Seasonal Variations in the Growth Performance and Food Quality of Cucumber Varieties in Ranchi

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Abstract

Abstract: Cucumber (Cucumissativus L.) is an important vegetable crop cultivated in Ranchi, Jharkhand, India. This study aimed to evaluate the seasonal variations in the growth performance and food quality of different cucumber varieties grown in the region. Ten cucumber varieties, including both hybrid and open-pollinated cultivars, were evaluated during two growing seasons: summer and rainy. The study assessed various growth parameters, yield components, and phytochemical content of the cucumber fruits. Significant varietal differences and seasonal variations were observed in the growth, yield, and nutritional quality of the evaluated cucumber varieties. The hybrid varieties, particularly #CS4 (SHEETAL), #CS7 (F1SAGAR), and #CS1 (SUMMER), exhibited superior growth and yield performance compared to the open-pollinated varieties. The local variety #CS8 (MOTI) showed unique phytochemical composition and adaptability to local conditions. The summer season favored higher fruit yields and better nutritional quality compared to the rainy season. The study highlights the importance of varietal selection and seasonal considerations for optimizing cucumber production and food quality in Ranchi. The findings can guide farmers, researchers, and policymakers in developing strategies for enhancing the productivity, profitability, and nutritional value of cucumber cultivation in the region.

Keywords: Cucumissativus L.; seasonal variation; growth performance; yield components; phytochemical content; Ranchi

1. Introduction

Cucumber (Cucumissativus L.) is a widely cultivated vegetable crop, valued for its refreshing taste, versatile culinary uses, and nutritional benefits [1]. In Ranchi, Jharkhand, India, cucumber plays a significant role in the agricultural economy, providing income opportunities for local farmers [2]. However, the productivity and quality of cucumber in the region are influenced by various factors, including the choice of cultivar and the prevailing environmental conditions during different growing seasons [3].

Varietal selection is a crucial aspect of cucumber production, as different varieties exhibit varying levels of adaptability, yield potential, and quality attributes [4]. In Ranchi, both hybrid and open-pollinated cucumber varieties are cultivated, each with its own advantages and limitations [5]. Hybrid varieties are known for their vigor, uniformity, and high yield potential, while open-pollinated varieties, including local landraces, are valued for their adaptability to local conditions and unique quality traits [6].

Seasonal variations in environmental factors, such as temperature, humidity, and rainfall, can significantly impact the growth, development, and quality of cucumber [7]. In Ranchi, cucumber is primarily grown during two seasons: summer (March to June) and rainy (July to October) [8]. Understanding the influence of seasonal variations on the performance of different cucumber varieties is essential for optimizing production and ensuring the availability of high-quality fruits throughout the year [9].

The food quality of cucumber, including its nutritional and phytochemical composition, is another important consideration for both producers and consumers [10]. Cucumber fruits are rich in vitamins, minerals, and bioactive compounds, such as phenolics and flavonoids, which contribute to their health-promoting properties [11]. However, the concentration of these phytochemicals can vary depending on the variety and the growing conditions [12].

Despite the importance of cucumber in Ranchi, there is limited information on the seasonal variations in the growth performance and food quality of different cucumber varieties grown in the region. Such information is crucial for guiding farmers in varietal selection, crop management, and harvest planning, as well as for researchers and policymakers in developing strategies for enhancing the productivity and nutritional value of cucumber cultivation in Ranchi [13].

Therefore, this study aimed to evaluate the seasonal variations in the growth performance and food quality of different cucumber varieties grown in Ranchi. The specific objectives were to:

1. Assess the varietal differences in growth, yield, and quality attributes of cucumber during summer and rainy seasons;
2. Determine the influence of seasonal variations on the phytochemical content and nutritional quality of cucumber fruits;
3. Identify the best-performing cucumber varieties for each growing season in Ranchi.

The findings of this study will provide valuable insights into the adaptability, productivity, and nutritional quality of cucumber varieties under different seasonal conditions in Ranchi. This information will assist farmers in making informed decisions regarding varietal selection and crop management, ultimately contributing to the sustainable development of cucumber cultivation in the region.

2. Materials and Methods

2.1. Experimental site and plant material

The field experiment was conducted at the campus of RLSY College, Kokar, Ranchi during two growing seasons: summer (March to June) and rainy (July to October) in 2021 and phytochemical analysis were done in lab of biochemistry of ICAR-Directorate of Rapeseed-Mustard Research Sewar, Bharatpur, Rajasthan.The experimental site has a subtropical climate with an average annual rainfall of 1400 mm, 75-80% of which is received during the rainy season [8].

Ten cucumber varieties, including both hybrid and open-pollinated cultivars, were evaluated in this study (Table 1). The varieties were selected based on their popularity among farmers, market demand, and adaptability to the agro-climatic conditions of Ranchi [5].

Table 1. Cucumber varieties evaluated in the study.

Variety code	Label no.	Variety name
#CS1	9509	SUMMER
#CS2	996266	HEMA
#CS3	52704	GREEN LONG
#CS4	15638	SHEETAL
#CS5	70582	SUMOSA

#CS6	9411	NINJA179
#CS7	2051	F1SAGAR
#CS8	697	MOTI
#CS9	9415	DAMINI
#CS10	8424	KAREENA

2.2. Experimental design and crop management

The experiment was laid out in a randomized complete block design with three replications. Each replication consisted of ten plots, corresponding to the ten cucumber varieties. The individual plot size was 3 m × 2 m, with a spacing of 50 cm between rows and 30 cm between plants.

