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THE MUTUAL EFFECTS OF QUANTITATIVE AND QUALITATIVE TRAITS ON THE PERFORMANCE OF CUCUMBER CULTIVARS IN MIXED CULTIVATION OF CUCUMBER WITH OKRA

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ABSTRACT

To analyze the correlation between crop yield and its components and choose the most favorable combination of okra and cucumber based on quantitative characteristics, an experiment was carried out in a greenhouse located in the Varamin region. The experiment followed a randomized complete block design with three replications conducted in both 2020 and 2021 under the supervision of the Horticultural Science Research Institute. The compound analysis results revealed significant variations among traits in relation to mixed cropping treatment and the combined impact of traits. Furthermore, the interaction effect of year and intercropping was found to be statistically significant for all traits, except for stem diameter. The results of comparing averages using Duncan's method indicated that, based on various characteristics such as fruit weight, plant height, stem diameter, fresh fruit yield, dry fruit yield, number of internodes, fruit diameter, fruit length, fruit number, chlorophyll a, chlorophyll b, and total chlorophyll, the following mixed cultures were identified as suitable: okra with greenhouse cucumber Viola, okra with greenhouse cucumber Fc-21, and okra with greenhouse cucumber Emilie. When considering the traits observed over the years of the experiment from multiple perspectives, it was determined that mixed crops of okra with Viola greenhouse cucumber and okra with Emilie greenhouse cucumber were chosen as desirable crops. Upon analyzing the main components, the researcher selected the first four components as they accounted for the largest amount of variance in the data. Consequently, okra crops with greenhouse cucumber Mirsoltan variety and okra with greenhouse cucumber Emilie variety were chosen as suitable crops based on the first and second main components during the experimental years. Based on the Land Equality Ratio (LER) in the experimental years, the cultivation of okra with greenhouse cucumber varieties Mirsoltan, Emilie, CUB-9042, and CUB-9045 proved to be more advantageous compared to growing pure okra.

KEYWORDS: Okra, Cucumber, Mixed cultivation, Multifaceted view, Main components, Correlation.

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INTRODUCTION

Okra, also known by its scientific name (esculentus abelmoschus L.) and English name Okra, is a plant that grows annually in America. It has a bushy structure with a thick main stem that produces multiple secondary branches in certain varieties (Tarassoum, 2019). Mixed cropping is a commonly used method in sustainable agriculture systems, which plays a significant role in increasing production and ensuring stable yields. This method aims to improve the utilization of resources and environmental factors (Alizadeh et al., 2010). Research conducted worldwide has demonstrated that mixed farming enhances ecological diversity and leads to higher production with beneficial yields. Furthermore, it promotes efficient utilization of water, land, labor, and food resources, while reducing issues caused by pests, diseases, and weeds (Awal et al., 2006). Intercropping offers several important advantages compared to monocropping. Firstly, it leads to increased production per unit area, as demonstrated by Banik et al. (2006). Additionally, intercropping promotes production diversity and sustainability in agricultural ecosystems, while also significantly boosting economic income and land productivity, as highlighted by Hamzei and Babaei (2017). In the case of okra and cucumber, which are both valuable fruit vegetables, it is crucial to conduct research to better understand the mutual effects of their mixed cultivation (Anim, 2007; Limbani). Numerous studies have consistently shown that intercropping outperforms pure cropping in terms of yield and various other aspects (Pelzer et al., 2012; Sujatha et al., 2011). A recent study by Sedigi Kamel et al. (2021) focusing on mixed farming confirmed that it enhances biodiversity, stabilizes ecosystems, and maximizes land productivity. Hamzei and Seddighi (2019) studied how beans and potatoes grow together in a mixed crop. They found that these two plants have different characteristics and can benefit from each other in this system (Hamzei and Kamel, 2019). One way to measure the success of mixed cropping is to use the land equivalent ratio (LER). This ratio compares how much land is needed to grow the same amount of crops separately or together. A LER higher than one means that mixed cropping is better, while a LER lower than one means that separate cropping is better (Ahmadi et al., 2009; Banik et al., 2006). This research aims to: 1) find the best combination of okra and cucumber for mixed cropping based on the traits measured in the experiment, 2) analyze the correlation and interaction of the traits in mixed cropping, and 3) compare and evaluate mixed cropping in different years and select the most profitable ones over separate cropping.

