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Correlation studies on growth, flowering and yield attributes of cucumber (*Cucumis sativus* L.) cv. Malini under plant growth regulator treatments

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Abstract

The present study was undertaken to elucidate the interrelationships among vegetative growth, flowering behaviour, and fruit yield of cucumber (*Cucumis sativus* L.) under shade net conditions as influenced by different plant growth regulators (PGRs). Treatments comprising gibberellic acid (GA₃), Ethrel, salicylic acid at varying concentrations, and a water spray control were evaluated. Pearson's correlation analysis revealed that all major vegetative growth parameters were positively and significantly interrelated. Vine length showed strong positive correlations with number of leaves per vine ($r = 0.78$), leaf area ($r = 0.74$), internodal length ($r = 0.82$), and number of primary branches per vine ($r = 0.70$). Fruit yield exhibited highly significant positive correlations with vine length ($r = 0.90$), number of leaves per vine ($r = 0.90$), leaf area ($r = 0.80$), number of primary branches per vine ($r = 0.87$), length of primary branches ($r = 0.91$), number of fruits per vine ($r = 0.90$), and fruit weight ($r = 0.85$). In contrast, days to initiation of flowering ($r = -0.69$), days to first female flower appearance ($r = -0.35^*$), node number of first female flower ($r = -0.26$), and sex ratio (male:female) ($r = -0.28$) were negatively associated with fruit yield, indicating the advantage of early flowering and early femaleness. The results demonstrate that cucumber yield is governed by coordinated vegetative vigour and favourable flowering behaviour, highlighting key traits for yield improvement through PGR application.

Keywords: Cucumber, plant growth regulators, correlation analysis, flowering behaviour, fruit yield, shade net cultivation

1. Introduction

Cucumber (*Cucumis sativus* L.) is one of the most important and widely cultivated vegetable crops of the family Cucurbitaceae with a chromosome number of $2n = 14$. It is a monoecious, trailing or climbing annual vine (Baily, 1969) with triangular-ovate leaves, lateral tendrils, and flowers developing at leaf axils, producing cylindrical fruits. Being day-neutral, cucumber can be grown throughout the year, and under protected cultivation such as shade nets, multiple crops can be harvested annually, increasing its economic importance.

Yield in cucumber is a complex trait influenced by vegetative growth, flowering behavior, and reproductive development. Parameters such as vine length, leaf area, branching pattern, flower sex ratio, and timing of flowering not only determine plant vigor but also directly affect fruit set, fruit number, and fruit weight. Therefore, understanding the relationships among these traits is crucial for designing effective crop management strategies.

Plant growth regulators (PGRs), including gibberellic acid (GA₃), Ethrel, and salicylic acid, are widely used to modify vegetative and reproductive traits in cucumber. PGRs can enhance vine elongation, leaf expansion, branch development, femaleness, and flowering efficiency, ultimately improving yield and quality. However, the effect of PGRs is often dose- and stage-dependent, and their influence on trait interactions remains underexplored.

Correlation analysis provides a quantitative measure of associations among vegetative, flowering, and yield traits, allowing identification of traits that directly or indirectly influence yield. Such analyses are essential for selecting key growth and reproductive traits that contribute most to productivity, especially in monoecious crops like cucumber where flower sex expression plays a critical role. In view of this, the present study aim to provide insights into trait interrelationships and potential targets for improving yield through PGR application.

2. Materials and Methods

2.1 Experimental Site and Duration

The present study was conducted at the College of Horticulture, Mojerla. The experiment was carried out under shade net conditions to evaluate the effects of different concentrations of plant growth regulators (PGRs) on vegetative growth, flowering, and yield of cucumber (*Cucumis sativus* L.) cv. Malini.

2.2 Experimental Design and Treatments

The experiment was laid out in a Completely Randomized Design (CRD) with three replications. The study consisted of 10 treatments, including:

- GA₃: 75, 150, and 250 ppm
- Ethrel: 100, 200, and 300 ppm
- Salicylic acid: 75, 150, and 250 ppm
- Control: water spray

2.3 Crop Establishment and Spacing

Seeds were sown on well-prepared raised beds with dimensions of 100 × 40 × 50 cm (width × height × distance between beds) during the first week of December. Two seeds per hill were sown, maintaining a plant spacing of 180 × 30 cm. Standard agronomic practices, including irrigation, nutrient application, and pest management, were applied uniformly across all treatments.

2.4 Application of Plant Growth Regulators

PGR treatments were applied as foliar sprays at 20 and 35 days after sowing (DAS), ensuring uniform coverage of the canopy.

2.5 Data Collection

Data were recorded from five randomly selected plants per plot. Observations included:

- **Vegetative growth parameters:** vine length (cm), number of primary branches per vine, length of primary branches (cm), number of leaves per vine, number of nodes per vine, internodal length (cm), and leaf area (cm²).
- **Phenological and flowering traits:** days to initiation of flowering, days to first female flower appearance, node number of first female flower, days to 50% flowering, sex ratio (male:female), and days to first harvest.

