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Diversity of Sweet Corn Canopy Architecture for Intercropping Pattern Suitability with Cayenne Pepper

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Abstract

The intercropping system has become increasingly important due to the limited availability of agricultural land. Sweet corn is one of the potential crops for intercropping; however, its compatibility with companion plants varies among genotypes. This study analyzed the canopy diversity of 10 sweet corn genotypes and their impact on temperature, humidity, and light intensity. The research was conducted at the Pasir Kuda Experimental Station, Bogor Agricultural University, from June to August 2024, using ten hybrid sweet corn genotypes in a randomized complete block design with three replications. Each genotype was planted in plots measuring 3.75 m², with a 25 cm × 75 cm spacing, resulting in 30 plants per bed. Principal component analysis (PCA) and hierarchical analysis identified three clusters of genotypes based on ten morphological traits. The first cluster included “Verona”, “Talenta”, “Paragon”, SM12 x SB13, “Exotic”, and “Secada”. The second cluster consisted of “Arinta”, SB8 x SM6, and SM12 x SM1, while the third cluster included SM1 x SM9. Temperature and humidity measurements revealed significant differences among clusters, influencing photosynthetic efficiency and yield potential. Denser canopies exhibited lower temperatures, higher humidity, and reduced light intensity, whereas more open canopies displayed higher temperatures, lower humidity, and increased light intensity. The study also analyzed cob weight, length, and diameter, as well as critical factors for yield potential and photosynthetic efficiency. Based on the results, genotypes with denser canopies from cluster one (“Verona”, “Talenta”, “Paragon”, SM12 x SB13, “Exotic”, and “Secada”) are recommended for intercropping with cayenne peppers due to their favourable microclimate compatibility.

Keywords: cultivation, genotype, growth, shade stress

Introduction

Intercropping is a form of mixed cropping, also known as polyculture, that involves cultivating two or more plant species in the same area simultaneously (Paut et al., 2024). This practice aims to optimize land use in the intensification process (Tripathi et al., 2021). The advantages of intercropping systems include utilizing empty spaces between main crops, increasing total productivity per unit area through more efficient use of light, water, and nutrients, as well as reducing the risk of crop failure and suppressing weed growth (Xu et al., 2020). The success of intercropping depends on factors such as selecting plant species with different morphological traits, growth factor requirements, and growth phase durations (Li et al., 2022; Paut et al., 2024).

Intercropping can be more beneficial when the right combination of crops, superior varieties, and appropriate planting distances are used (Alemayehu et al., 2017; Raza et al., 2019). A favorable combination in intercropping systems involves pairing short plants with tall plants, allowing more efficient light distribution (Liu et al., 2018; Evers et al., 2019). Previous studies have also demonstrated that low light intensity or shading can impact plant growth and development, resulting in reduced yield and quality (Siahaan et al., 2023). Insufficient light intensity in cultivation systems can disrupt plant metabolism and decrease productivity. Shading above 50% has been reported to reduce the quantity and weight of marketable tomatoes and lower chili yields (Masabni et al., 2016).

Several crops commonly cultivated by farmers include sweet corn and cayenne pepper (Alemayehu et al., 2017; Indriani et al., 2020), corn and soybeans (Xu et al., 2020), and corn and peanuts (Li et al., 2022). Intercropping systems involving corn and these crops are highly suitable due to the compatibility of tall and short plants in such arrangements (García-Gaytán et al., 2017).

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One way to enhance the productivity of sweet corn in intercropping systems is using superior varieties or the development of high-yielding varieties (Ahmad et al., 2015; Kartahadimaja and Syuriani, 2021). Superior sweet corn varieties can be hybrid or open-pollinated. Hybrid varieties generally have higher yield potential than open-pollinated varieties due to the heterosis effect resulting from the genes that constitute hybrid corn (Sirih et al., 2021). The productivity of hybrid and open-pollinated varieties is influenced by their adaptability, which depends on the selection process used to develop them.

Researchers at Bogor Agricultural University have conducted crosses to develop high-yielding sweet corn varieties, producing numerous genotypes (Azrai et al., 2022). Further evaluations of these genotypes by previous researchers have shown significant diversity. Comparisons between commercial hybrid varieties and genotypes from crosses reveal that leaf length, width, number, and plant height are generally greater in commercial corn varieties than in the crossed genotypes (Susanti et al., 2023; Utari et al., 2023). On the other hand, research has been conducted to assess the shade tolerance levels of 20 cayenne pepper genotypes as a companion crop component in intercropping systems. The findings revealed that one genotype was shade-sensitive, five genotypes exhibited moderate tolerance, 5 genotypes were shade-tolerant, and nine genotypes were shade-loving (Siahaan et al., 2023).

Examining the suitability of intercropping patterns between various sweet corn genotypes and cayenne pepper is closely related to the microclimate generated by the intercropping system. The diversity of sweet corn canopies creates variations in microclimatic conditions that can influence the growth and yield of cayenne pepper plants. Therefore, further research is necessary to observe the canopy diversity of different hybrid sweet corn genotypes and their impact on the resulting microclimate. This study aims to explore the most promising intercropping patterns for establishing an optimal microclimate that supports the growth and productivity of companion crops, with specific recommendations regarding their suitability for cayenne pepper based on the research findings.

