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Interactive Effects of Fertigation and Varieties on Plant Growth Attributes and Yield of Soilless Cucumbers

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Abstract: A study was undertaken to monitor the plant growth attributes and yield of soilless cucumbers (V1: Kafka, V2: Multistar and V3: PBRK-4) in relation to differential fertigation scenarios (F1: 100%, F2: 85% and F3: 70% of nutrient solution under optimal microclimatic conditions) during two successive growing seasons of 2016-17 (Season 1: September 2016 to January 2017 and Season 2: February to May 2017). The yield of cucumbers was significantly affected by fertigation treatments in interaction with crop varieties. The plant growth attributes viz. plant height, number of nodes per plant, leaf area index (LAI), plant intermodal distance, fruit water content (FWC) and others in association affected the yield. Irrespective of the growing seasons, the average fruit yield was recorded to be in the range of 2.5-3.5 kg per plant with having highest and lowest values under F1V2 and F3V3 respectively, in relation to plant height, number of nodes per plant and inter-nodal distance per plant per variety. Among crop varieties, the highest yield was recorded under V2, chiefly due to larger intermodal distance and FWC for same average number of nodes per plant and plant height. Thus, monitoring plant growth attributes is essentially required for better understanding of their relationship with the fruit yield.

Keywords: Fertigation, Growth Attributes, Cucumber, Varieties, Yield

1. Introduction

Cucumber (*Cucumis sativus* L.) plants have rapid vegetative and reproductive growth rates, high water and nutrient uptake rates and large root masses [1]. Water and nutrients are two vital inputs for plant growth particularly in soilless media and their uptake by plants are two independent processes. Fertigation in soilless cultivation provides efficient use of water and nutrients [2], through precise and uniform application of nutrients directly to the active root system of the plant [3]. In past, numerous researchers have studied the effect of fertigation [4] on cucumber yield. Drip irrigation is the most suitable method for fertigating the greenhouse cucumbers in both soil and soilless media as it minimizes the leaching of nutrients or chemicals from root-zone system of the plants [5].

A growing media serves as a reservoir of plant nutrients [6], anchors the root system and consequently supports the plant. Nowadays, the prevalence of soil borne diseases has restricted cultivation of vegetable crops in soil under both open field conditions and protective structures [7]. The soilless cultivation has become an alternative due to its ability to offer a better growing environment [8]. Soilless cultivation offers a better control on plant nutrition and diseases due to its capability to control water availability, pH and nutrient concentration in the root zone of plants [9]. Moreover, the productivity of cucumbers under protective structures, particularly, in soilless media has increased to a significant level compared to conventional or open field conditions. Alifar et al. [10] obtained the highest and lowest yield of cucumber fruit from cocopeat and perlite-cocopeat by investigating the effect of five different growing media *viz*. cocopeat, perlite: cocopeat (50: 50), perlite: cocopeat: peatmoss (50: 20: 30 and 50: 30: 20) and perlite: peat moss on volume basis. Ghehsareh et al. [11] reported higher yield, biomass, plant height, root weight, leaf area index (LAI) and total soluble solids

of cucumber fruit on using date-palm as growing media compared to the conventional soil system. The present study was thus undertaken to investigate the performance of seedless cucumbers cultivated in soilless media in relation to its growth attributes under partially controlled greenhouse conditions.

2. Materials and Methods

2.1. General Description of Study Area and Data Meansurement

Experimental trials were carried out inside a naturally ventilated greenhouse (20% side ventilation (adjustable) and 10% fixed top ventilation), located at the Research Farm of Department of Soil and Water Engineering, Punjab Agricultural University, Ludhiana (latitude: 30° 56′ N, longitude: 75° 52′ E and altitude: 247.0 m above mean sea level). The entire surface area of the greenhouse floor was covered with a mat for avoidance of weed emergence. Parthenocarpic cucumbers (V1: Kafka, V2: Multistar and V3: PBRK-4) were cultivated in coco-peat under three levels of fertigation (F1: 100%, F2: 85% and F3: 70%), inside the greenhouse for two growing seasons (Season 1: September 2016 to January 2017 and Season 2: February to May 2017). The plants were trained vertically up and fertigated with nutrient solution on daily basis for a predetermined time. The plant growth parameters were recorded at a regular interval of time (Table 1).

