

Response of Cucumber to Plant Density

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Abstract. An experiment was conducted in unheated fiberglass greenhouse, over two growing seasons, to study the responses of "sahara" parthenocarpic cucumber to plant spacings of 25, 35 and 45 cm, with one or two plants per hill. Yield per unit area (1 m^2) increased as the spacing among plants declined to 25 cm and, also, with increasing number of plants per hill to 2 plants/hill. The increase in yield was positively associated with fruit number. Increasing plant density decreased plant height, number of leaves/plant, yield and fruit number per plant. Significant correlation coefficients were found among the studied cucumber traits on unit area basis or per plant.

Introduction

Studies on open field cucumber indicated that decreasing plant spacing resulted in higher yields per unit area [1-4]. The determinate and indeterminate cultivars showed the same trend [5]. Nevertheless, concomitant decrease in plant growth and both number and weight of fruits per plant was recorded with increasing plant population [1,6].

Studies on cucumber under plastic tunnels revealed that decreasing plant spacing did increase in yield per unit area and decreased both plant growth and yield [7]. Such results were also reported when the plant density increased from 2.4 to 5.4 plants per m^2 [6]. It was also noted that doubling the number of plants per hill increased total fruit yield of muskmelon [8].

Although, cucumber is commonly grown under greenhouse with plant spacing of 35 to 45 cm and row spacing of about 100-125 cm making a plant density of 2-3 plants per m^2 , little work has been conducted to evaluate the effects of plant density on plant growth and fruit yield.

Therefore, the present study was carried out to evaluate the effects of increasing plant density, through doubling the number of plants/hill and decreasing plant spacing on the growth and yield of an indeterminate hybrid of cucumber, under unheated greenhouse conditions.

Materials and Methods

Unheated fiberglass greenhouse experiments were conducted during two growing seasons at the Experimental Station of College of Agriculture and Veterinary Medicine, King Saud University, Qassim Branch.

Seeds of parthenocarpic cucumber hybrid "Sahara" were direct seeded on January 20th and 24th in 1990 and 1991, respectively. Rows of one meter-wide were constructed in the greenhouse, whereas the soil was sandy loam. Drip irrigation was located over rows. Three seeds were sown per hill and the seedlings were thinned out to one or two plants, 7 days after emergence.

The experimental design was a split-plots system in randomized complete block design, with six replications. The main plots were devoted for the first factor, i.e. one or two plants per hill. The sub-plots contained the second factor, which was three spacings among plants within row, i.e. 25, 35 and 45 cm. Therefore, the sub-plots contained plant populations of 2.2, 2.9 and 4.0 plants/m² for the treatments of one plant per hill and 4.4, 5.7 and 8.0 plants/m² when two plants per hill were left. Each sub-plot was one row, 5m long.

Cultural practices, including irrigation and fertilization, were carried out, following the standard commercial procedures. Spraying for pests and diseases were applied whenever it appeared necessary throughout the growing season. Vines were vertically trained and maintained as single stems by the continuous pruning of all laterals.

Four random plants, from each experimental unit, were used to determine average plant height at 60, 75 and 110 days from planting. Number of leaves per plant were estimated at 110 days from planting. Fruits were harvested twice a week, when its weight reached about 80-100 g. Fruit number and weight were recorded per experimental unit and then calculated per plant or per unit area (1 m²). Fruits of the initial three weeks of harvest were considered as the early yield; whereas, total fruits yield was the accumulated records of fruits over the entire harvesting period.

All data were subjected to analysis of variance to determine main treatment effects and interactions. Means were compared, to detect significant differences, using Duncan's multiple range test, at $p=0.05$. Correlation coefficients among different traits were calculated and tested for significance. Analysis of variance and correlation coefficients were performed using SAS.

Results and Discussion

There were differences ($p=0.01$) among number of plants per hill or plant spacing for cucumber traits evaluated in both seasons (Table 1). The differences among plant spacing treatments were found more pronounced than those noticed between number of plants per hill, in both seasons. However, the effect of plant spacing and number of plants/hill on plant heights did not reflect significant differences in 1990 and 1991, respectively. The interactions between number of plants per hill and plant spacing appeared insignificant of all respects, in both seasons, indicating that both factors were acting independently.

Table 1. Mean squares form analysis of variance for cucumber traits as influenced by number of plants per hill and plant spacing.