Materials and Methods

Genetic Materials and Field Conditions

This study's genetic materials comprised four commercial sweet corn varieties and six hybrid sweet corn genotypes derived from crosses conducted at the Plant Breeding Laboratory, Department of Agronomy and Horticulture, IPB University (Table 1). The field research was conducted from June to August 2024 at the Pasir Kuda experimental field (6°36'31.7"S, 106°47'3.26"E) at IPB University. The study employed a completely randomized block design with a single factor comprising 10 hybrid sweet corn genotypes with three replications. The hybrid sweet corn was planted in 10 raised beds, each representing a different genotype, with a total experimental area of 193.5 m².

Procedures

The study began with preparing 10 raised beds, each measuring 1 m × 11.25 m, for each sweet corn genotype. Each bed consisted of three replications, with plot sizes of 3.75 m². A spacing of 80 cm was maintained between the beds to facilitate management practices such as irrigation, fertilization, weeding, and pesticide application. Initial treatments included the application of 1 ton.ha^{-1} of manure and 2 tons.ha^{-1} of dolomite.

The planting distance in this study was set at 25 cm × 75 cm, where 25 cm refers to the spacing between

Table 1. List of sweet corn genotypes

No	Genotypes	Owner Agency
G1	"Exotic"	Hybrid commercial variety (Agri Makmur Pertiwi Company)
G2	"Paragon"	Hybrid commercial variety (Agri Makmur Pertiwi Company)
G3	SM12-2-13 x SB13-12b-16	Hybrid lines (Breeding Laboratory, IPB University)
G4	"Talenta"	Hybrid commercial variety (Agri Makmur Pertiwi Company)
G5	"Secada"	Hybrid commercial variety (East Seed Indonesia Company)
G6	SB8-4-3 x SM6-3-1	Hybrid lines (Breeding Laboratory, IPB University)
G7	SM12-2-13 x SM1-1-9	Hybrid lines (Breeding Laboratory, IPB University)
G8	"Arinta"	Hybrid lines (Breeding Laboratory, IPB University)
G9	"Verona"	Hybrid lines (Breeding Laboratory, IPB University)
G10	SM1-1-9 x SM9-3A-1	Hybrid lines (Breeding Laboratory, IPB University)

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plants within a row, and 75 cm refers to the spacing between rows. Each experimental unit measured 1.5 m × 3.75 m (totaling 5.625 m²), consisting of two planting rows per bed. Each row contained 15 plants in this arrangement, achieved by dividing the row length (3.75 m) by the within-row spacing (25 cm). With two rows in each bed, the total number of plants per bed was 30. This layout was designed to ensure uniform spacing for optimal growth and to facilitate accurate microclimate measurements under different canopy structures.

Maintenance included irrigation every two days without rain, manual weeding conducted up to three times before harvest, and fertilization with 300 $kg.ha^{-1}$ of NPK. Fungicides and insecticides were applied as needed, based on the intensity of pests and diseases.

Microclimate Data

Microclimate recordings were conducted using an Elitech RC-4HC Data Logger to record temperature and humidity data installed in each raised bed. The Elitech RC-4HC was positioned under the corn canopy at a height of 30 cm above the soil surface. Light intensity data were measured manually using a Digital Lux Meter LX1010B, placed beneath the corn canopy. The Elitech RC-4HC Data Logger and Digital Lux Meter LX1010B were moved weekly across replications to ensure more accurate data collection.

Microclimate data were recorded at 7:30 AM, 12:30 PM, and 4:30 PM, at 7-day intervals, starting 5 weeks after planting. These specific times were selected to capture the diurnal variations in temperature, humidity, and light intensity, which fluctuate significantly throughout the day. Morning measurements reflect the initial environmental conditions after sunrise, midday measurements capture peak solar radiation and heat accumulation, while afternoon measurements indicate the declining phase of these variables. This approach ensures a comprehensive understanding of microclimate dynamics under the corn canopy.

Growth, Biomass, and Yield Variable Measurements

The measured growth variables included plant height (cm), measured from the soil surface to the tip of the highest leaf using a measuring tape, leaf number, manually counted on each plant; leaf length (cm) and leaf width (cm), measured using a ruler from the leaf base to the tip and at the broadest part of the leaf, respectively. The axillary angle (AA) (°) was measured using a protractor, determining the angle formed between the main stem and the leaf sheath at the point of emergence.

Destructive characteristics included the leaf area index (LAI), a unitless value calculated as the ratio of total leaf area (m²) to land area (m²), measured using a leaf area meter. The Relative Growth Rate (RGR) ($g.g^{1}$ per day) was calculated based on changes in dry biomass over a given period. The Net Assimilation Rate (NAR) ($g.m^{-2}$ per day) was determined by dividing the increase in biomass by the leaf area and the time interval. The leaf area ratio (LAR) ($cm^2.g^{-1}$) was calculated by dividing the total leaf area by the plant's dry biomass. The Specific Leaf Area (SLA) ($cm^2.g^{-1}$) was determined by dividing the leaf area by the dry leaf mass. All these destructive traits were measured eight weeks after planting.