Table 1. *Plant growth parameters.*

Plant parameter	Unit of measurement	Time of measurement	Instrument/method used
Leaf length (LL)	m	Weekly	Measuring scale
Leaf width (LW)	m	Weekly	Measuring scale
Leaf area (LA)	m^2	Weekly	Grid paper
Plant height (h)	m	Weekly	Measuring scale
Number of nodes (N)	-	Weekly	Manual counting
Leaf area index (LAI)	m^2 m^{-2}	Weekly	Sunscan (Delta-T Devices)
SPAD reading (SR)	-	Weekly	Empirical formula*
Chlorophyll content (CC)	μg cm^{-2}	Weekly	Chlorophyll meter (SPAD-502 Plus)
Fruit length (FL)	cm	At each harvest	Digimatic Caliper
Fruit diameter (FD)	cm	At each harvest	Digimatic Caliper
Fruit dry matter (FDM)	%	Thrice a season	Oven method
Fruit water content (FWC)	%	Thrice a season	Oven method
Fruit yield (FY)	kg $plant^{-1}$	2-3 times a week	Manual harvesting

2.2. Leaf Chlorophyll Content

The SPAD value (SPAD index) for plant leaves was recorded on weekly basis and converted to chlorophyll content using a suitable relationship between chlorophyll content and SPAD values. The leaf chlorophyll content was calculated using the formula given [12]*.

$$CC=6.91\times\exp(0.0459\times SR)$$

2.3. Nutrient Application

The water soluble fertilizers were used as the sources of micro and macro nutrients. The quantity of each nutrient applied to the crop was computed through multiplying the total volume of nutrient solution with mean concentration of each nutrient in the solution (Table 2). The applied N, P, K, Ca, Mg, S, Fe, Mn, Mo, Cu, Zn, B were higher by 37.7, 31.0, 50.4, 31.4, 32.5, 38.5, 35.3, 33.3, 31.8, 31.8, 34.2 and 33.9% respectively during season 2 compared to season 1, mainly due to increased crop water requirement or nutrient solution. The order of quantity of macro and micronutrients applied was as K>Ca>N>S>Mg>P>Fe>Mn>B>Zn>Cu≥Mo for both growing seasons.

Table 2. *Nutrient applied after transplanting.*

Nutrient	Nutrient applied (kg ha^{-1})	
	Season 1	Season 2
N	429.0	590.7
P	112.0	146.7
K	696.1	1047.0
Ca	432.1	567.9
Mg	155.9	206.6
S	354.3	490.6
Fe	1.7	2.3
Mn	1.2	1.6
Mo	0.11	0.145
Cu	0.11	0.145
Zn	0.26	0.349
B	0.57	0.763

3. Results and Discussion

3.1. Plant Height

During season 1, the plant height under V1 was significantly different from that under V2 and V3. The maximum and minimum height was recorded under V2 and V1 respectively mainly due to the varietal difference when subjected to similar microclimatic conditions and the inputs (Table 3). Among the fertigation levels, the plant height

remained statistically similar with maximum height under F2 and similar under rest two levels of fertigation. Irrespective of the varieties and fertigation levels, the plant height at 27, 55, 76 and 90 DAT was 2.4, 3.4, 3.7 and 3.8 m respectively. The plant height under F3V2 was significantly higher than F1V1 and F3V1 respectively at 27 DAT, while the height under F2V2 was significantly higher than F3V1 at 55 DAT. The height under F2V2, F2V3 and F3V2 was significantly higher than F3V1 at 76 DAT. Similarly at 90 DAT, the height under F2V2 was significantly higher than F3V1.

During season 2, the highest and lowest plant height was recorded under V2 (4.3 m) and V3 (3.9 m) respectively. The plant height was recorded to be statistically similar among fertigation levels and different among cultivars at 27 DAT. Irrespective of the fertigation levels and cultivars, the average plant height was recorded to be 0.7, 3.3, 4.0 and 4.4 m at 27, 55, 76 and 90 DAT respectively. The height under F1V1 was significantly higher than F1V3 and F3V3 at 27 DAT. Similarly, the plant height under F1V2 was significantly higher than F1V3 (Figure 1).