MATERIALS AND METHODS

In this experiment, we tested different combinations of okra and cucumber plants in a mixed cropping system. We used the okra variety Baker as the pure crop, and mixed it with different cucumber varieties: Viola, Mirsoltan, Mito, Emilie, CUB-9042, FC-21, CUB-9045, FC-27, NAGIN, and NEGIN. We used a randomized complete block design with three replicates and conducted the experiment in two consecutive years (1399 and 1400) in Varamin, a region with the coordinates 51…735011"E 35.249504"N. We kept the greenhouse at 28°C and 42% humidity. At the end of the season, we collected 10 okra and 10 cucumber plants from each plot and dried them in the oven at 70°C for a day. We compared the mixed and pure crops using the land equivalent ratio (LER) index, which we calculated with equation (1):

Eq. 1

$$LER = \sum \left(\frac{Yi}{Ys}\right)$$

We used the following formula to calculate the land equivalent ratio (LER), which shows how well the crops grow together or separately: LER = Yi/Ys, where Yi is the yield of one crop in mixed cropping and Ys is the yield of the same crop in pure cropping. We also used another formula to analyze how mixed cropping and the traits we measured affect each other:

Eq. 2

$$\frac{\alpha_{ij} - \beta_j}{\sigma_j} = \sum_{n=1}^{2} \lambda_n \xi_{in} \eta_{jn} \mid \varepsilon_{ij} = \sum_{n=1}^{2} \xi_{in}^{*} \eta_{jn}^{*} \mid \varepsilon_{ij}$$

This formula shows how to calculate the values for the main component analysis (PCA). It uses the following symbols: αij is the mean of the i-th mixed crop for the j-th trait, βj is the overall mean of the mixed crops for the trait, σj is the standard deviation of the trait in the mixed crops, εij is the error term of the mixed crop for the trait, λn is the eigenvalue for the n-th principal component (PCn), ξi is the PCn score for the i-th mixed crop, and ηjn is the PCn loading for the j-th trait. We standardized the traits to make them comparable in a graph. This was necessary because the traits had different units:

Eq. 3

$$Z = \frac{X - \mu}{\sigma}$$

This formula shows how to calculate the standard score (Z) for each trait. It uses the original data (X), the mean (μ), and the standard deviation (σ) of the trait. Table 1 and Table 2 describe the soil and the mixed crops used in the experiment, as well as the traits we measured.

Table 1 Characteristics of the tested soil

TNV %	OC %	PH	EcDs/m	B ppm	Mn ppm	Cu ppm	Zn ppm	Fe ppm	Texture	Sand %	Silt %	Clay %	P ppm	K ppm	
19.25	3.42	7.51	6.94	2.3	5.07	2.69	6.26	17.87	loam	28	46	26	358.8	2433	0.34

Table 2 Code and characteristics of mixed crop combinations and traits evaluated in the experiment

Trait	Trait code	intercropping of okra and cucumber	intercropping okra and cucumber code
Fruit weight in each section	FWN	Baker okra variety	A1B0
Bush height	PLH	Baker x Viola	A1B1
stem diameter	STD	Baker x Mirsoltan	A1B2
Fresh fruit yield	WFY	Baker x Mito	A1B3
Dry fruit yield	DFY	Baker x Emilie	A1B4
The number of internodes	NI	Baker × CUB-9042	A1B5
Fruit diameter	FD	Baker × FC-21	A1B6
Fruit length	FL	Baker × CUB-9045	A1B7
Number of fruits	NF	Baker × FC-27	A1B8
a chlorophyll	Cha	Baker x NAGIN	A1B9
b Chrophyll	Chb	Baker x NEGIN	A1B10
Total chlorophyll	Ch		

RESULTS AND DISCUSSION

The composite analysis table revealed a statistically significant difference among the traits in terms of treatment, with a probability level of 0.01. Additionally, there was a significant disparity observed between the years for various characteristics such as fruit weight, plant height, stem diameter, fruit dry yield, fruit length, number of fruits, chlorophyll a, and total chlorophyll in each section. The significance of the year effect in the experiment indicates the changes and responses of different traits under different treatments from one year to another. Furthermore, the interaction effect between year and mixed crop demonstrated a significant impact on all investigated traits, except for stem diameter. The trait with the highest coefficient of variation was fresh fruit yield (28.5), while the lowest coefficient of variation was observed for plant height (12.6) (Table 3).