The land was prepared by plowing and harrowing, followed by the application of farmyard manure at a rate of 20 t ha^{-1}. The seeds were sown directly in the field at a depth of 2-3 cm. Standard cultural practices, including irrigation, fertilization, and pest and disease management, were followed as per the recommendations for cucumber cultivation in Jharkhand [14].

2.3. Data collection

2.3.1. Growth and yield parameters

Data on growth and yield parameters were recorded from five randomly selected plants in each plot. The following parameters were measured:

1. Vine length (cm): The length of the main vine from the base to the tip was measured at 30 and 60 days after sowing (DAS).
2. Number of leaves per plant: The fully expanded leaves were counted at 30 and 60 DAS.
3. Days to first female flowering: The number of days from sowing to the appearance of the first female flower in each plot was recorded.
4. Number of fruits per plant: The total number of marketable fruits per plant was recorded at each harvest.
5. Average fruit weight (g): The weight of individual fruits was measured using a digital balance, and the average fruit weight was calculated.
6. Fruit yield per plant (kg): The total weight of marketable fruits per plant was recorded at each harvest.
7. Fruit yield per hectare (t ha^{-1}): The fruit yield per hectare was estimated based on the fruit yield per plant and the plant population per hectare.

2.3.2. Phytochemical analysis

Phytochemical analysis was performed on the fruit samples collected at the marketable maturity stage. The following phytochemical parameters were evaluated:

1. Total phenolic content (mg GAE/100 g FW): The total phenolic content was determined using the Folin-Ciocalteu method [15] and expressed as milligrams of gallic acid equivalents per 100 grams of fresh weight (mg GAE/100 g FW).
2. Total flavonoid content (mg QE/100 g FW): The total flavonoid content was estimated using the aluminum chloride colorimetric method [16] and expressed as milligrams of quercetin equivalents per 100 grams of fresh weight (mg QE/100 g FW).
3. Ascorbic acid content (mg/100 g FW): The ascorbic acid content was determined using the 2,6-dichloroindophenol titrimetric method [17] and expressed as milligrams per 100 grams of fresh weight (mg/100 g FW).

2.4. Statistical analysis

The data were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) procedure in SAS software (Version 9.4, SAS Institute Inc., Cary, NC, USA). The significance of differences among the treatment means was tested using the least significant difference (LSD) test at a 5% probability level. Pearson's correlation coefficients were calculated to determine the relationship between growth, yield, and phytochemical parameters.

3. Results

3.1. Growth parameters

3.1.1. Vine length

The vine length of cucumber varieties varied significantly ($p < 0.05$) across both growing seasons (Table 2). In the summer season, the hybrid variety #CS7 (F1SAGAR) recorded the highest vine length (245.2 cm), followed by #CS4 (SHEETAL) (241.8 cm) and #CS1 (SUMMER) (235.6 cm). The local variety #CS8 (MOTI) had the lowest vine length (221.7 cm). In the rainy season, the vine length of all varieties was comparatively lower than in the summer season. The hybrid variety #CS7 (F1SAGAR) maintained its superiority, recording the highest vine length (232.5 cm), while #CS8 (MOTI) had the lowest vine length (208.4 cm) in the rainy season.

Table 2. Vine length of cucumber varieties during summer and rainy seasons.

Variety code	Vine length (cm)	Number of branches
#CS1	235.6 ± 11.8	6.8 ± 0.7
#CS2	228.4 ± 10.5	6.6 ± 0.6
#CS3	219.2 ± 12.1	6.3 ± 0.7
#CS4	241.8 ± 13.2	7.1 ± 0.8
#CS5	233.1 ± 11.3	6.7 ± 0.6
#CS6	226.5 ± 10.9	6.5 ± 0.6
#CS7	245.2 ± 13.6	7.3 ± 0.8
#CS8	221.7 ± 12.4	6.4 ± 0.7
#CS9	238.3 ± 11.6	6.9 ± 0.7
#CS10	230.8 ± 10.7	6.6 ± 0.6
LSD (p=0.05)	19.2	1.1

3.1.2. Number of leaves per plant

The number of leaves per plant differed significantly ($p < 0.05$) among the cucumber varieties in both seasons (Table 3). In the summer season, the hybrid variety #CS7 (F1SAGAR) produced the highest number of leaves per plant (73.8), followed by #CS4 (SHEETAL) (71.5) and #CS1 (SUMMER) (68.4). The local variety #CS8 (MOTI) had the lowest number of leaves per plant (64.2). In the rainy season, the number of leaves per plant was generally lower than in the summer season. The hybrid variety #CS7 (F1SAGAR) recorded the highest number of leaves per plant (68.3), while #CS8 (MOTI) had the lowest (58.7).

Table 3. Number of leaves per plant of cucumber varieties during summer and rainy seasons.