Physiological observations were conducted visually and included the time to male flowering (in days), measured from planting until tassel emergence; the time to female flowering (in days), recorded from planting until silk emergence; and the harvest time (in days), measured from planting until the plants reached physiological maturity.

Yield-related characteristics included the number of ears per plant, manually counted; ear weight with husk (CWH) (g), measured using a digital scale; ear weight without husk (CWoH) (g), measured after husk removal; husk weight (HW) (g), calculated as the difference between CWH and CWoH; ear diameter (CD) (cm), measured at the widest point using a caliper; and ear length (CL) (cm), measured from the base to the tip of the ear using a ruler.

The primary traits for principal component analysis (PCA) and agglomerative hierarchical clustering (AHC) analyses include plant height, leaf number, leaf length, leaf width, leaf area index (LAI), relative growth rate (RGR), net assimilation rate (NAR), leaf area ratio (LAR), specific leaf area (SLA), and axillary angle (AA). These traits were selected due to their influence on the maize canopy and the surrounding microclimate.

Data Analysis

The data were analyzed using analysis of variance (ANOVA). If significant differences were found, an Honestly significant difference (HSD) test was conducted at the 5% level using PKBT Stat 3.1 (http://pbtstat.com/pkbt-stat/). Pearson's correlation test assessed the strength of the linear relationship between characteristics. Hierarchical cluster analysis (HCA) was conducted to examine the similarities and differences among the 10 hybrid sweet corn genotypes using Microsoft Excel and RStudio v.9.0 software. Principal component analysis (PCA) was applied to summarize and describe the inherent

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genetic variation in the maize genotypes based on the selected main canopy traits. The PCA was performed using the Star software by the International Rice Research Institute (IRRI) (http://bbi.irri.org/products).

Results and Discussion

Principal Component Analysis

To examine the influence of each character on the variation among genotypes, a principal component analysis was performed on 10 canopy traits of sweet corn (Table 2). Of the three principal components generated, the first and second principal components showed eigenvalues greater than 1.0. This indicates that these two components contributed the most to the existing variance, with their proportional variation accounting for 83.5% of the genetic variation among the genotypes (Rosmaina et al., 2022). The first principal component, PC1, with an eigenvalue of 6.01, contributed 60.13%, while the second principal component, PC2, with an eigenvalue of 2.34, contributed 23.46% (Table 2).

In PC1, the characters with the highest absolute loading values were axillary angle (-0.931), leaf length (0.859), leaf area index (0.859), and specific leaf area (-0.831). In PC2, the characters with the highest absolute contributions were net assimilation rate (-0.798), leaf area ratio (0.663), and leaf width (0.639). With the highest absolute loading values, these characters could serve as key traits for selecting sweet corn varieties (Peter 2022). These traits, including leaf length, leaf area index, specific leaf area, and leaf width, will be considered primary selection traits for sweet corn genotypes (Tuhina-Khatun et al., 2015).

Agglomerative Hierarchical Clustering (AHC) Analysis

Figure 1 illustrates the results of hierarchical clustering analysis, presented as a dendrogram that divides the 10 sweet corn genotypes into three main clusters. This division is based on the similarity of the measured morphological characteristics. Each cluster in the Agglomerative Hierarchical Clustering (AHC) method is represented as a dendrogram, showing each case's hierarchical structure. This hierarchical structure is a descriptor matrix with n x n dimensions (Jafarzadegan et al., 2019). The matrix represents the relative distance between cases in the dendrogram. Several approaches can be used to create the descriptor matrix, such as partition membership divergence (PMD), sub-dendrogram membership divergence (SMD), cluster membership dendrogram (CMD), cophenetic difference (CD), and maximum number of edge distance (MNED). PMD displays the number of clusters in the dendrogram, where two specific cases are not grouped in the same cluster. SMD indicates the number of sub-dendrograms missing for two specific cases. CMD shows the number of cases in the nearest cluster that contains the two specific cases. CD indicates the height of the closest cluster that connects two specific cases. MNED represents the cluster level at which two specific cases are connected (Li et al., 2022).

Based on the cluster analysis, the ten genotypes tested are divided into three main groups. Cluster

Table 2. Principal component analysis for 10 canopy traits in 10 sweet corn genotypes

Character	PC1	PC2	PC3
Axillary angle	-0.931	-0.099	0.085
Leaf area index	0.859	0.478	-0.001
Leaf number	0.812	0.133	-0.269
Leaf length	0.869	0.417	-0.051
Leaf width	0.669	0.639	-0.167
Plant height	0.688	-0.363	0.567
Specific leaf area	-0.831	0.510	-0.001
Leaf area ratio	-0.666	0.663	0.290
Relative growth rate	0.797	0.191	0.415
Net assimilation rate	-0.798	-0.798	-0.134
Standard deviation	2.452	1.531	0.841
Proportional variation	0.601	0.234	0.070
Cumulative proportion	0.601	0.835	0.906
Eigenvalue	6.013	2.345	0.707

Notes: PC1 is the first principal component; PC2 is the second principal component; PC3 is the third principal component.