Table 3 Composite analysis of investigated traits in mixed crops in the years of testing

Sources Change	Degrees of freedom	Fruit weight in each section	Bush height	stem diameter	Fresh fruit yield	Dry fruit yield	Number of nodes	Fruit diameter	Fruit length	Number of fruits	Chlorophyll a	Chlorophyll b	Total chlorophyll

S.O.V	Year	Treat	Error 1	Year×Treat	Error 2	coefficient of variation
Df	1	10	4	10	40	-
FWN	0.6*	3.28*	4.88	8.77**	2.72	20.9
PLH	10261.4**	506.7**	116.1	551.9*	315	12.6
STD	27.09*	13.4*	2.05	8.7ns	7.3	17.5
WFY	197578.4 ns	659118*	574820	422240	787160	28.5
DFY	2967533*	408893*	143379	186299*	364628	25.3
NI	3.4ns	1.9*	1.7	1.4*	2.2	19.9
FD	4.8ns	16.1*	3.07	19.5**	8.8	16.1
FL	79.6**	8.1*	14.2	12.9*	11.5	25.5
NF	10.5*	2.5*	0.65	2.6*	2.2	21.5
Cha	130.9**	10.5**	8.6	9.02**	4.5	14.3
Chb	1.9ns	0.45*	1.2	0.72*	0.75	19.6
Ch	1.2*	0.37*	0.24	0.37*	0.66	15.1

According to the comparison of various traits and treatments, unsatisfactory cultivars are treatments of okra with greenhouse cucumber of Viola variety, okra with greenhouse cucumber of Mirsoltan variety, okra with greenhouse cucumber of CUB-9042 variety, okra with greenhouse cucumber of CUB-9042 variety in terms of fruit weight in each section, okra mixed cultivation treatments of okra with greenhouse cucumber of Viola variety, Okra with greenhouse cucumber of Mirsoltan variety, okra with greenhouse cucumber of FC-21 variety and okra with greenhouse cucumber of Nagin variety in terms of plant height traits, treatments of okra with greenhouse cucumber of Mirsoltanan variety, okra with greenhouse cucumber of Emilie variety and okra with greenhouse cucumber of Nagin variety In terms of stem diameter trait, treatments of okra with greenhouse cucumber Viola, CUB-9042, okra with greenhouse cucumber FC-21, okra with greenhouse cucumber CUB-9045, okra with greenhouse cucumber FC-27 and okra with greenhouse cucumber Nagin, in terms of fresh fruit yield, okra treatments, okra with greenhouse cucumber Viola variety, okra with greenhouse cucumber variety CUB-9042, okra with greenhouse cucumber variety FC-21, okra with greenhouse cucumber variety CUB-9045 and okra with greenhouse cucumber variety 27 of 7 in terms of dry fruit yield traits, okra treatments, okra with greenhouse cucumber Viola, okra with greenhouse cucumber Mirsoltan, okra with greenhouse cucumber Mito, okra with greenhouse cucumber CUB-9042, okra with greenhouse cucumber FC-21, okra with greenhouse cucumber cultivar FC-27 and okra with greenhouse cucumber cultivar Nagin in terms of internode number trait, okra treatments with greenhouse cucumber Mirsoltan cultivar, okra with greenhouse cucumber cultivar Emilie, okra with greenhouse cucumber cultivar FC-27 and okra with Greenhouse cucumber of Nagin variety in terms of fruit diameter traits, okra treatments, okra with greenhouse cucumber of Viola variety, okra with greenhouse cucumber of Mirsoltan variety, okra with greenhouse cucumber of Emilie variety, Okra with greenhouse cucumber cultivar FC-21 and okra with greenhouse cucumber cultivar Nagin in terms of fruit length traits, treatments of okra with greenhouse cucumber Emilie cultivar, okra with greenhouse cucumber cultivar FC-21 and okra with greenhouse cucumber cultivar FCC-27 in terms of number traits Fruit, treatments of okra with greenhouse cucumber Viola, okra with greenhouse cucumber CUB-9042, okra with greenhouse cucumber FCFC-21, okra with greenhouse cucumber CUB-9045, okra with greenhouse cucumber FC-27 and okra with greenhouse cucumber Nagin cultivar in terms of chlorophyll a trait, okra treatments with Mito cultivar greenhouse cucumber, okra with greenhouse cucumber cultivar FC-21, okra with greenhouse cucumber cultivar CUB-9045 and okra with greenhouse cucumber cultivar Nagin cultivar in terms of chlorophyll b trait and okra treatments, With greenhouse cucumber Viola variety, okra with greenhouse cucumber Mito variety, okra with greenhouse cucumber variety CUB-9042, okra with greenhouse cucumber variety FC-21, okra with greenhouse cucumber variety FC-27, okra with greenhouse cucumber variety FC-27 and Nagin had the highest value in terms of total chlorophyll and were placed in the top group. In general, in terms of the amount of all the traits, okra with greenhouse cucumber Viola, okra with greenhouse cucumber FC-21, okra with greenhouse cucumber Emilie and okra with greenhouse cucumber Fc-27 as desirable crops and okra cultivation, okra with greenhouse cucumber Mito cultivar and okra with greenhouse cucumber cultivar Negin (Table 4).