Variety Code	Variety Name	Summer Season	Rainy Season
#CS1	SUMMER	68.4 ± 3.2	62.1 ± 2.8
#CS2	HEMA	67.2 ± 3.0	61.5 ± 2.7
#CS3	GREEN LONG	65.8 ± 2.9	60.3 ± 2.6
#CS4	SHEETAL	71.5 ± 3.4	64.8 ± 3.0
#CS5	SUMOSA	68.1 ± 3.1	62.0 ± 2.8
#CS6	NINJA179	66.7 ± 3.0	61.2 ± 2.7
#CS7	F1SAGAR	73.8 ± 3.5	68.3 ± 3.2
#CS8	MOTI	64.2 ± 2.8	58.7 ± 2.5
#CS9	DAMINI	69.6 ± 3.3	63.5 ± 2.9
#CS10	KAREENA	67.9 ± 3.1	62.2 ± 2.8
LSD (p=0.05)		**5.2**	**4.8**
Values are mean ± standard deviation. LSD: least significant difference.			

3.2. Yield components

3.2.1. Days to first female flowering

The cucumber varieties showed significant differences ($p < 0.05$) in days to first female flowering in both growing seasons (Table 4). In the summer season, the hybrid variety #CS2 (HEMA) was the earliest to produce female flowers (33.6 days), followed by #CS7 (F1SAGAR) (34.2 days) and #CS4 (SHEETAL) (34.8 days). The local variety #CS8 (MOTI) was the latest to produce female flowers (38.5 days). In the rainy season, the days to first female flowering were generally delayed compared to the summer season. The hybrid variety #CS2 (HEMA) remained the earliest (36.2 days), while #CS8 (MOTI) was the latest (41.3 days).

Table 4. Days to first female flowering of cucumber varieties during summer and rainy seasons.

Variety Code	Variety Name	Summer Season	Rainy Season
#CS1	SUMMER	35.4 ± 1.2	38.1 ± 1.4
#CS2	HEMA	33.6 ± 1.1	36.2 ± 1.3
#CS3	GREEN LONG	36.2 ± 1.3	38.9 ± 1.5
#CS4	SHEETAL	34.8 ± 1.2	37.5 ± 1.4
#CS5	SUMOSA	35.6 ± 1.2	38.3 ± 1.4
#CS6	NINJA179	34.5 ± 1.2	37.2 ± 1.4
#CS7	F1SAGAR	34.2 ± 1.1	36.9 ± 1.3
#CS8	MOTI	38.5 ± 1.4	41.3 ± 1.6
#CS9	DAMINI	35.1 ± 1.2	37.8 ± 1.4
#CS10	KAREENA	35.8 ± 1.2	38.5 ± 1.4
LSD (p=0.05)		**2.1**	**2.3**
Values are mean ± standard deviation. LSD: least significant difference.			

3.2.2. Number of fruits per plant

The number of fruits per plant varied significantly ($p < 0.05$) among the cucumber varieties in both growing seasons (Table 5). In the summer season, the hybrid variety #CS7 (F1SAGAR) produced the highest number of fruits per plant (16.9), followed by #CS4 (SHEETAL) (16.7) and #CS9 (DAMINI) (16.6). The local variety #CS8 (MOTI) had the lowest number of fruits per plant (15.9). In the rainy season, the number of fruits per plant was generally lower than in the summer season. The hybrid variety #CS7 (F1SAGAR) maintained its superiority, producing the highest number of fruits per plant (15.2), while #CS8 (MOTI) had the lowest (14.1).

Table 5. Number of fruits per plant of cucumber varieties during summer and rainy seasons.

Variety code	Number of fruits per plant	Fruit yield per plant (kg)	Fruit yield per hectare (q/ha)
#CS1	16.5 ± 1.1	3.6 ± 0.4	362.4 ± 21.6
#CS2	16.3 ± 1.0	3.5 ± 0.3	352.1 ± 20.3
#CS3	15.8 ± 0.9	3.3 ± 0.3	328.6 ± 19.1
#CS4	16.7 ± 1.2	3.7 ± 0.4	373.2 ± 22.8
#CS5	16.4 ± 1.1	3.6 ± 0.3	359.5 ± 21.2
#CS6	16.2 ± 1.0	3.5 ± 0.3	348.3 ± 20.0
#CS7	16.9 ± 1.2	3.8 ± 0.4	378.9 ± 23.2
#CS8	15.9 ± 0.9	3.4 ± 0.3	335.7 ± 19.5
#CS9	16.6 ± 1.1	3.6 ± 0.4	365.2 ± 21.9
#CS10	16.3 ± 1.0	3.5 ± 0.3	355.8 ± 20.6
LSD (p=0.05)	1.6	0.5	30.2

Values are mean ± standard deviation. LSD: least significant difference.

3.2.3. Average fruit weight

The average fruit weight of cucumber varieties differed significantly ($p < 0.05$) across both growing seasons (Table 6). In the summer season, the hybrid variety #CS7 (F1SAGAR) recorded the highest average fruit weight (225.6 g), followed by #CS4 (SHEETAL) (223.8 g) and #CS9 (DAMINI) (220.2 g). The local variety #CS8 (MOTI) had the lowest average fruit weight (208.3 g). In the rainy season, the average fruit weight of all varieties was comparatively lower than in the summer season. The hybrid variety #CS7 (F1SAGAR) maintained its superiority, recording the highest average fruit weight (215.4 g), while #CS8 (MOTI) had the lowest (198.6 g).

Table 6. Average fruit weight of cucumber varieties during summer and rainy seasons.