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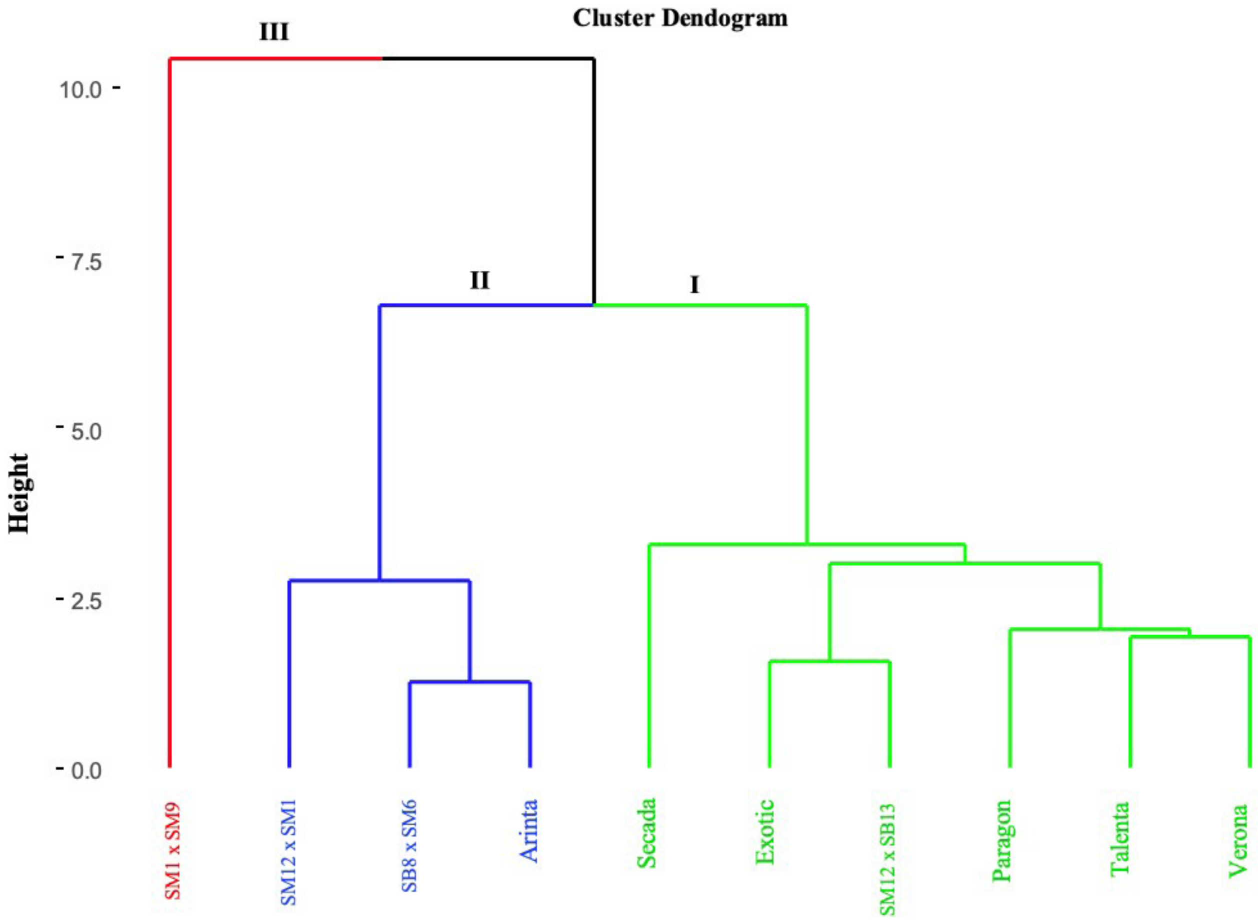

Figure 1. Dendrogram of 10 hybrid sweet corn genotypes based on 10 corn canopy characteristics

I comprises the genotypes “Verona,” “Talenta,” “Paragon,” SM12 x SB13, “Exotic,” and “Secada.” Cluster II comprises the genotypes “Arinta,” SB8 x SM6, and SM12 x SM1, while cluster III contains only SM1 x SM9.

The genotypes in cluster I tend to have superior characteristics in terms of leaf length (LL), leaf width (LW), and leaf area index (LAI) (Table 3). This cluster shows a combination of genotypes with larger canopy sizes and broader, longer leaves (Feng et al., 2016). Additionally, the genotypes in this cluster generally have smaller axillary angles (AA) than those in other clusters, indicating more upright leaves. The high LAI also suggests that the genotypes in this cluster have dense canopies, which can maximize sunlight capture, particularly under high-density planting conditions (Feng et al., 2016).

Cluster II consists of genotypes that have relatively uniform characteristics in terms of leaf number (LN), leaf area index (LAI), and leaf length (LL), but with relatively higher axillary angles compared to cluster I, particularly in the “Arinta” genotype (35.78°). This suggests that the leaves of genotypes in cluster II are more likely to be lateral or slightly drooping than the cluster I genotypes. The genotypes in this cluster also have lower LAI values, indicating smaller leaf area indices, resulting in lower light capture efficiency than genotypes in cluster one (Liu et al., 2024).