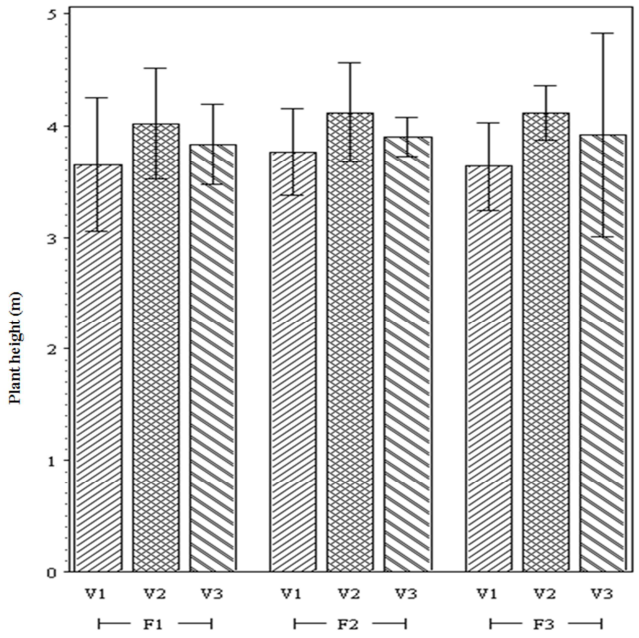


Figure 1. *Average plant height.*

3.2. Number of Nodes Per Plant

During season 1, the nodes per plant were found statistically similar among fertigation levels and different among cultivars at 74 DAT. The nodes per plant under V3 (41 nodes) were recorded significantly higher than V1 (37 nodes) (Figure 2). Moreover, the nodes per plant under F2V3 were significantly higher than F3V1. The number of nodes per plant was recorded to be statistically similar among fertigation levels and different among cultivars with a non-significant difference between them at 90 DAT. Similar at 74 DAT, the nodes per plant under V3 (42) were recorded significantly higher than V1 (39). Irrespective of the fertigation levels and cultivars, the nodes per plant were 39 and 40 at 74 and 90 DAT respectively.

During season 2, the nodes per plant were found statistically similar among fertigation levels and different among cultivars at 27 DAT with a significant interaction. Among cultivars, the nodes per plant under V1 (12 nodes) and V2 (12 nodes) were significantly higher than V3 (9 nodes). The nodes per plant under F1V1 were found significantly higher than F1V3 and F3V3 respectively (Table 3). Similarly, the nodes per plant under F3V1 were significantly higher than F1V3. Irrespective of the fertigation levels and cultivars, the average number of nodes per plant was 11, 37, 46 and 47 at 27, 55, 76 and 90 DAT respectively. LAI was one of the important factors which indirectly affected the greenhouse crop transpiration and remained less than or equal to 2.7 during both growing seasons.

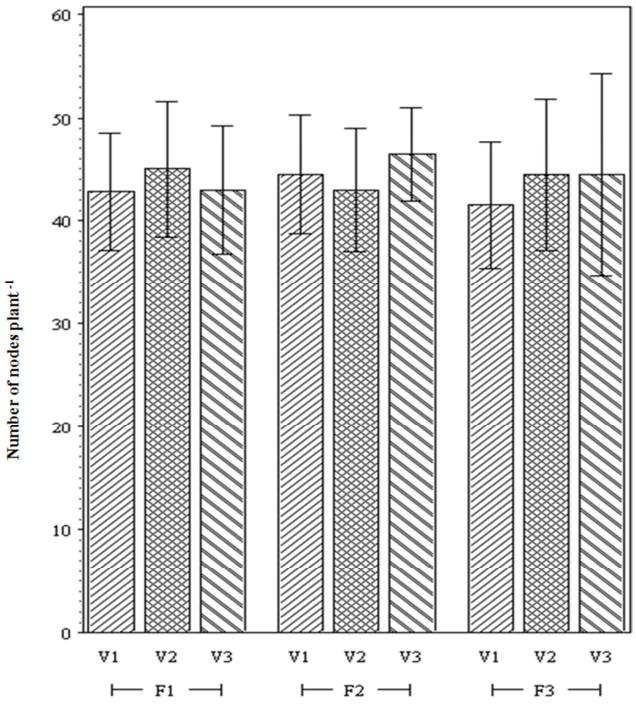


Figure 2. *Number of nodes per plant.*

3.3. Internodal Distance

Irrespective of the growing seasons, the internodal distance of the cucumber plants under V1, V2 and V3 was recorded to be in the range of 2.0-11.0, 4.0-12.5 and 2.0 to 12.5 cm respectively (Figure 3). The average internodal distance was highest in V2 (9.1 cm) and lowest in V1 (8.0 cm).