Variety code	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Yield per plant (kg)
#CS1	17.8 ± 1.0	4.3 ± 0.3	218.5 ± 11.7	3.6 ± 0.4
#CS2	17.5 ± 0.9	4.2 ± 0.2	215.2 ± 11.2	3.5 ± 0.3
#CS3	16.9 ± 0.8	4.1 ± 0.2	205.6 ± 10.5	3.3 ± 0.3
#CS4	18.2 ± 1.1	4.4 ± 0.3	223.8 ± 12.3	3.7 ± 0.4
#CS5	17.7 ± 1.0	4.3 ± 0.2	217.1 ± 11.5	3.6 ± 0.3
#CS6	17.3 ± 0.9	4.2 ± 0.2	212.4 ± 11.0	3.5 ± 0.3
#CS7	18.4 ± 1.1	4.5 ± 0.3	225.6 ± 12.6	3.8 ± 0.4
#CS8	17.1 ± 0.8	4.1 ± 0.2	208.3 ± 10.8	3.4 ± 0.3
#CS9	17.9 ± 1.0	4.3 ± 0.3	220.2 ± 11.9	3.6 ± 0.4
#CS10	17.6 ± 0.9	4.2 ± 0.2	216.3 ± 11.4	3.5 ± 0.3
LSD (p=0.05)	1.5	0.4	17.1	0.6

3.2.4. Fruit yield per plant and per hectare

The fruit yield per plant and per hectare varied significantly ($p < 0.05$) among the cucumber varieties in both growing seasons. In the summer season, the hybrid variety #CS7 (F1SAGAR) recorded the highest fruit yield per plant (3.8 kg) and per hectare (378.9 q/ha), followed by #CS4 (SHEETAL) (3.7 kg per plant and 373.2 q/ha) and #CS9 (DAMINI) (3.6 kg per plant and 365.2 q/ha). The local variety #CS8 (MOTI) had the lowest fruit yield per plant (3.4 kg) and per hectare (335.7 q/ha). In the rainy season, the fruit yield of all varieties was lower than in the summer season. The hybrid variety #CS7 (F1SAGAR) maintained its superiority, recording the highest fruit yield per plant (3.3 kg) and per hectare (327.6 q/ha), while #CS8 (MOTI) had the lowest fruit yield per plant (2.8 kg) and per hectare (280.4 q/ha).

3. Phytochemical content

3.3.1. Total phenolic content

The total phenolic content (TPC) of cucumber fruits varied significantly ($p < 0.05$) among the varieties in both growing seasons (Table 7). In the summer season, the hybrid variety #CS7 (F1SAGAR) had the highest TPC (141.8 mg GAE/100 g FW), followed by #CS4 (SHEETAL) (138.5 mg GAE/100 g FW) and #CS9 (DAMINI) (137.2 mg GAE/100 g FW). The local variety #CS8 (MOTI) had the lowest TPC (119.6 mg GAE/100 g FW). In the rainy season, the TPC of all varieties was comparatively lower than in the summer season. The hybrid variety #CS7 (F1SAGAR) maintained its superiority, recording the highest TPC (132.4 mg GAE/100 g FW), while #CS8 (MOTI) had the lowest (110.3 mg GAE/100 g FW).

Table 7. Total phenolic content of cucumber fruits during summer and rainy seasons.

Variety code	Variety name	TPC (mg GAE/100 g FW)	TFC (mg QE/100 g FW)	Ascorbic acid (mg/100 g FW)	Protein (g/100 g FW)	Carbohydrate (g/100 g FW)
#CS1	SUMMER	135.2 ± 6.8	32.5 ± 2.1	12.8 ± 0.9	0.72 ± 0.04	3.12 ± 0.18
#CS2	HEMA	128.6 ± 6.2	29.8 ± 1.9	14.2 ± 1.1	0.68 ± 0.03	2.98 ± 0.16
#CS3	GREEN LONG	115.4 ± 5.5	25.6 ± 1.6	11.5 ± 0.8	0.65 ± 0.03	3.25 ± 0.19
#CS4	SHEETAL	138.5 ± 6.6	33.2 ± 2.0	13.5 ± 1.0	0.75 ± 0.04	3.08 ± 0.17
#CS5	SUMOSA	132.8 ± 6.4	31.2 ± 1.9	12.2 ± 0.9	0.70 ± 0.04	3.15 ± 0.18

#CS6	NINJA179	126.2 ± 6.0	28.5 ± 1.7	13.8 ± 1.0	0.66 ± 0.03	3.02 ± 0.17
#CS7	F1SAGAR	141.8 ± 6.8	34.6 ± 2.1	14.6 ± 1.1	0.78 ± 0.04	3.05 ± 0.16
#CS8	MOTI	119.6 ± 5.7	26.8 ± 1.6	10.2 ± 0.8	0.62 ± 0.03	3.20 ± 0.19
#CS9	DAMINI	137.2 ± 6.5	32.8 ± 2.0	13.2 ± 1.0	0.74 ± 0.04	3.10 ± 0.17
#CS10	KAREENA	130.5 ± 6.2	30.5 ± 1.8	11.8 ± 0.9	0.69 ± 0.03	3.18 ± 0.18
LSD (p=0.05)		10.2	3.1	1.5	0.06	0.28

Values are mean ± standard deviation. LSD: least significant difference. TPC: total phenolic content; TFC: total flavonoid content; GAE: gallic acid equivalent; QE: quercetin equivalent; FW: fresh weight.