Cluster III, which consists of the single genotype SM1 x SM9, exhibits distinctly different characteristics from the other genotypes, particularly in its very high axillary angle (AA) of 48.67°. This high axillary angle suggests that the leaves of this genotype tend to droop more than those of the other genotypes, which have lower angles. This genotype has the highest specific leaf area (SLA) value (243.91 $cm^2.g^{-1}$), which also influences its placement in a separate cluster. The more open canopy in Cluster III allows each leaf to receive more direct sunlight, which may be advantageous in environments with limited sunlight. However, this structure can result in inefficient light interception for the lower leaves, especially in intercropping systems where companion plants depend on sufficient light penetration. Additionally, it may lead to suboptimal land use under high planting densities, increasing the risk of moisture loss and evaporation (Liu et al., 2023).

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Generative Growth of 10 Sweet Corn Genotypes

Genotypes such as “Verona”, “Paragon”, SM12 x SB13, “Exotic”, and “Secada” exhibit nearly the same male and female flowering times, with a relatively short interval between these two phases (Table 4). Their male flowering time ranges from 51.67 to 52.67 days, while the female flowering time for these genotypes is also very close, ranging from 54.67 to 56.33 days. This pattern suggests that these genotypes exhibit good synchronization between the male and female flowering phases, typically a key indicator of high productivity, especially under dry environmental conditions such as drought (Kinyua et al., 2023). Furthermore, the harvest age for these genotypes also falls within a similar range, from 71.33 to 74.67 days. This suggests that these genotypes have a relatively consistent life cycle, albeit with a slightly more extended harvest period than others.

In contrast, genotypes such as “Talenta” and “Arinta” exhibit longer male and female flowering periods, especially with “Talenta”, which has a male flowering time of 44 days and a female flowering time of 47.67 days. However, their harvest age is faster than several other genotypes, ranging from 68.67 to 69.33 days.

Table 3. Canopy characteristics of 10 sweet corn genotypes

Genotype	Canopy characteristics									
	Axillary angle (°)	Leaf area index	Leaf number	Leaf length (cm)	Leaf width (cm)	Plant height (cm)	Specific leaf area ($cm^2.g^{-1}$)	Leaf area ratio $cm^2.g^{-1}$)	Relative growth rate (g per day)	Net assimilation rate ($g.cm^{-2}$ per day)
“Verona”	25.78^{def}	3.64^{a}	11.44^{ab}	98.20^{ab}	13.23^{a}	198.18^{bc}	158.71^{b}	44.48^{bc}	0.10^{ab}	0.33^{ab}
“Talenta”	26.89^{de}	3.17^{b}	11.22^{bc}	95.77^{abc}	10.23^{cde}	196.74^{bc}	168.35^{b}	45.07^{bc}	0.10^{a}	0.34^{a}
“Paragon”	23.89^{f}	3.61^{ab}	11.00^{bc}	97.17^{ab}	11.10^{bc}	202.64^{abc}	192.20^{ab}	52.52^{bc}	0.09^{ab}	0.32^{ab}
SM12 x SB13	24.78^{ef}	3.47^{ab}	12.22^{ab}	94.87^{abc}	10.70^{bcd}	203.00^{abc}	155.90^{b}	42.30^{bc}	0.09^{ab}	0.34^{a}
“Exotic”	27.44^{d}	3.35^{ab}	12.56^{a}	99.30^{ab}	11.77^{ab}	184.80^{cd}	167.34^{b}	45.34^{bc}	0.09^{bc}	0.33^{ab}
“Secada”	28.11^{d}	3.70^{a}	12.00^{ab}	104.07^{a}	11.93^{ab}	226.42^{a}	158.12^{b}	54.58^{ab}	0.10^{a}	0.31^{ab}
“Arinta”	35.78^{b}	2.57^{c}	11.00^{bc}	90.00^{bcd}	9.43^{de}	203.40^{abc}	153.58^{b}	39.47^{c}	0.08^{d}	0.34^{a}
SB8 x SM6	30.56^{c}	2.51^{c}	11.11^{bc}	87.00^{cd}	9.40^{de}	210.28^{ab}	147.58^{b}	38.25^{c}	0.08^{cd}	0.37^{a}
SM12 x SM1	32.56^{c}	2.67^{c}	11.33^{ab}	85.33^{d}	9.13^{e}	223.89^{a}	153.47^{b}	44.80^{bc}	0.10^{ab}	0.35^{a}
SM1 x SM9	48.67^{a}	1.84^{d}	10.00^{c}	75.47^{e}	8.83^{e}	161.32^{d}	243.91^{a}	68.58^{a}	0.07^{d}	0.28^{b}
Sig.	**	**	**	**	**	**	**	**	**	**

Notes: Values followed by the same letter in the same column for each character indicate no significant difference in the HSD test at the 5% level; ** = significant at the 1% level; tn = not significant.