3.4. Fruit Water and Dry Matter Content (FWC & FDM)

The percent FWC was significantly different among cultivars (V2 and V3) and non-significant among the fertigation levels. Among interactions, the highest value of FWC was 90.8 under F2V2 with a similar trend for FDM content (≥9.2%).

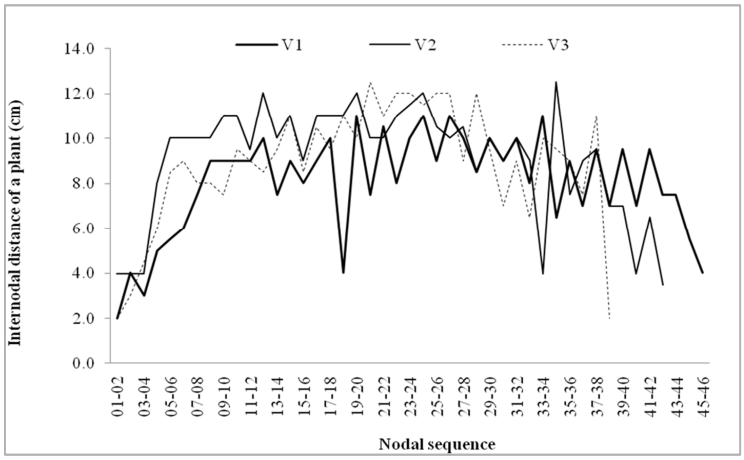
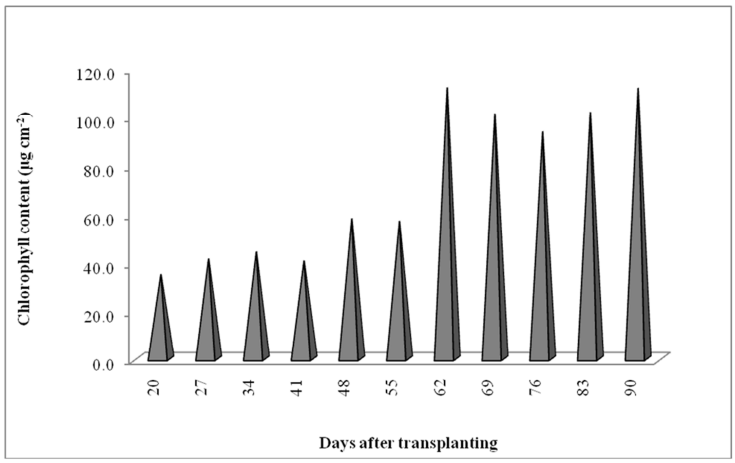


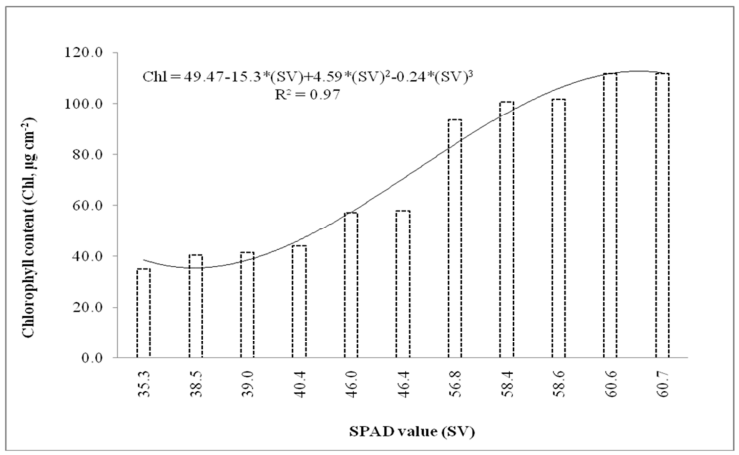
Figure 3. *Internodal distance of cucumber plants.*

3.5. Leaf Chlorophyll Content and SPAD Values

The SPAD value of cucumber leaves was not significantly affected by both fertigation levels and cultivars. The lowest and highest values of chlorophyll content were 35.0 and 112.0 µg cm^{-2} respectively at 20 and 62 DAT. Irrespective of the cultivars and fertigation levels, the chlorophyll content of cucumber leaves was correlated to SPAD values in a cubic trend (R^2=0.97). Higher the SPAD value, higher was the chlorophyll content. The chlorophyll content was lowest and highest of 34.9 and 111.9 µg cm^{-2} for corressponding SPAD values of 35.3 and 60.7 at 20 and 62 DAT respectively. Figure 4a and b demonstrate the variation of leaf chlorophyll content with DAT and SPAD values respectively.