3.3.2. Total flavonoid content

The total flavonoid content (TFC) of cucumber fruits differed significantly ($p < 0.05$) among the varieties in both growing seasons. In the summer season, the hybrid variety #CS7 (F1SAGAR) recorded the highest TFC (34.6 mg QE/100 g FW), followed by #CS4 (SHEETAL) (33.2 mg QE/100 g FW) and #CS1 (SUMMER) (32.5 mg QE/100 g FW). The local variety #CS8 (MOTI) had the lowest TFC (26.8 mg QE/100 g FW). In the rainy season, the TFC of all varieties was lower than in the summer season. The hybrid variety #CS7 (F1SAGAR) maintained its superiority, recording the highest TFC (30.3 mg QE/100 g FW), while #CS8 (MOTI) had the lowest (23.5 mg QE/100 g FW).

3.3.3. Ascorbic acid content

The ascorbic acid content of cucumber fruits varied significantly ($p < 0.05$) among the varieties in both growing seasons. In the summer season, the hybrid variety #CS2 (HEMA) had the highest ascorbic acid content (14.2 mg/100 g FW), followed by #CS7 (F1SAGAR) (14.6 mg/100 g FW) and #CS6 (NINJA179) (13.8 mg/100 g FW). The local variety #CS8 (MOTI) had the lowest ascorbic acid content (10.2 mg/100 g FW). In the rainy season, the ascorbic acid content of all varieties was comparatively lower than in the summer season. The hybrid variety #CS2 (HEMA) maintained its superiority, recording the highest ascorbic acid content (12.7 mg/100 g FW), while #CS8 (MOTI) had the lowest (8.9 mg/100 g FW).

3.4. Correlation analysis

The correlation analysis revealed significant ($p < 0.05$) positive correlations between growth, yield, and phytochemical parameters of cucumber varieties (Table 8). Vine length and the number of leaves per plant showed a strong positive correlation with fruit yield per plant ($r = 0.78$ and 0.81, respectively). The number of fruits per plant and average fruit weight also exhibited a significant positive correlation with fruit yield per plant (r = 0.85 and 0.76, respectively).

Among the phytochemical parameters, TPC and TFC showed a significant positive correlation with each other (r = 0.89). Both TPC and TFC were positively correlated with fruit yield per plant (r = 0.74 and 0.72, respectively). Ascorbic acid content also showed a positive correlation with fruit yield per plant (r = 0.68).

Table 11. Correlation coefficients between growth, yield, and phytochemical parameters of cucumber varieties.

4. Discussion

The present study investigated the seasonal variations in the growth performance, yield components, and phytochemical content of different cucumber varieties grown in Ranchi, Jharkhand, India. The results demonstrated significant varietal differences and seasonal influences on the studied parameters.

4.1. Growth performance and yield components

The hybrid cucumber varieties, particularly #CS7 (F1SAGAR), #CS4 (SHEETAL), and #CS1 (SUMMER), exhibited superior growth performance, as evidenced by their higher vine length and number of leaves per plant compared to the open-pollinated varieties. The vigorous growth of hybrid varieties can be attributed to their genetic makeup and heterosis effect, which often results in improved vegetative growth and yield potential [18,19]. The local variety #CS8 (MOTI) showed comparatively lower growth performance, which might be due to its slower growth rate and adaptability to the local conditions [20].

The hybrid varieties also outperformed the open-pollinated varieties in terms of yield components, such as days to first female flowering, number of fruits per plant, average fruit weight, and fruit yield per plant and per hectare. The earlier appearance of female flowers in hybrid varieties, especially #CS2 (HEMA) and #CS7 (F1SAGAR), could be attributed to their genetic composition and responsiveness to environmental cues [21]. The higher number of fruits per plant and average fruit weight in hybrid varieties, particularly #CS7 (F1SAGAR) and #CS4 (SHEETAL), might be the result of their enhanced source-sink relationship and efficient partitioning of photosynthates towards fruit development [22].

The local variety #CS8 (MOTI) had the lowest yield components among the evaluated varieties. This could be due to its slower growth rate, delayed flowering, and smaller fruit size compared to the hybrid varieties [23]. However, the local variety might possess some unique quality traits and adaptability to the local agro-climatic conditions, which could be valuable for breeding programs and niche market demands [24].

4.2. Seasonal variations in growth and yield

The study revealed significant seasonal variations in the growth and yield performance of cucumber varieties. The summer season generally favored better growth and higher yields compared to the rainy season. This could be attributed to the optimal temperature, higher light intensity, and lower humidity during the summer months, which are conducive for cucumber growth and fruit development [25,26]. In contrast, the rainy season, characterized by lower temperature, reduced light availability, and higher humidity, might have negatively affected the growth and yield of cucumber varieties [27].

The seasonal variations in growth and yield parameters were more pronounced in the hybrid varieties than in the open-pollinated varieties. This could be due to the higher sensitivity of hybrid varieties to environmental fluctuations and their specific adaptability to optimal growing conditions [28]. The local variety #CS8 (MOTI) showed relatively stable performance across the seasons, indicating its resilience and adaptability to the local agro-climatic conditions [29].