Table 4. Generative growth of 10 hybrid sweet corn genotypes

Genotypes	Generative characters		
	Male flowering time	Female flowering time	Harvest time
“Verona”	52.33^{a}	55.33^{a}	73.33^{abc}
“Talenta”	44.00^{d}	47.67^{c}	68.67^{f}
“Paragon”	52.33^{a}	56.00^{a}	73.67^{ab}
SM12 x SB13	52.67^{a}	55.33^{a}	74.67^{a}
“Exotic”	52.00^{a}	54.67^{a}	72.67^{abcd}
“Secada”	51.67^{a}	56.33^{a}	71.33^{cde}
“Arinta”	45.67^{cd}	47.00^{cd}	69.33^{ef}
SB8 x SM6	45.33^{cd}	45.33^{d}	71.00^{de}
SM12 x SM1	47.67^{bc}	51.33^{b}	70.67^{def}
SM1 x SM9	49.67^{ab}	51.67^{b}	71.67^{bcd}
Sig.	**	**	**

Notes: values followed by the same letter in the same column for each characteristic indicate no significant difference according to the HSD test at the 5% level, ** = significant at the 1% level, ns = not significant.

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This indicates that “Talenta” and “Arinta” may require less time to adapt to drought stress before reaching the optimal harvest phase. The time between the emergence of male and female flowers can affect fruit yield. This is consistent with research by Sa’adah et al. (2022), which states that a prolonged time gap between the emergence of male and female flowers in maize plants results in the inability to pollinate the ear silks, as the amount of pollen produced may decrease or run out, thus affecting the seed filling process in the ears.

The genotype SM1 x SM9 occupies a unique position. It is characterized by relatively short male and female flowering times, yet has a harvest age approaching that of genotypes with good synchronization, such as “Exotic”. This suggests that although this genotype reaches the generative phase more quickly, it requires a slightly extended period to reach the harvest phase after flowering.

Yield Performance of Hybrid Sweet Corn

The productivity results indicate that the “Secada” genotype exhibits the most significant advantages in all aspects of production (Table 5). “Secada” recorded the highest cob weight with husk, at 553.33 g, emphasizing that this genotype can maximize the existing climatic conditions to enhance plant productivity. Additionally, its cob weight without the husk is also the highest, reaching 388.33 g, indicating high production efficiency once the husk is removed. “Secada” also has the largest cob length and diameter, demonstrating its ability to produce large and dense cobs, a characteristic of plants that adapt well to drought conditions. Previous studies have demonstrated that low light intensity significantly impacts plant growth, photosynthesis, and sugar translocation, leading to reduced nitrogen accumulation, dry matter, grain yield, and corn quality (Gao et al., 2020; Liang et al., 2020; Waqas et al., 2019).

In contrast, the SM1 x SM9 genotype performed the worst across all parameters. Its cob weight with husk was only 245.00 g, significantly lower than that of other genotypes, and its cob weight without husk was also the lowest, indicating that it produced fewer seeds compared to all other genotypes. The cob length of only 13.70 cm and its small diameter of 41.47 mm further reinforced the indication that this genotype could not produce optimal cobs under drought stress. This is due to genetic weaknesses that hinder the genotype’s ability to absorb or utilize water and nutrients efficiently under dry conditions. This finding aligns with research conducted by Fitrah et al. (2022), which reported that maize cob length in environments with limited light results in a decrease and variation in average cob length among the tested strains.

Other genotypes, such as “Exotic” and “Paragon”, showed better results compared to SM1 x SM9 but not as good as “Secada”. These two genotypes had relatively high cob weights with husk, 485.00 g and 518.33 g, respectively, and cob lengths close to those of “Secada”, although still below them in terms of overall production efficiency. This suggests that while “Exotic” and “Paragon” are reasonably well-adapted to drought conditions, they are still less efficient than

Table 5. Yield components of 10 hybrid sweet corn genotypes

Genotypes	Yield				
	Cob weight with husk (g)	Husk weight (g)	Cob weight without husk (g)	Cob length (cm)	Cob diameter (mm)
“Verona”	375.00[c]	101.67[bc]	273.33[cd]	21.33[b]	49.13[cd]
“Talenta”	416.67[c]	130.00[abc]	286.67[cd]	18.77[c]	50.17[ab c]
“Paragon”	518.33[ab]	153.33[ab]	365.00[ab]	21.33[b]	50.10[abc]
SM12 x SB13	396.67[c]	130.00[abc]	266.67[cd]	16.90[d]	48.70[d]
“Exotic”	485.00[b]	170.00[a]	315.00[bc]	22.13[ab]	50.47[ab]
“Secada”	553.33[a]	165.00[a]	388.33[a]	23.00[a]	50.90[a]
“Arinta”	403.33[c]	111.67[abc]	291.67[cd]	19.03[c]	49.63[bcd]
SB8 x SM6	405.00[c]	128.33[abc]	276.67[cd]	19.20[c]	49.70[bcd]
SM12 x SM1	358.33[c]	120.00[abc]	238.33[d]	16.77[d]	45.23[e]
SM1 x SM9	245.00[d]	73.33[c]	171.67[e]	13.70[e]	41.47[f]
Sig.	**	**	**	**	**

Notes: values followed by the same letter in the same column for each characteristic indicate no significant difference according to the HSD test at the 5% level; ** = significant at the 1% level, ns = not significant.