(a)



(b)

Figure 4. *Variation of leaf chlorophyll content with a) DAT and b) SPAD values.*

3.6. Fruit Length, Diameter and Weight

Fruit samples were taken at each picking for measurement of fruit length, diameter and weight. The average diameter of 3.5 cm of cucumber fruit was considered as the main parameter for picking. The average fruit length and weight of cucumbers were 16.3 cm and 140 g respectively were also considered.

3.7. Yield in Relation to Growth Attributes

During season 1, cucumber yield was statistically different among fertigation levels and similar among the varieties. The yield under F1 was significantly higher than that under F3. The yield under F1V2 was significantly higher than that under F3V1 and F3V3 respectively (Figure 5). The fruit yield was obtained in the range of 2.4-3.4 kg plant^{-1} and 2.5-3.6 kg plant^{-1} for season 1 and 2 respectively. The fruit yield per plant was higher during season 2 compared to season 1 under all treatments except for F1V3, where it was lower by 3.1% during season 2. The fruit yield was recorded to be highest and lowest under F1V2 and F3V3 respectively, in relation to plant height, nodes per plant and inter-nodal distance per plant. Among crop varieties, the highest yield was recorded under V2, may be due to larger intermodal distance and FWC for same number of nodes per plant and plant height on an average. During season 2, the highest yield was 3.6 kg/plant under F1V2 mainly due to highest number of nodes (50) and plant height (4.3 m). The minimum yield was recorded to be 2.5 kg/plant under F3V3 having minimum plant height and number of nodes/plant for same variety under F1 level of fertigation.

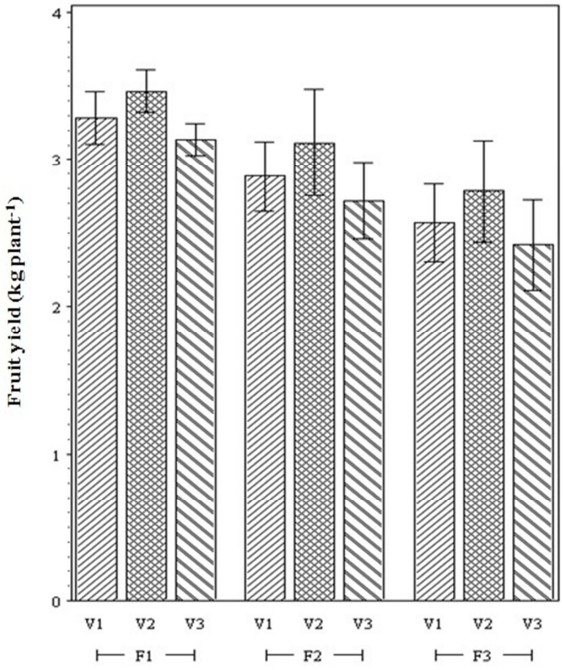


Figure 5. *Fruit yield (pooled).*

Table 3. *Plant growth indicators and fruit yield.*

Parameter	Value/range	Pr>F (≤5%)
Fruit length (cm)	14.0-18.5	-
Fruit diameter (cm)	3.3-3.7	-
Fruit weight (g)	120.0-160.0	-
Fruit water content (%)	<90.8	-
Fruit dry matter content (%)	≥9.2	-
LAI	≤2.7	
Plant height (m)	3.5-4.3	V=0.0004 (P≤5%)
Nodes per plant	37-50	V=0.0133 (P≤5%)
Internodal distance (cm)	2.0-12.5	-
Leaf chlorophyll content (μg cm^{-2})	34.9-112.0	-
Yield (kg/plant)	2.5-3.5 kg/plant	
Yield comparison (%)	4.2-5.9% higher during season 2 compared to season 1	

4. Conclusions

The cucumber yield (2.5-3.5 kg/plant) was significantly affected by interaction of fertigation and varieties in relation to the growth attributes viz. plant height, nodes per plant, leaf area index (LAI), plant intermodal distance, fruit water content and others. The fruit yield was recorded to be highest and lowest under F1V2 and F3V3 respectively, chiefly affected by plant height, nodes/plant and inter-nodal distance/plant. Among crop varieties, the highest yield was recorded under V2, may be due to larger intermodal distance and FWC for same number of nodes per plant and plant height on an average. Thus, monitoring plant growth attributes is essentially required for better understanding of their relationship with the fruit yield (as fruit yield indicators).

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