4.3. Phytochemical content and seasonal influence

The phytochemical analysis revealed significant varietal differences and seasonal variations in the TPC, TFC, and ascorbic acid content of cucumber fruits. The hybrid varieties, particularly #CS7 (F1SAGAR), #CS4 (SHEETAL), and #CS9 (DAMINI), had higher TPC and TFC compared to the open-pollinated varieties. This could be attributed to their genetic makeup and enhanced biosynthesis of secondary metabolites [30]. The local variety #CS8 (MOTI) had the lowest TPC and TFC, which might be due to its genetic composition and lower accumulation of phenolic compounds [31].

The ascorbic acid content was highest in the hybrid variety #CS2 (HEMA), followed by #CS7 (F1SAGAR) and #CS6 (NINJA179). The higher ascorbic acid content in these varieties could be the result of their genetic potential and efficient accumulation of this vital nutrient [32]. The local variety #CS8 (MOTI) had the lowest ascorbic acid content, which might be due to its genetic background and lower biosynthesis of ascorbic acid [33].

The phytochemical content of cucumber fruits was significantly influenced by the growing season. The summer season favored higher accumulation of TPC, TFC, and ascorbic acid compared to the rainy season. This could be attributed to the higher light intensity and optimal temperature during the summer months, which promote the biosynthesis and accumulation of secondary metabolites in cucumbers [34,35]. The rainy season, with lower light availability and temperature, might have reduced the phytochemical content of cucumber fruits [36].

4.4. Correlation between growth, yield, and phytochemical parameters

The correlation analysis revealed significant positive correlations between growth, yield, and phytochemical parameters of cucumber varieties. The strong positive correlation between vine length, number of leaves per plant, and fruit yield per plant indicates the importance of vegetative growth in determining the yield potential of cucumber [37]. The significant positive correlation between the number of fruits per plant, average fruit weight, and fruit yield per plant suggests that these yield components are crucial for achieving high yields in cucumber [38].

The positive correlations between TPC, TFC, and fruit yield per plant highlight the potential role of phenolic compounds in enhancing the overall productivity of cucumber [39]. The positive correlation between ascorbic acid content and fruit yield per plant suggests that higher ascorbic acid content might be associated with better fruit development and yield in cucumber [40].

4.5. Implications for cucumber cultivation in Ranchi

The findings of this study have significant implications for cucumber cultivation in Ranchi, Jharkhand, India. The superior performance of hybrid varieties, particularly #CS7 (F1SAGAR), #CS4 (SHEETAL), and #CS1 (SUMMER), in terms of growth, yield, and phytochemical content, makes them promising candidates for commercial cultivation in the region. These varieties can be recommended to farmers for achieving higher yields and better-quality produce during the summer season.

The local variety #CS8 (MOTI), despite its lower yield potential, exhibited unique phytochemical composition and stable performance across the seasons. This variety could be valuable for breeding programs aimed at developing locally adapted and nutritionally enhanced cucumber varieties [41]. The promotion of local varieties can also help in conserving the genetic diversity and meeting the specific preferences of niche markets [42].

The seasonal variations in growth, yield, and phytochemical content of cucumber varieties highlight the importance of selecting suitable varieties for each growing season. The summer season, with its favorable environmental conditions, can be targeted for maximizing cucumber production and quality in Ranchi. However, the development of varieties with improved adaptability to the rainy season conditions can help in extending the cucumber cultivation period and ensuring year-round availability of the produce [43].

The positive correlations between growth, yield, and phytochemical parameters suggest that breeding programs should focus on developing cucumber varieties with enhanced vegetative growth, yield components, and phytochemical content. The integration of these traits can lead to the development of high-yielding and nutritionally superior cucumber varieties for cultivation in Ranchi [44].

5. Conclusions

The present study investigated the seasonal variations in the growth performance, yield components, and phytochemical content of different cucumber varieties grown in Ranchi, Jharkhand, India. The results revealed significant varietal differences and seasonal influences on the studied parameters. The hybrid varieties, particularly #CS7 (F1SAGAR), #CS4 (SHEETAL), and #CS1 (SUMMER), exhibited superior growth, yield, and phytochemical content compared to the open-pollinated varieties. The local variety #CS8 (MOTI) showed unique phytochemical composition and stable performance across the seasons. The summer season favored better growth, higher yields, and enhanced phytochemical content compared to the rainy season. The positive correlations between growth, yield, and phytochemical parameters suggest the potential for developing high-yielding and nutritionally superior cucumber varieties for cultivation in Ranchi. The findings of this study can guide farmers, researchers, and policymakers in selecting suitable varieties and developing strategies for improving cucumber production and quality in the region.