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"Secada" in utilizing limited resources.

Microclimate Data

Based on microclimate observations, the genotypes in Cluster I create relatively lower temperatures beneath the canopy compared to the other two clusters, with temperatures ranging from 31.35°C to 33.33°C and an average temperature of 32.41°C (Figure 2). Additionally, the humidity generated by the canopy of genotypes in this cluster tends to be higher, ranging from 51.13% to 61.88%, with an average humidity of 59.29%. The recorded light intensity in Cluster I is 34,392 lux, approximately 59.5% of the light intensity outside the maize canopy. These findings suggest that this cluster's genotypes effectively create a cooler and more humid microenvironment beneath the canopy.

In Cluster II, the Leaf Area Index (LAI) is more moderate, lower than that of Cluster I but higher than that of Cluster III, resulting in a more balanced microclimate. The daytime temperatures in this cluster range from 33.70°C to 33.87°C, with an average of 33.78°C, which is higher than in Cluster I but still lower than in Cluster III. Cluster II's humidity is also lower than Cluster I's, ranging from 46.55% to 48.78%, with an average of 47.32%. A lower LAI, combined with more moderate leaf dimensions in length and width, allows more light to penetrate the canopy, creating conditions more suitable for companion plants that require greater light exposure (Stiegel et al., 2017). The light intensity recorded in this cluster ranges from 43,283 lux to 47,633 lux, with an average of 45,744 lux, equivalent to 46.1% of the light intensity outside the maize canopy.

Meanwhile, the SM1 x SM9 genotype in Cluster III exhibits a more open canopy structure than the Clusters I and II genotypes. This structure allows for greater light penetration to the soil surface, leading to higher daytime temperatures of up to 34.47°C and lower humidity levels of 43.40%. These conditions suggest that the canopy in Cluster III is less effective at blocking light, allowing more sunlight to reach the soil surface, which increases temperature and decreases humidity compared to the other clusters. The light intensity penetrating the canopy in Cluster III reaches 56,883 lux, approximately 33.3% of the light intensity outside the maize canopy. These findings suggest that a more open canopy structure, as observed in the SM1 x SM9 genotype, may offer potential benefits in intercropping systems, particularly for companion plants that require higher light intensities. However, it is important to note that excessive light penetration can significantly increase temperature and reduce humidity beneath the canopy. Therefore, balancing companion plants' light requirements with the microclimate's stability is essential to optimize the intercropping system's outcomes (Ferrante and Mariani, 2018).

The Prediction of Intercropping Patterns for Sweet Corn

Based on the cluster divisions obtained from the observed canopy characteristics, several clusters can serve as a reference for predicting the intercropping patterns of sweet corn with companion plants. Adequate light is crucial for optimal growth of horticultural plants, but excessive direct sunlight exposure can lead to suboptimal development (Pascale et al., 2022). Low humidity causes a high vapor pressure deficit, which can lead to water stress on leaves, decreased stomatal conductance and photosynthesis, flower drop, as well as a reduction in the number of fruits per plant, fruit weight, uniformity, and production (Shafiq et al., 2021). High temperatures and radiation often cause spots or lesions on vegetable fruits.

Siahaan et al. (2023) studied 20 chili genotypes and found that one genotype was sensitive to shading, five were tolerant, five were moderately tolerant, and nine grew well under shaded conditions. The study found that at temperatures between 28-34°C, with average humidity between 54-68% and average light intensity below 23,000 lux, these conditions were generally suboptimal for chili plant growth. The optimal light intensity for chili plant growth is reported to be between 35,000 and 50,000 lux (Samanta and Hazra, 2019). Under shaded conditions, the microclimate changes significantly. Light intensity decreases with increasing shade levels, reducing the amount of Photosynthetically Active Radiation (PAR), which can potentially disrupt plant growth (Wang et al., 2022). However, at certain levels, shading can have a positive impact on plant growth and enhance productivity (Jeeatid et al., 2017; Pascale et al., 2022). A 50% shading treatment with a maximum light intensity of 50,812 lux, temperature of 32.33°C, and humidity of 60.46% can increase chili production per plant in shade-loving genotypes by up to 36%. Conversely, other genotypes showed a relative yield reduction of 44% in sensitive genotypes, 33% in moderate genotypes, and 4% in tolerant genotypes under 50% shading (Siahaan et al., 2023).