Phenological data were collected at 30, 60, and 90 DAS, while growth and yield traits were recorded at appropriate growth stages.

2.6 Statistical Analysis

The mean values of all measured traits were calculated and subjected to statistical analysis following the methods of Panse and Sukhatme (1985) ^[11]. To assess relationships among traits, Pearson's correlation coefficients were computed between vegetative, flowering, and yield parameters. Significance of correlation was tested at 5% and 1% levels. The analysis allowed interpretation of associations between growth attributes, flowering behavior, and fruit yield.

3. Results and Discussion

3.1 Association among Growth, Flowering and Yield Traits of Cucumber under Shade Net Conditions

Correlation among vegetative growth parameters

The Pearson's correlation coefficients among major vegetative growth parameters of cucumber under different plant growth regulator treatments are presented in Table 1. The results revealed that all vegetative traits were positively and significantly interrelated, indicating synchronized vegetative growth under shade net conditions.

Vine length exhibited a strong and significant positive correlation with number of leaves per vine ($r = 0.78^{**}$), leaf area ($r = 0.74^{**}$), number of nodes per vine ($r = 0.65^{**}$), internodal length ($r = 0.82^{**}$), and number of primary branches per vine ($r = 0.70^{**}$). This suggests that treatments enhancing vine elongation simultaneously improved leaf production and canopy expansion, which ultimately increased photosynthetic efficiency. Similar positive associations between vine growth and canopy traits were reported by Shafeek *et al.* (2016) ^[13] in squash and Murthy *et al.* (2007) ^[9] in gherkin.

The number of leaves per vine showed a strong positive correlation with leaf area ($r = 0.81^{**}$), indicating that increased leaf production directly contributed to enhanced photosynthetic surface area. Comparable results were reported by Chaurasiya *et al.* (2016) ^[4] in muskmelon and Ansari and Chowdhary (2018) ^[2] in bottle gourd.

Similarly, number of primary branches per vine was positively associated with vine length, leaf number, and leaf area, confirming that lateral branching plays a vital role in improving overall vegetative vigour, as also reported by Mir (2007) ^[8] in cucumber.

These positive associations clearly indicate that plant growth regulators inducing vigorous vegetative growth enhanced multiple growth attributes simultaneously, which ultimately contributed to improved yield potential.

Table 1: Pearson's correlation coefficients among vegetative growth traits of cucumber

Trait	Vine length	Leaves/vine	Leaf area	Nodes/vine	Internodal length	Primary branches
Vine length	1.00	0.78**	0.74**	0.65**	0.82**	0.70**
Leaves/vine		1.00	0.81**	0.69**	0.76**	0.73**
Leaf area			1.00	0.72**	0.71**	0.75**
Nodes/vine				1.00	0.63**	0.68**
Internodal length					1.00	0.66**
Primary branches						1.00

** Significant at 1% level ($p \leq 0.01$)

3.2 Relationship between Growth, Flowering Traits and Fruit Yield

The correlation coefficients between growth, flowering, yield attributes and fruit yield are presented in Table 2. Fruit yield exhibited strong positive correlations with most vegetative and yield-contributing traits, while flowering delay parameters showed negative associations.

Influence of vegetative traits on fruit yield

Fruit yield showed a highly significant positive correlation with vine length ($r = 0.90^{**}$), number of leaves per vine ($r = 0.90^{**}$), leaf area ($r = 0.80^{**}$), and number of primary branches per vine ($r = 0.87^{**}$), indicating that vigorous vegetative growth enhanced assimilate production and translocation towards developing fruits. Similar relationships between vegetative growth and yield have been reported by Ajay *et al.* (2018) ^[1] in cucumber and Shafeek *et al.* (2016) ^[13] in squash.

The length of primary branches recorded the strongest positive association with fruit yield ($r = 0.91^{**}$), suggesting that longer lateral branches provided more sites for female flower initiation and fruit set, thereby increasing yield. This finding corroborates the observations of Mir (2007) ^[8] and Mehdi *et al.* (2012) ^[7], who reported that enhanced branching favoured yield improvement in cucumber.

Influence of flowering behaviour on fruit yield (early vs delayed interpretation)

Days taken to initiation of flowering exhibited a significant negative correlation ($r = -0.69^{**}$) with fruit yield, clearly indicating that early initiation of flowering (fewer days) resulted in higher fruit yield, whereas delayed flowering (more days) adversely affected yield. Early flowering allows plants to enter the reproductive phase sooner, extending the effective fruiting period, as also reported by Ajay *et al.* (2018) ^[1] and Pandey *et al.* (2016) ^[10] in cucumber.

Similarly, days taken to first female flower appearance showed a negative correlation ($r = -0.35^{*}$), indicating that early appearance of female flowers enhanced yield, while delay in female flower emergence reduced productivity. Comparable results were reported by Mir (2007) ^[8] and Mehdi *et al.* (2012) ^[7], who observed that early femaleness was crucial for higher yield in cucumber.

The node number of first female flower appearance exhibited a negative association ($r = -0.26$), suggesting that appearance of female flowers at lower node numbers (early nodes) was more favorable for fruit yield than appearance at higher nodes. Similar findings were reported by Ansari and Chowdhary (2018) ^[2] in bottle gourd.