Table 4 The mean comparison by Duncan's method in terms of traits evaluated in two years of testing

	order	Fruit weight in each section	Bush height	stem diameter	Fresh fruit yieldمیوه	Dry fruit yield	Number of nodes	Fruit diameter	Fruit length	Number of fruits	Chlorophyll a	Chlorophyll b	Total chlorophyll
	Rank	**FWN**	**PLH**	**STD**	**WFY**	**DFY**	**NI**	**FD**	**FL**	**NF**	**Cha**	**Chb**	**Ch**
A1B0	9	7.9b	85.7cde	14.6bcd	3099cd	2099abcd	7.8ab	17.1cd	14.4ab	6.2bcd	0.46bcd	0.39bc	0.85ab

A1B1	1	8.3ab	102.07ab	16.8ab	3287ab	2159ab	7.6ab	18.3bc	15a	7.3bc	0.48abcd	0.37bcd	0.83abc
A1B2	5	8.2ab	104.7a	16.5ab	2800cde	1841cd	8.33a	19.6ab	13.8abc	7.1bc	0.4cd	0.39bc	0.79bc
A1B3	10	6.4d	87bcde	13.5cd	3121bcd	1961bcd	7.6ab	15.9e	1.5cd	6.5bcd	0.38d	0.47ab	0.83abc
A1B4	3	7.4bcd	98.3bc	17.8a	3231abc	1914bcd	7.3bc	21.8a	14.4ab	7.5ab	0.42bcd	0.32bcd	0.74bc
A1B5	7	9.07a	79.07de	14.5bcd	3405a	2304ab	8.16ab	17.9bcd	11.8bcd	5.9cd	0.59ab	0.32bcd	0.91ab
A1B6	2	7.6bcd	102.7ab	15.3bc	3476a	2316a	7.5ab	16.4cde	13.8abc	7.5ab	0.55abc	0.46ab	1.1a
A1B7	8	8.7a	90bcd	16.2abc	3338ab	2147abc	6.1c	18.2bc	12.5bc	7.1bc	0.53abc	0.37bcd	0.9ab
A1B8	4	7.8bc	97.7bcd	12.7d	3199bc	2057abcd	7.8ab	19.1ab	12.7bc	8.02a	0.596ab	0.48a	0.96ab
A1B9	6	7.09cd	100.6ab	16.03abc	2317e	1524cd	7.6ab	19.3ab	13.6abc	6.9bc	0.6a	0.4abc	1a
A1B10	11	7.6bcd	81.4cde	15.5bc	2894cde	1589cd	7.3bc	18.9bc	12.3bc	6.1bcd	0.42bcd	0.32bcd	0.74bc

Multifaceted view

A polygon view was created to determine the most suitable cultivation methods for the traits that were evaluated. This diagram was created by connecting the cultures that were farthest from the starting point. Starting from the starting point, a line is drawn perpendicular to each side of the shape until the diagram is divided into multiple parts. In this way, crops located in a specific section with one or more particular traits perform well in relation to those traits (Yan and Kang, 2003). Based on the diagram that represents the average data from the two years of the experiment, the first principal component accounted for 23.81% of the variance, and the second principal component accounted for 26.29%. Altogether, more than 50% of the total data variance was explained. The mixed combinations consisting of okra and greenhouse cucumber varieties Viola, FC-21, CUB-9042, Nagin, and Emilie exhibited the furthest distance from the center of the graph and were identified as suitable crop pairings. Among these combinations, certain characteristics such as fresh fruit yield, dry fruit yield, and total chlorophyll content in the mixed culture of okra with greenhouse cucumber variety FC-21 showed more favorable traits. Additionally, the chlorophyll a trait in the okra culture with greenhouse cucumber variety CUB-9045, as well as the traits including plant height, stem diameter, fruit diameter, fruit length, and number of fruits in the okra cultivation with Emilie greenhouse cucumber, were deemed more desirable compared to other investigated mixed crops (Figure 1).