In Cluster I, which consists of the genotypes "Verona", "Talenta", "Paragon", SM12 x SB12, "Exotic", and "Secada", the average light intensity generated is 34,392 lux, with an average humidity of 59.29% and a temperature of 32.41°C. Meanwhile, in Cluster II, which comprises the genotypes "Arinta", SB8 x SM6, and SM12 x SM1, the average light intensity is 45,744

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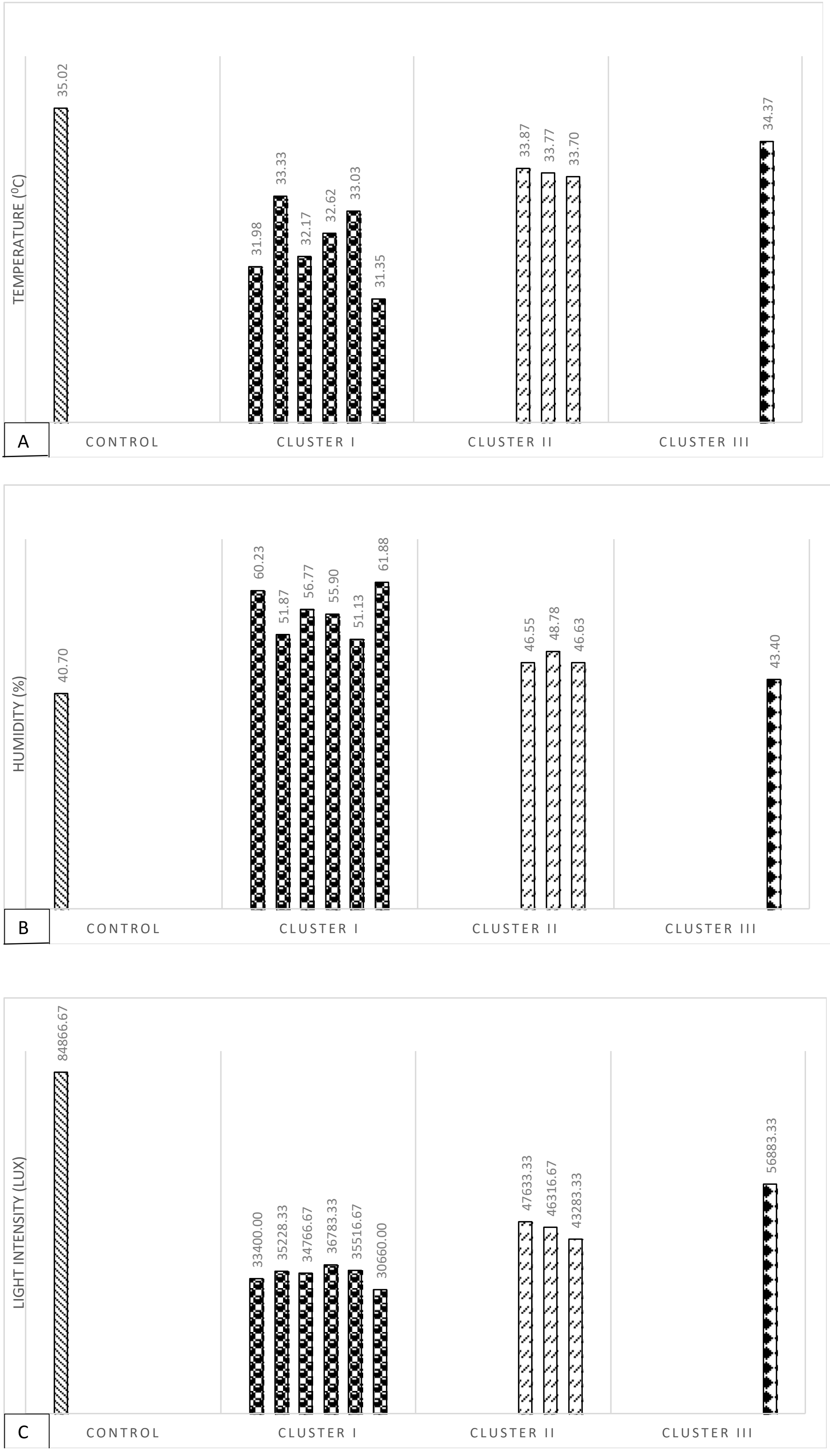

Figure 2. Microclimates data during the dry season: temperatures (A), humidity (B), and light intensity (C)

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lux, with a humidity of 47.32% and a temperature of 33.78°C. Finally, in Cluster III, which consists of only one genotype, SM1 x SM9, the light intensity is 56,883 lux, with humidity of 43.40% and temperature of 33.30°C.

Issukindarsyah et al. (2020) explained in their study that a 50% shading treatment with a light intensity of 32,000 lux increased the length of both orthotropic and plagiotropic branches by 68%, 54%, and 62%, respectively, in chili plants. The optimal light intensity for chili growth is 550 $\mu mol.m^{-2}.s^{-1}$, with higher air temperatures and light intensities promoting leaf development and growth (Kwack et al., 2021). Liu et al. (2016) also stated that plants will increase their leaf area by 55.4% under shaded conditions. Therefore, based on several studies, Cluster I and Cluster II can be recommended as suitable intercropping combinations with chili peppers during the dry season.

Conclusions

Based on the results of this study, it can be concluded that there are differences in growth, canopy shape, and size among the 10 hybrid sweet corn genotypes tested. Additionally, the diversity of microclimates generated by these genotypes formed three clusters, each showing different microclimate characteristics. Considering the suitability of intercropping patterns, particularly to sweet corn productivity and the compatibility of the microclimate with companion plants, corn with a denser canopy type, as observed in cluster one (“Verona”, “Talenta”, “Paragon”, SM12 x SB12, “Exotic”, and “Secada”), is recommended for intercropping with cayenne peppers.

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