Trait	Mean squares					
	Block	No. of plants/hill	Error a	plant spacing	Inter-action	Error b
d.f.	5	1	5	2	2	20
Season of 1990						
Leaf no./plant	7.26	296.99**	3.17	18.59*	4.50	3.35
Plant height at 60 days	84.80**	1694.69**	7.56	42.35	157.78	71.49
Plant height at 75 days	222.51	1980.25**	73.72	360.44	53.33	268.66
Plant height at 110 days	637.36	2737.03*	188.16	953.67	3.22	599.18
Early fruit no.	7.95	610.09**	26.64	1442.49**	111.84	32.45
Early yield	0.34	3.398*	0.25	11.84**	0.86	0.36
Total fruit no.	73.07	8864.22**	400.85	10089.59**	373.74	263.55
Total yield	1.62	36.02*	3.12	82.45**	0.15	4.14
Fruit no./plant	1.23	1181.07**	28.11	202.63**	11.51	9.42
Fruit yield/plant	0.07	11.79**	0.26	2.21**	0.19	0.13
Season of 1991						
Leaf no./plant	4.65	43.12**	2.71	81.21**	4.08	3.05
Plant height at 60 days	359.84*	16.40	49.96	2525.75**	256.16	191.25
Plant height at 75 days	327.24*	169.43	54.41	6974.07**	59.14	135.27
Plant height at 110 days	185.10	214.62	242.64	2497.19**	594.20	215.63
Early fruit no.	30.62	1385.08**	21.73	1164.52**	85.09	57.66
Early yield	0.50	5.90**	0.28	9.62**	1.04	0.42
Total fruit no.	80.72	13018.81**	160.05	7433.84**	364.37	362.99
Total yield	1.88	50.43**	2.57	58.31**	0.72	4.46
Fruit no./plant	1.67	1240.21**	32.04	195.97**	16.10	12.39
Fruit yield/plant	0.09	10.97**	0.22	1.49**	0.19	0.15

*, ** indicates significant at 5% and 1% levels, respectively.

Doubling the plant population (2 plants/hill) significantly increased early and total yields, and number of fruits per unit area. On the contrary, the mean values of plant leaf number, plant height, fruit number and yield showed an opposite trend (Table 2). These results indicated that maximum yields are functions of greater numbers of plants per unit area. It was also reported that fruit count per plot was directly correlated with plant count [5].

Table 2. Effect of No. plants/hill on leaf no./plant, plant height and fruiting in cucumber

Trait	Season of 1990		Season of 1991	
	one plant	two plants	one plant	two plants
Leaf no./plant	37.4 a	31.6 b	37.1 a	34.9 b
Plant height at 60 days	110.1 a	96.5 b	96.4 a	95.0 a
Plant height at 75 days	153.2 a	138.3 b	121.8 a	126.2 a
Plant height at 110 days	227.4 a	209.9 b	200.4 a	205.2 a
Early yield (kg/m ²)	3.286b	3.899a	3.305b	4.114a
Early fruit no./m ²	36.2 b	44.4 a	36.3 b	48.7 a
Total yield (kg/m ²)	8.840b	10.841a	8.874b	11.239a
Total fruit no./m ²	99.0 b	130.4 a	98.8 b	136.8 a
Fruit yield/plant (kg)	2.966a	1.821b	2.995a	1.891b
Fruit no./plant	33.4 a	21.9 b	33.4 a	21.7 b

Means in the same row, within a comparable group, having the same letter are not significantly different, according to Duncan's multiple range test at $p=0.05$.

The decrease of fruit yields and fruit number per plant, which resulted from doubling number of plants/hill, might be related to the clear reduction on plant growth (Table 2). A decline (38%) in plant leaf area, due to doubling number of plants/hill was noticed by Knavel [8] on muskmelon plants grown in a greenhouse. The harmful effects of high density planting on individual plants could be due to the excessive shading, which would certainly lower the photosynthetic rate and products and this by turn would reduce plant growth as expressed by leaf number (Table 2). Similar explanations were reached concerning shoot fresh and dry weight [5-7].

Early and total yields and fruit number per unit area (m²) significantly increased as the spacing between plants within rows was decreased i.e. as plant density was increased (Table 3). On the other hand, both fruit yield and number per plant declined as the plant density was raised. Plant leaf number and plant height showed almost the same trend of plant yield (Table 3). These results agreed with the results obtained in pervious works on cucumber [1-3, 5-7], muskmelon [8] and watermelon [9].

Table 3. Effect of plant spacing on leaf no./plant, plant height and fruiting in cucumber

Trait	Season of 1990			Season of 1991		
	plant spacing cm			plant spacing cm		
	25	35	45	25	35	45
Leaf no./plant	35.1 a	33.1 b	35.3 a	34.2 b	34.9 b	39.0 a
Plant height at 60 days	104.5 a	101.1 a	104.0 a	93.4 b	82.6 b	111.2 a
Plant height at 75 days	152.1 a	142.4 a	142.8 a	112.6 b	107.7 b	151.7 a
Plant height at 110 days	214.5 a	212.5 a	228.9 a	196.6 b	192.5 b	219.3 a
Early yield (kg/m ²)	4.738a	3.028b	3.007b	4.718a	3.403b	3.006b
Early fruit no./m ²	53.0 a	34.4 b	33.6 b	53.5 a	39.4 b	34.5 b
Total yield (kg/m ²)	12.830a	7.938b	8.753b	12.601a	8.814b	8.753b
Total fruit no./m ²	148.2 a	96.3 b	99.7 b	146.2 a	107.4 b	99.8 b
Fruit yield/plant (kg)	2.336b	1.996c	2.848a	2.278b	2.204b	2.847a
Fruit no./plant	26.4 b	24.3 b	32.3 a	25.9 b	24.7 b	32.2 a

Means in the same row, within a comparable group, having the same letter are not significantly different, according to Duncan's multiple range test at $p=0.05$.