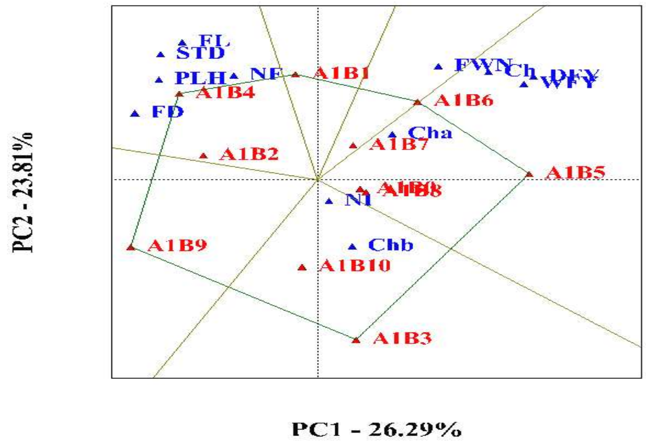


Figure 1 Multivariate comparison of mixed crops evaluated in terms of traits (FWN: fruit weight per node, PLH: plant height, STD: stem diameter, WFY: fresh fruit yield, DFY: dry fruit yield, NI: number of internodes , FD: fruit diameter, FL: fruit length, NF: fruit number, Cha: chlorophyll a, Chb: chlorophyll b, Ch: chlorophyll

Correlation between traits

This figure displays a cosine biplot representing the angle between trait vectors and indicates the strength of correlation between the traits. When the angle between the vectors is less than 90 degrees, the correlation between the vectors is +1. If the angle between the trait vectors is exactly 90 degrees, the correlation between them is zero. Similarly, when the angle between the vectors is 180 degrees, the correlation is -1 (Yan and Kang, 2003).

Based on the correlation coefficient table, the average data from a two-year experiment indicated a clear positive and significant correlation between fruit weight and both fresh fruit yield and dry fruit yield. This means that as the fruit weight increases, we can expect an increase in both fresh fruit yield and dry fruit yield. On the other hand, there was a negative and significant correlation between plant height and fruit yield. The stem diameter showed a positive and significant correlation with the total chlorophyll trait, but a negative and significant correlation with the chlorophyll b trait. Additionally, there was a positive and significant correlation observed between fresh fruit yield and dry fruit yield, internode number and fruit number. There was also a positive and significant correlation between chlorophyll a and fruit number, as well as between chlorophyll a and total chlorophyll (see Table 5). Based on the graph representing the average data from the first and second years of the experiment, there was a positive correlation observed among various traits including fruit weight in each section, total chlorophyll, fresh fruit yield, dry fruit yield, chlorophyll a, number of internodes, chlorophyll b, fruit number, fruit length, fruit diameter, stem diameter, and plant height. Conversely, the number of fruit traits showed a negative correlation with the number of internodes and chlorophyll b, as indicated by the 180-degree angle between the trait vectors (Figure 2). This type of diagram was utilized by Shojaei et al. in their research (Shojaei et al., 2022). By examining both the correlation coefficient table (Table 5) and the correlation graphs from different years of the experiment, it is possible to report the correlation between the traits of fresh fruit yield, dry fruit yield, and total chlorophyll.

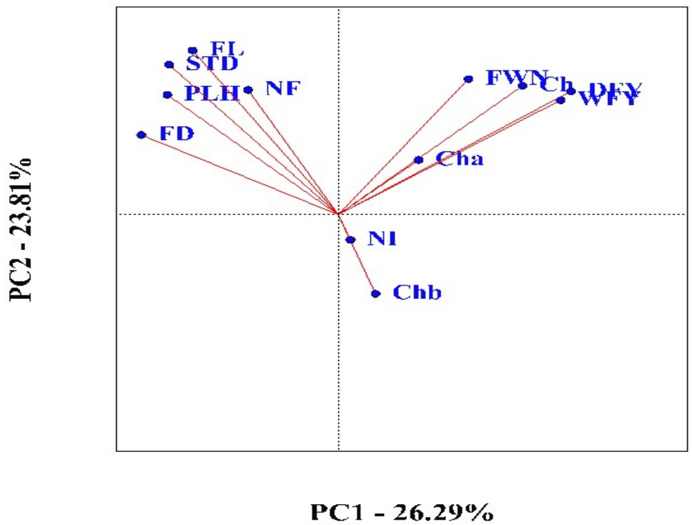


Figure 2 Correlation diagram between the traits evaluated in the experiment (FWN: fruit weight per node, PLH: plant height, STD: stem diameter, WFY: fresh fruit yield, DFY: dry fruit yield, NI: number of internodes, FD: fruit diameter, FL: fruit length, NF: fruit number, Cha: chlorophyll a, Chb: chlorophyll b, Ch: total chlorophyll)

The correlation between fresh fruit yield, dry fruit yield, and total chlorophyll can be determined by analyzing the correlation coefficients table (Table 5) and the correlation graphs from different years of the experiment.