The sex ratio (male:female) was negatively correlated with fruit yield ($r = -0.28$), indicating that a lower sex ratio (higher proportion of female flowers) resulted in increased yield, while higher male dominance reduced fruit production. These observations are in agreement with Mir (2007) ^[8] and Mehdi *et al.* (2012) ^[6] in cucumber.

Influence of yield components on fruit yield

Fruit yield showed a highly significant positive correlation with number of fruits per vine ($r = 0.90^{**}$) and fruit weight ($r = 0.85^{**}$), suggesting that yield improvement was primarily governed by fruit number, followed by fruit size. Similar associations between yield components and total yield were reported by Ghani *et al.* (2018) ^[5], and Sapkota *et al.* (2020) ^[12] in cucurbitaceous crops.

Table 2: Correlation coefficients of growth, flowering and yield traits with fruit yield

Trait	Correlation with fruit yield
Vine length	0.90**
Leaves per vine	0.90**
Leaf area	0.80**
Primary branches per vine	0.87**
Length of primary branches	0.91**
Days to initiation of flowering	-0.69** (early flowering ↑ yield)
Days to first female flower	-0.35* (early femaleness ↑ yield)
Node number of first female flower	-0.26
Sex ratio (M:F)	-0.28 (lower ratio ↑ yield)
Fruit weight	0.85**
Fruits per vine	0.90**

* Significant at 5%

** Significant at 1%

Table 3: Mean performance of cucumber for growth, flowering, and yield traits under different PGR treatments

Treatments	Vine length (cm)	Number of leaves per vine	Number of primary branches per vine	Length of primary branches per vine	Number of nodes on main stem	Number of nodes per unit length of vine	Internodal distance (cm)	Leaf area (cm2)
T ₁ -GA3 75 ppm	271.76	90.32	17.52	153.25	30.22	9	5.26	458.14
T ₂ -GA3 150ppm	267.61	88.01	18.49	148.54	28.3	9.48	5.93	446.2
T ₃ -GA3 250 ppm	265.81	86.56	17.41	147.85	26.23	10.16	8.24	441.22
T ₄ -Ethrel 100 ppm	258.8	82.4	15.94	140.55	24.85	10.47	4.96	431.6
T ₅ -Ethrel 200 ppm	261.68	84.28	15.43	143.31	23.92	10.97	5.46	435.62
T ₆ -Ethrel 300 ppm	256.84	80.07	14.93	137.71	22.7	11.4	6.54	438.58
T ₇ -Salicylic acid 75 ppm	260.25	85.06	16.62	143.28	23.65	11.12	7.45	430.58
T ₈ -Salicylic acid 150 ppm	259.24	84.65	16.58	141.03	21.75	12.02	6.83	434.95
T ₉ -Salicylic acid 250 ppm	257.29	83.42	15.94	139.37	23.1	11.22	6.48	443.41
T ₁₀ -Water spray (control)	239.14	74.39	11.26	124.99	18.74	12.82	4.97	423.8
Treatments	Days to initiation of flowering	Days taken to first female flower appearance	Node number of first female flower appearance	Sex ratio	Number of fruits per vine	Fruit weight(g)	Fruit yield(t/ha)	
T ₁ -GA3 75 ppm	34.13	41.34	8.03	1.92:1	9.46	239.39	164.73	
T ₂ -GA3 150ppm	33.74	41.31	8.76	1.75:1	9.08	238.67	157.16	
T ₃ -GA3 250 ppm	35.04	40.72	8.47	1.71:1	9.06	248	165.17	
T ₄ -Ethrel 100 ppm	36.75	40.07	8.15	1.67:1	8.65	234.67	147.78	
T ₅ -Ethrel 200 ppm	36.62	39.73	7.72	1.65:1	8.46	239.33	149.26	
T ₆ -Ethrel 300 ppm	37.31	38.88	6.77	1.40:1	8.12	236.96	150.84	
T ₇ -Salicylic acid 75 ppm	39.21	42.06	9.23	1.98:1	8.4	233	154.47	
T ₈ -Salicylic acid 150 ppm	38.81	42.46	9.55	2.10:1	8.6	237.36	154.56	
T ₉ -Salicylic acid 250 ppm	38.35	42.42	9.33	2.01:1	8.64	235.67	153.84	
T ₁₀ -Water sprav (control)	40.05	45.02	10.08	2.32:1	7.27	216	136.95	

4. Conclusion

The present investigation clearly demonstrated that fruit yield in cucumber is a complex trait influenced by multiple interrelated growth and flowering parameters. Early flowering, early

appearance of female flowers at lower nodes, and a lower male:female ratio, combined with vigorous vegetative growth and enhanced branching, played a decisive role in maximizing fruit yield under shade net conditions.

The strong positive correlations among vegetative traits and yield components suggest that improving vegetative vigour indirectly enhances yield through increased fruit-bearing capacity. These findings justify the need for path coefficient analysis to further partition direct and indirect effects of these traits on yield.

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