% FC	115.071±12.57[a]
iii	50% FC	112.85±12.69[a]
iv	Rain fed	45.11±3.29[b]

*different superscript in a column means there is significant difference

3.3.2 Stem Diameter

The stem diameter was measured using a digital Vernier caliper, from the second week after planting (2WAP) till the tenth week after planting (10WAP) at the completion of harvesting. For the 100% FC treatment, the plant with the highest stem diameter was okra in plot 1 (sole okra) which had a stem diameter of 24.09 in while the plant with the smallest stem diameter in this treatment was cucumber in plot 3 (cucumber okra intercrop) which had a stem diameter of 7.03 in. For the 75% FC treatment, okra from plot 4 (sole okra) had a stem diameter of 20.39 in, making it the plant with the biggest stem diameter in this treatment while cucumber in plot 6 (sole cucumber) was the plant with the smallest stem diameter, with a value of 7.45in (inches not allowed. Convert to cm). In the 50% FC treatment, okra in plot 8 (sole okra) had the biggest stem diameter of 28.61 in, while cucumber in plot 7 (cucumber and okra intercrop) with a stem diameter of 7.26 in was the plant with the smallest stem diameter in this treatment (Figure 4.2). For the rain fed treatment, okra in plot 10 (cucumber and okra intercrop) had the biggest stem

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diameter of 13.19in while cucumber from plot 10 (cucumber and okra intercrop) had the smallest stem diameter of 4.18in.

In general, at 10 WAP, the 100% FC treatment had a mean stem diameter of 8.05 ± 1.05in, 75% FC treatment had a mean stem diameter of 9.13 ± 0.91in and 50% FC treatment had a mean stem diameter of 9.84 ± 1.15in. It can be deduced from this experiment that the stem diameter for the different treatments increased as the water application reduced. This may be because the water deficit is moderate, and not severe. The observed higher stem diameter under reduced water application is likely an adaptive morphological response. The mild water stress triggers hormonal changes and a shift in carbon allocation away from primary growth (height) towards secondary growth (stem thickening and root development). The intercropping system mitigates the severity of the water stress through microclimate modification and reduced evaporation, allowing this adaptive response to express itself clearly as thicker stems rather than just overall stunted growth. This is in line with researches conducted by Li. (2019) and Wang (2025) where they found out that enhanced soil aeration increased plant agronomic parameters; stem diameter included. The rain fed treatment had a mean stem diameter of 5.51 ± 0.56 in (Figure 4.2). The stem diameter for the rain fed treatment was low in all replicates due to a limited amount of rain the plots received during the course of the experiment.

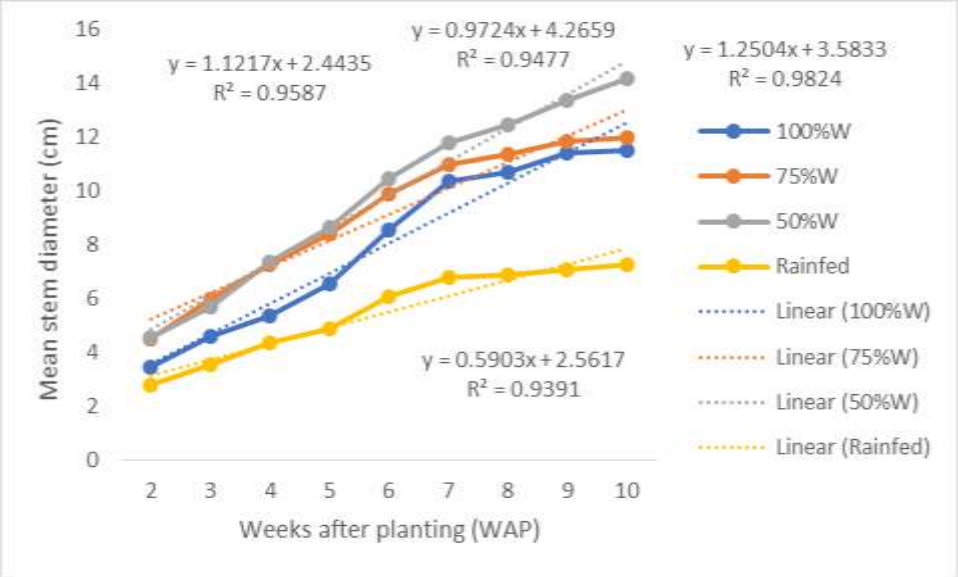

Figure 2: Mean stem diameter per week

Table 6: Mean (Standard Deviation) stem diameter of the different treatment plots