Table 5 Correlation coefficients of the studied traits in the years of the experiment (FWN: fruit weight per section, PLH: plant height, STD: stem diameter, WFY: fresh fruit yield, DFY: dry fruit yield, NI: number of internodes, FD: fruit diameter, FL: fruit length, NF: fruit number, Cha: chlorophyll a, Chb: chlorophyll b, Ch: total chlorophyll)

	Fruit weight in each section	Bush height	stem diameter	Fresh fruit yield	Dry fruit yield	Number of nodes	Fruit diameter	Fruit length	Number of fruits	Chlorophyll a	Chlorophyll b
	FWN	PLH	STD	WFY	DFY	NI	FD	FL	NF	Cha	Chb
Bush height PLH	-0.09										

stem diameter	Fresh fruit yield	Dry performance	Number of nodes	Fruit diameter FD	Fruit length FL	Fruit length NF	Chlorophyll a Cha	Chlorophyll b Chb	Total chlorophyll
0.1	0.12*	0.24*	-0.17	0.27	0.08	0.07	0.18	0.18	0.06
0.27	-0.3*	-0.16	-0.04	0.1	0.1	0.4	0.38	-0.1	0.01
	-0.2	-0.16	-0.17	0.2	0.22	0.08	-0.04	-0.4*	0.47**
		0.88*	0.3*	-0.08	0.2	0.14	0.03	0.2	-0.1
			0.2	-0.15	0.2	0.2	0.17	0.24	-0.11
				-0.08	-0.09	-0.04	0.16	0.1	-0.03
					0.12	0.03	0.006	0.11	-0.17
						0.22	-0.04	0.17	0.13
							0.3*	0.005	0.4
								0.1	0.16*
									0.18

Analysis of main components

Based on the eigenvalue pattern observed in the average data from the first and second year of the experiment, the first four factors accounted for over 62% of the overall data variability (Figure 3). Consequently, the initial factor alone contributed to more than 21% of the total data variance. Within this factor, traits such as fruit weight in each section, fresh fruit yield, dry fruit yield, number of internodes, fruit length, fruit number, chlorophyll a, and chlorophyll b exhibited a positive influence. The most significant positive impact was associated with fresh fruit yield and dry fruit yield. The second factor explained over 16% of the total data variance. With the exception of the number of internodes and chlorophyll b, all traits exhibited a positive impact on this factor. The traits of fruit number and plant height had the most significant positive influence on this factor. The third factor accounted for over 12% of the total variability. In this factor, except for plant height, number of internodes, number of fruits, and chlorophyll a, the remaining traits showed a positive effect. The attribute of fruit weight in each section had the most significant positive impact. The fourth factor explained more than 11% of the data's variance, and in this factor, fruit weight in each section, plant height, fruit diameter, number of fruits, chlorophyll a, and chlorophyll b all exhibited positive coefficients.