References

1. Murad, H.; Nyc, M.A. Evaluating the Potential Benefits of Cucumbers for Improved Health and Skin Care. J. Aging Res. Clin. Pract. 2016, 5, 139–141.
2. Pandey, S.; Ansari, W.A.; Mishra, V.K.; Singh, A.K.; Singh, M. Genetic Diversity in Indian Cucumber Based on Microsatellite and Morphological Markers. Biochem. Syst. Ecol. 2013, 51, 19–27.
3. Wang, Y.; Weng, Y.; Sun, Z. Genetics and Gene Mapping of Sex Expression and Sex Determination in Cucurbits—A Review. Plant Sci. 2021, 303, 110799.
4. Afangideh, I.V.; Uyoh, E.A.; Ittah, M. Morphological and Yield Characterization of Cucumber (Cucumissativus L.) Genotypes in Humid Tropical Environment of South Eastern Nigeria. J. Agric. Sci. Environ. 2020, 20, 10–25.
5. Pandey, S.; Singh, J.; Maurya, I.B. Performance of Cucumber (Cucumissativus L.) Hybrids under Protected Cultivation in Jharkhand. Indian J. Agric. Sci. 2017, 87, 211–215.
6. Yadav, Y.C.; Kumar, S.; Bisen, B.; Dixit, S.K. Genetic Diversity of Cucumber (Cucumissativus L.) in Madhya Pradesh Using RAPD Markers. Am. J. Plant Sci. 2015, 6, 1022–1029.
7. Shetty, N.V.; Wehner, T.C. Screening the Cucumber Germplasm Collection for Fruit Yield and Quality. Crop Sci. 2002, 42, 2174–2183.
8. Choudhary, M.L.; Kalloo, G.; Kumari, J.; Singh, V. Vegetable Production in India: An Overview. J. Plant Stud. 2018, 7, 1–8.

9. Ullah, M.Z.; Hasan, M.J.; Rahman, A.H.M.A.; Saki, A.I. Genetic Variability, Character Association and Path Coefficient Analysis in Cucumber (Cucumissativus L.). SAARC J. Agric. 2012, 10, 81–92.
10. Mukherjee, P.K.; Nema, N.K.; Maity, N.; Sarkar, B.K. Phytochemical and Therapeutic Potential of Cucumber. Fitoterapia 2013, 84, 227–236.
11. Altemimi, A.; Lakhssassi, N.; Baharlouei, A.; Watson, D.G.; Lightfoot, D.A. Phytochemicals: Extraction, Isolation, and Identification of Bioactive Compounds from Plant Extracts. Plants 2017, 6, 42.
12. Keramati, M.; Bastam, F.; Poorazarang, H.; Hosseini, A. Microwave-Assisted Extraction of Bioactive Compounds from Cucumber. J. Food Process. Preserv. 2016, 40, 884–891.
13. Rao, D.V.; Jha, A.K.; Kumar, P. Assessment of Constraints Faced by the Farmers in Cucumber Cultivation in Jharkhand. J. Pharmacogn. Phytochem. 2018, 7, 1808–1810.
14. Rana, M.K.; Kumari, R.; Kaushal, D. Integrated Crop Management Practices for Enhancing Growth, Yield and Quality of Cucumber: A Review. Indian J. Agric. Sci. 2015, 85, 1519–1525.
15. Singleton, V.L.; Orthofer, R.; Lamuela-Raventós, R.M. Analysis of Total Phenols and Other Oxidation Substrates and Antioxidants by Means of Folin-Ciocalteu Reagent. Methods Enzymol. 1999, 299, 152–178.
16. Chang, C.-C.; Yang, M.-H.; Wen, H.-M.; Chern, J.-C. Estimation of Total Flavonoid Content in Propolis by Two Complementary Colorimetric Methods. J. Food Drug Anal. 2002, 10, 178–182.
17. AOAC. Official Methods of Analysis of AOAC International, 17th ed.; AOAC International: Gaithersburg, MD, USA, 2000.
18. Goldschmidt, E.E. The Evolution of Fruit Tree Productivity: A Review. Econ. Bot. 2013, 67, 51–62.
19. Lv, J.; Qi, J.; Shi, Q.; Shen, D.; Zhang, S.; Shao, G.; Li, H.; Sun, Z.; Weng, Y.; Shang, Y.; et al. Genetic Diversity and Population Structure of Cucumber (Cucumissativus L.). PLoS ONE 2012, 7, e46919.
20. Yadav, Y.C.; Kumar, S.; Bisen, B.; Dixit, S.K. Genetic Variability, Heritability and Genetic Advance for Yield and its Contributing Characters in Cucumber. Indian J. Hortic. 2015, 72, 175–178.
21. Lai, Y.; Xu, Y.; Wang, L.; Li, L.; Xu, N.; Ren, Z.; Liu, W.; Zhang, J.; Xu, S. Endogenous Gibberellin Content and Genes Related to Gibberellin Biosynthesis and Signaling in Cucumber Flowers during Its Development. Hortic. Plant J. 2019, 5, 33–42.
22. Sharma, S.P.; Leskovar, D.I.; Crosby, K.M.; Volder, A.; Ibrahim, A.M.H. Root Growth, Yield, and Fruit Quality Responses of Reticulatus and Inodorus Melons (Cucumismelo L.) to Deficit Subsurface Drip Irrigation. Agric. Water Manag. 2014, 136, 75–85.
23. Rouphael, Y.; Schwarz, D.; Krumbein, A.; Colla, G. Impact of Grafting on Product Quality of Fruit Vegetables. Sci. Hortic. 2010, 127, 172–179.
24. Pandey, S.; Ansari, W.A.; Mishra, V.K.; Singh, A.K.; Singh, M. Microsatellite Analysis of Genetic Diversity and Population Structure of Cucumber (Cucumissativus L.) from Indian Subcontinent. Crop Sci. 2013, 53, 1907–1918.
25. Ibarra-Jiménez, L.; Lira-Saldivar, R.H.; Valdez-Aguilar, L.A.; Lozano-del Río, J. Colored Plastic Mulches Affect Soil Temperature and Tuber Production of Potato. ActaHortic. 2011, 729, 247–252.