S/N	Treatments	Mean stem diameter
I	100% FC	8.05 ± 1.05^{ab}
Ii	75% FC	9.13 ± 0.91^{a}
Iii	50% FC	9.84 ± 1.15^{a}
Iv	Rain fed	5.51 ± 0.56^{b}

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3.3.3 Leaf area index (LAI) per plot

For the 100% FC treatment, plot 2 (sole cucumber) had the highest LAI value of 0.55, while plot 1 (sole okra) had the lowest value of 0.05 (Table 4.3, Figure 4.7). This may be due to the fact that cucumber plant had more leaves than okra, thereby covering more soil area than okra.

For the 75% FC treatment, plot 5 (cucumber and okra intercrop) had the highest LAI of 0.39, while plot 4 (sole okra) had the lowest LAI of 0.24. For the 50% FC treatment, plot 9 (sole cucumber) had the highest LAI with a value of 0.33, while plot 8 (sole okra) had the lowest LAI with a value of 0.18. For the rain fed treatment, plot 10 (cucumber and okra intercrop) had the highest LAI of 0.31, while plot 12 (sole cucumber) had the lowest LAI value of 0.18.

In summary, sole cucumber treatments had a mean LAI of 0.8546±0.05, cucumber and okra intercrop treatment had a mean LAI of 0.3871±0.03, while sole okra treatment had a mean LAI value of 0.1192±0.01.

It was observed that the treatments with sole cucumber plants generally had higher LAI than sole okra treatments. This may be because of its large overlapping leaves and vining growth habit (Liu. et al., 2021).

Table 7: Mean (Standard deviation) Leaf Area Index (LAI) cropping method

S/N	Treatments	LAI
I	Cucumber only	0.8546±0.04759[a]
Ii	Okra + Cucumber	0.3871±0.02608 [a]
Iii	Okra only	0.1192±0.01151 [a]

*different superscript in a column means there is significant difference

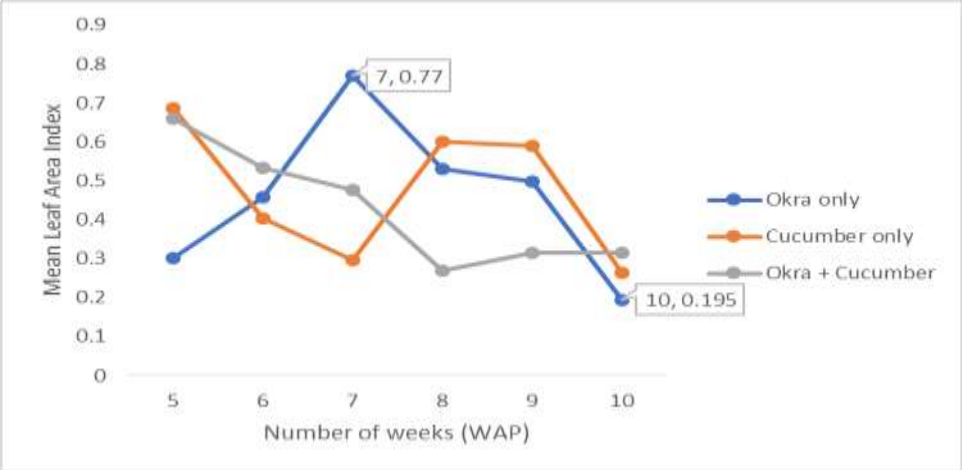

Figure 3: Leaf area index per plot

IV. CONCLUSION

An experiment was conducted in a screenhouse to determine some radiation indices and response of sole planted and intercropped cucumber and okra. The cucumber and okra intercrop plots had higher value of the ratio of below canopy PAR to the above canopy PAR than sole cucumber and sole okra. This spatial and temporal complementarity may have led to a more efficient overall use of light, water, and nutrients in the intercrop system Cucumber/okra intercrop had highest land equivalent ratio (LER), while the sole cropping of either cucumber or okra had lower LER. This observation translated to higher productivity in terms of yield of both crops. In the cucumber-okra intercrop system, the cucumber plant perceives okra plant as a competitor. This resulted to shade avoidance syndrome (SAR**),** leading to significant energy utilization in stem elongation, resulting in taller plant compared to a sole crop environment where the competitive signals are more diffuse and overwhelming.

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