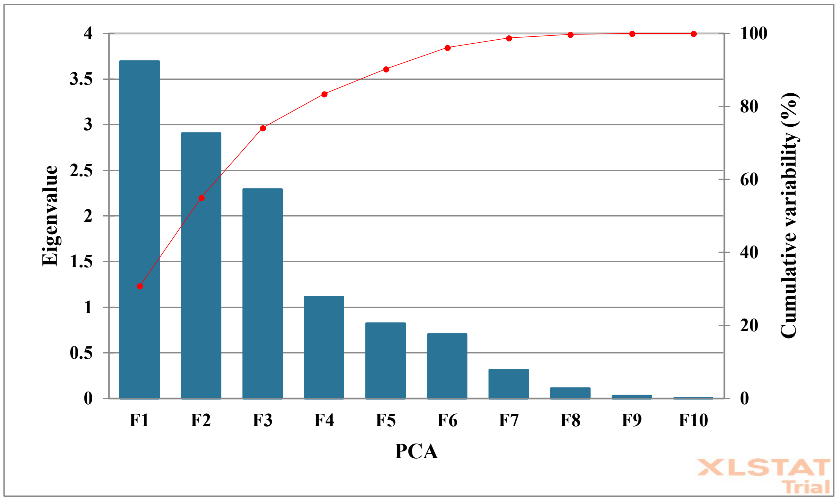
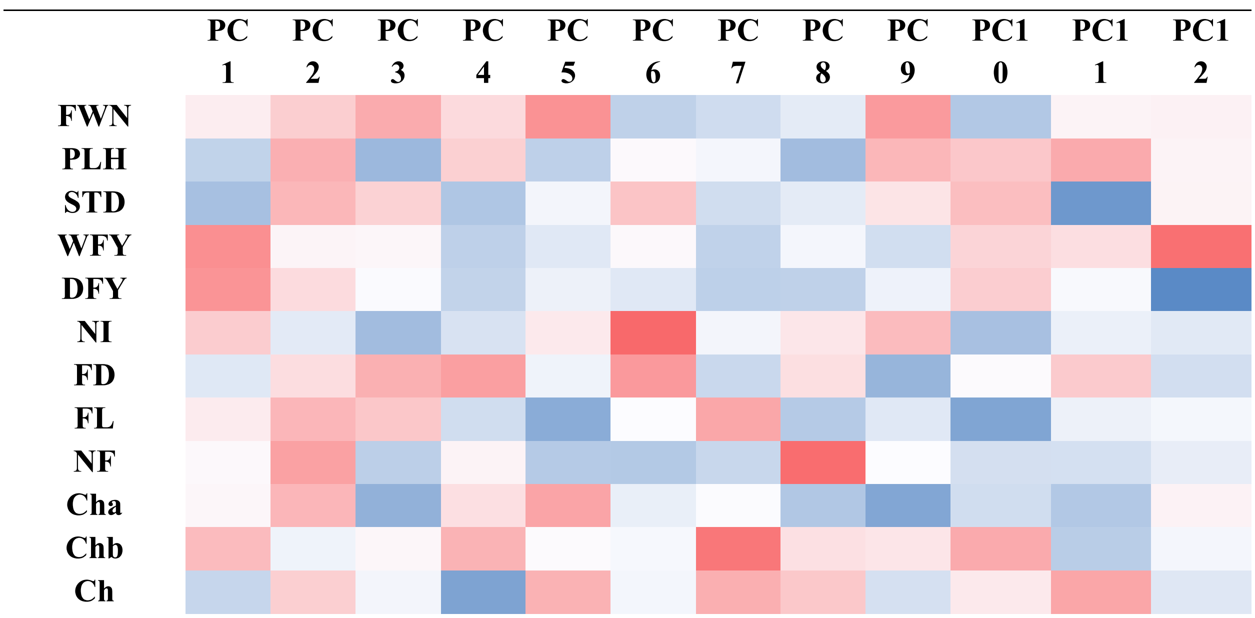


Figure 3 Eigenvalue and cumulative variance in principal component analysis

The fruit diameter and chlorophyll b traits had the greatest positive impact on this component, as shown in Figure 4. When considering the distribution of cultures based on the first and second main components, it resulted in the formation of four distinct groups.



	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC1 0	PC1 1	PC1 2
Proportion	0.21	0.16	0.12	0.11	0.08	0.07	0.07	0.04	0.03	0.02	0.01	0.00 6
Cumulativ e	0.21	0.38	0.51	0.62	0.71	0.79	0.86	0.91	0.94	0.97	0.99	1

Figure 4 Eigenvalue and cumulative variance in principal component analysis (FWN: fruit weight per section, PLH: plant height, STD: stem diameter, WFY: fresh fruit yield, DFY: dry

fruit yield, NI: number of internodes, FD: fruit diameter, FL: fruit length, NF: number of fruits, Cha: chlorophyll a, Chb: chlorophyll b, Ch: total chlorophyll)

The first group consists of okra crops grown alongside greenhouse cucumbers of the Mirsoltan variety, as well as okra paired with Emilie variety greenhouse cucumbers. The second group involves okra cultivation with Nagin variety greenhouse cucumbers, along with okra paired with CUB-9045, Mito, and CUB-9042 varieties of greenhouse cucumbers. The third group includes okra crops grown alongside FC-27 and FC-21 variety greenhouse cucumbers. Lastly, the fourth group comprises okra cultivation with Viola greenhouse cucumbers as well as okra paired with Nagin greenhouse cucumbers. In this grouping, the first group exhibited positive coefficients in relation to the first and second components (Figure 5). In 2019, Dos Santos et al. and in 2020, Bajtor et al. utilized the distribution chart of treatments based on the first and second principal components to assess the characteristics and distribution of the evaluated treatments (Dos Santos et al., 2019, Bojtor et al., 2020).