Such responses may be due to the increase in plant competition apparently increased with increasing plant density, as shown by the inverse relationship between vegetative and reproductive yields per plant with population density (Table 3). The competition among neighboring plants for soil moisture [1, 3] and nutrients [3], becomes a significant growth limiting factor at high density as plants reached anthesis. It has been also mentioned that light, water and/or nutrient availability can all become limiting factors at high plant densities, when plant interactions become to have a major effect on productivity of individual plants [5, 10].

Correlation coefficients between pairs of cucumber traits in both seasons of study are listed in Tables 4 and 5. The estimated values were highly significant for the coefficients between each of early and total yields and fruit number per m², in both seasons, i.e. when these traits were determined on unit area basis. Fruit number, yield, leaf number/plant and plant height showed significant correlation coefficients between one another. The correlation coefficients between a trait of those determined on unit area basis, and another, of those recorded on plant basis, were found negative and, in most cases, insignificant. Similar findings were reported with other cucumber cultivars [6, 11].

It can be concluded that the yield of cucumber (cv. Sahara) could be substantially increased with decreasing plant spacing to 25 cm between hills within one meter-wide rows and by growing two plants/hill (i.e. 8 plants/1 m²), without affecting fruit quality. The high plant density is expected to increase relative humidity in the greenhouse. Therefore, good ventilation is apparently needed to avoid excess humidity, which is favorable for diseases and insects development. Also, the removal of older leaves, that have low net assimilation rates [12], may play an appreciable role in improving productivity.

Table 4. Correlation coefficients between cucumber traits pairs, in 1990 season

Trait	Early fruit no.	Early yield	Total fruit no.	Total yield	Fruit no./plant	Fruit yield/plant	Leaf no./plant	Plant height at	
	no.	yield	no.	yield	no./plant	yield/plant	no./plant	60 days	75 days
Early yield	0.966**								
Total fruit no.	0.956**	0.930**							
Total yield	0.892**	0.923**	0.954**						
Fruit no./plant	-0.231	-0.148	-0.268	-0.104					
Fruit yield/plant	-0.192	-0.067	-0.211	0.001	0.970**				
Leaf no./plant	-0.179	-0.141	-0.268	-0.130	0.728**	0.717**			
Plant height at 60 days	-0.021	-0.025	-0.145	-0.056	0.637**	0.588**	0.573**		
Plant height at 75 days	0.247	0.301	0.158	0.291	0.453**	0.492**	0.451**	0.611**	
Plant height at 110 days	-0.099	0.001	-0.095	0.083	0.532**	0.577**	0.340*	0.402**	0.504**

*, ** indicates significant at 5% and 1%, respectively.

Table 5. Correlation coefficients between cucumber traits pairs, in 1991 season

Trait	Early fruit no.	Early yield	Total fruit no.	Total yield	Fruit no./plant	Fruit yield/plant	Leaf no./plant	Plant height at	
	no.	no.	no.	no.	no./plant	no./plant	no./plant	60 days	75 days
Early yield	0.927**								
Total fruit no.	0.910**	0.918**							
Total yield	0.829**	0.912**	0.946**						
Fruit no./plant	-0.462**	-0.297	-0.441**	-0.210					
Fruit yield/plant	-0.382*	-0.209	-0.360*	-0.134	0.958**				
Leaf no./plant	-0.519**	-0.487**	-0.548**	-0.442**	0.624**	0.611**			
Plant height at 60 days	-0.173	-0.149	-0.142	-0.032	0.337*	0.364*	0.472**		
Plant height at 75 days	-0.297	-0.327*	-0.232	-0.205	0.316	0.273	0.641**	0.573**	
Plant height at 110 days	-0.193	-0.133	-0.060	0.034	0.233	0.213	0.498**	0.540**	0.661**

*, ** indicates significant at 5% and 1%, respectively.

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علاقة إنتاجية الخيار بزيادة الكثافة النباتية

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ملخص البحث. أجريت التجربة في صوبة من الفيرجلاس غير مدفأة خلال عامي ١٩٩٠، ١٩٩١م لدراسة علاقة إنتاجية صنف الخيار «صحارا» لزيادة عدد النباتات في وحدة المساحة. زرعت النباتات على مسافات ٢٥، ٣٥، ٤٥ سم بين الجورة والأخرى، كما ترك في الجورة نبات واحد أو نباتان. واستخدم في التجربة تصميم القطع المنشفة. وأظهرت النتائج زيادة في كل من المحصول المبكر والكلي لوحدة المساحة عند تقليل مسافة الزراعة بين النباتات أو عند زراعة نباتين في الجورة الواحدة. وترجع الزيادة في المحصول أساساً لزيادة عدد الثمار الناتجة. وتم الحصول على أعلى محصول عندما زرعت النباتات على مسافة ٢٥ سم مع ترك نباتين في الجورة. كما قل عدد ثمار ومحصول النباتات في وحدة المساحة. وقد وجد ارتباط مؤكد بين أزواج الصفات التي قدرت على أساس وحدة المساحة، أو بين تلك التي قدرت على أساس النبات الواحد.