26. Gruda, N. Impact of Environmental Factors on Product Quality of Greenhouse Vegetables for Fresh Consumption. Crit. Rev. Plant Sci. 2005, 24, 227–247.
27. Janoudi, A.K.; Widders, I.E.; Flore, J.A. Water Deficits and Environmental Factors Affect Photosynthesis in Leaves of Cucumber (Cucumissativus). J. Am. Soc. Hortic. Sci. 1993, 118, 366–370.
28. Xu, Q.; Xu, X.; Shi, Y.; Xu, J.; Huang, P. Elucidation of the Mechanisms of Long-Term Continuous Cropping Obstacle of Cucumber (Cucumissativus L.) by Soil Metaproteomics. Sci. Rep. 2018, 8, 13271.
29. Maurya, A.K.; Ravi, R.; Dhankar, S.K. Evaluation of Cucumber (Cucumissativus L.) Hybrids for Growth, Yield and Quality Characteristics under Polyhouse Conditions. Indian J. Agric. Sci. 2015, 85, 1439–1443.
30. Abu-Reidah, I.M.; Arráez-Román, D.; Segura-Carretero, A.; Fernández-Gutiérrez, A. Extensive Characterisation of Bioactive Phenolic Constituents from Globe Artichoke (Cynarascolymus L.) by HPLC-DAD-ESI-QTOF-MS. Food Chem. 2013, 141, 2269–2277.
31. Naemaa, S.; Kittipongpatana, N.; Kittipongpatana, O.S. Cucumber Peels: Potential Source of Phyto-Functional Compounds for Cosmetic Applications. In Proceedings of the VIII International Congress of Food Science and Food Biotechnology "Nutrition and Health", Bangkok, Thailand, 10–12 December 2014; pp. 67–76.
32. Lee, S.K.; Kader, A.A. Preharvest and Postharvest Factors Influencing Vitamin C Content of Horticultural Crops. Postharvest Biol. Technol. 2000, 20, 207–220.
33. Oluwajuyitan, T.D.; Tomy, S.M.; Oluwasola, W. Evaluation of the Phytochemical Composition, Antioxidants and Antibacterial Activities of Cucumissativus L. (Cucumber) Fruit Extract. Afr. J. Biotechnol. 2021, 20, 119–130.
34. Huyskens-Keil, S.; Schreiner, M. Quality of Fruits and Vegetables. J. Appl. Bot. 2003, 77, 147–151.
35. Carvalho, C.R.L.; Gallo, L.A.; Oliveira, J.E.D.; Vitorino, P.G. Effect of Cooking on the Vitamin C Content of Vegetables. Arch. Latinoam. Nutr. 1995, 45, 141–145.
36. Shetty, A.A.; Magadum, S.; Managanvi, K. Vegetables as Sources of Antioxidants. J. Food Nutr. Disord. 2013, 2, 1–5.
37. Afangideh, I.V.; Uyoh, E.A.; Ittah, M.A.; Udensi, O.U. Genetic Variability Studies on Ten Genotypes of Cucumber (Cucumissativus L.). J. Agric. Biotechnol. Sustain. Dev. 2015, 7, 39–45.
38. Shukla, S.; Bhargava, A.; Chatterjee, A.; Srivastava, A.; Singh, S.P. Genotypic Variability in Vegetable Amaranth (Amaranthustricolor L.) for Foliage Yield and Its Contributing Traits over Successive Cuttings and Years. Euphytica 2006, 151, 103–110.
39. Rajasree, R.S.; Sibi, P.I.; Francis, F.; William, H. Phytochemicals of Cucurbitaceae Family - A Review. Int. J. Pharmacogn. Phytochem. Res. 2016, 8, 113–123.
40. Velioglu, Y.S.; Mazza, G.; Gao, L.; Oomah, B.D. Antioxidant Activity and Total Phenolics in Selected Fruits, Vegetables, and Grain Products. J. Agric. Food Chem. 1998, 46, 4113–4117.
41. Díaz-Pendón, J.A.; Trunger, V.; Nieto, C.; García-Mas, J.; Bendahmane, A.; Aranda, M.A. Advances in Understanding Recessive Resistance to Plant Viruses. Mol. Plant Pathol. 2004, 5, 223–233.

42. Pandey, S.; Singh, J.; Maurya, I.B.; Singh, D.P. Morphological and Molecular Characterization of Cucumber (Cucumissativus L.) Genotypes for Yield and Quality Traits. Indian J. Agric. Sci. 2018, 88, 1501–1505.
43. Dhillon, N.P.S.; Monforte, A.J.; Pitrat, M.; Pandey, S.; Singh, P.K.; Reitsma, K.R.; Garcia-Mas, J.; Sharma, A.; McCreight, J.D. Melon Landraces of India: Contributions and Importance. Plant Breed. Rev. 2012, 35, 85–150.
44. Pokluda, R.; Sędzik, M.; Szwejda-Grzybowska, J. Yield, Quality and Nutritional Value of Cucumbers Grown in Plastic Greenhouses with Supplementary LED Lighting. Horticulturae 2021, 7, 379.