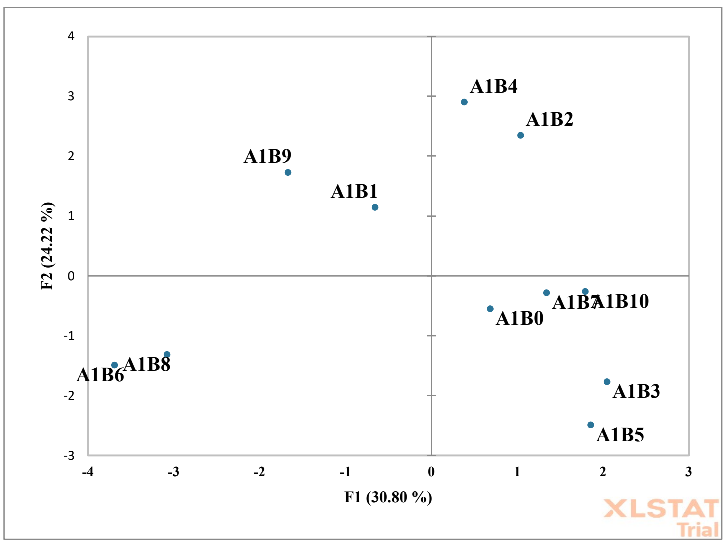


Figure 5 Distribution value of okra: cucumber mixed crops based on the first and second principal components

Land equality ratio

When the land equality ratio (LER) equals 1, it indicates that the yield of mixed crops and monoculture is the same. LER values greater than 1 suggest the usefulness of mixed cultivation, while LER values less than 1 indicate the unprofitability of mixed cultivation (Dhima et al., 2007). The results from various treatment combinations showed that in the first year of the experiment, okra crops paired with greenhouse cucumber varieties Viola, Mirsoltan, Emilie, CUB-9042, CUB-9045, and FC-27 were more beneficial. In the second year, okra crops paired with greenhouse cucumber varieties Mirsoitn, Emilie, CUB-9042, CUB-9045, and Nagin were found to be beneficial. On average, across both years, okra crops paired with greenhouse cucumber varieties Viola, Mirsoltan, Emilie, CUB-9042, and CUB-9045 were more beneficial than pure cultivation.

The highest LER values observed during the experimental years were for okra cultivation with greenhouse cucumber varieties FC-27 (1.36), A1B5 (1.19), and Emilie (1.16).

By analyzing the various years of the experiment, it is feasible to determine that okra paired with greenhouse cucumber Mirsoltan, okra paired with greenhouse cucumber Emilie, okra paired with cucumber CUB-9042, and okra paired with cucumber CUB-9045 were chosen as the most advantageous crops in terms of land equality ratio (LER). Previous studies have reported physiological and morphological differences, as well as higher LER, in mixed cropping systems involving potato and beans (Nasrollahzadeh et al., 2012) and sunflower and beans (Hamzei and Babaei, 2017).

Table 6 The beneficial effect of different cultivation combinations on the efficiency of mixed culture of okra: cucumber

	A1B1	A1B2	A1B3	A1B4	A1B5	A1B6	A1B7	A1B8	A1B9	A1B10
Year 1	**1.14**	**1.03**	**0.9**	**1.04**	**1.1**	**1**	**1.5**	**1.36**	**0.6**	**0.99**
Year 2	**0.96**	**1.04**	**0.73**	**1.3**	**1.19**	**0.92**	**1.06**	**0.63**	**1.18**	**0.94**
Mean of year 1 and 2	**1.05**	**1.03**	**0.81**	**1.16**	**1.14**	**0.96**	**1.11**	**0.99**	**0.89**	**0.97**

CONCLUSION

In this research, several favorable cultivars of okra were identified through mean comparison. These include okra cultivated with the greenhouse cucumber cultivar Viola, okra cultivated with the greenhouse cucumber cultivar FC-21, okra cultivated with the greenhouse cucumber cultivar Emilie, and okra cultivated with the greenhouse cucumber cultivar FC-27. The investigation also involved graphic analysis, correlation, main components, and land equality ratio. Based on these analyses, it was determined that cultivating okra with the Mirsoltan variety of greenhouse cucumber, Viola variety okra with Viola variety greenhouse cucumber, and Emilie variety greenhouse okra cultivation were selected as crops that are highly useful and desirable in terms of yield and all the quantitative traits evaluated in this study.

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