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Effect of fertigation levels and spacing on growth and yield of cucumber (*Cucumis sativus* L.) cv. KPCH-1 grown under polyhouse

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Abstract
An experiment was conducted to study the effect of different spacing and fertigation levels on growth and yield of cucumber (*Cucumis sativus* L.) cv. KPCH-1 under naturally ventilated polyhouse. The experiment was laid out following Factorial Randomized Block Design (FRBD) with three replications. The experiment was comprised of total nine treatment combinations of two factors, three levels of spacing viz. 60 cm × 35 cm (S_1), 60 cm × 35 cm (S_2) and 60 cm × 55 cm (S_3) with three levels of fertigation *viz.* 80% RDF (F_1), 100% RDF (F_2) and 120% RDF (F_3). Among the treatment combinations, S_3F_2treatment (60 cm ×55 cm with 100% RDF) showed the best interaction effect for vine length at 30 DAT (69.47 cm), at 60 DAT (229.40cm), at final harvest (339.73 cm),crop duration (103.93 days)number of fruits per vine (37.67), fruit length (17.13 cm), fruit girth (11.57 cm),average fruit weight (122.33 g), fruit yield per vine (4.20 kg), days to first flower appearance (28.13 days), intermodal length (8.90 cm), nodal position of first flower (2.73) and days to first picking of fruits (35.93 days). The maximum vegetative growth and yield of the cucumber were found in S_3F_2 treatment. The maximum available nitrogen, available phosphorus and available potassium were found in S_3F_3 (60 cm ×55 cm with120 % RDF as compared to initial fertilizer in polyhouse. The maximum benefit-cost ratio was found in the treatment S_3F_2 (2.90) followed by S_3F_1 (2.67). Based on these findings, it is recommended that spacing of 60 cm × 55 cm and application of fertilizer with 100% RDF under naturally ventilated polyhouse is economical and found suitable for vegetative growth and yield of the cucumber.

Keywords: Cucumber, fertigation, spacing, available nitrogen, B: C ratio

Introduction
Cucumber (*Cucumis sativus* L.) is grown in many parts of the country especially in tropical and sub- tropical areas. It is cultivated as salad crop, whereas non deserts used as vegetables (Chadha and Lal 1993) [1]. It belongs to family cucurbitaceous and consisting of 130 genera and 800 species. It is not only grown in polyhouse conditions but also grown in open conditions. Parthenocarpic cucumber is generally grown in polyhouse because of pollination is not needed for its fruit setting. If pollination occurs, seed will develop and fruit develop in bitter taste. It has 15-20 cm long, dark green in colour, burp less in taste and thin skin fruit which is eaten as whole fruit along with its peel. In this fruit, peel can also be eaten. This type of cucumber does not require any pollinator because of parthenocarpic nature. Cucumber is a warm season crop and is grown throughout the world. In temperate parts of the country and in temperate countries, it is grown under glass. In India, cucumber is cultivated in area 10.29 M ha and its production is 180.64 M MT and productivity is 17.50 MT/ha (Anonymous 2017)[2]. Spacing and nutrients for the vegetable are two important factors under production technique of the polyhouse to increase the production and productivity of vegetable. Application of fertilizers is very important for the vegetative growth and yield of the cucumber. Application of the optimum amount of fertilizers gives good growth and yield. If the recommended dose of fertilizer increases, the leaching of nutrient, soil degradation, etc. may take place. So, as per requirement fertilizer should be applied for getting better results. Very few reports are available on the production of cucumber under protected condition in India. Hence the present investigation was conducted to study the effect of spacing and fertigation levels on the growth and yield of the polyhouse cucumber.

Materials and Methods

The variety KPCH-1 of cucumber was selected for experiment and the experiment was conducted at Polyhouse Complex, Department of Horticulture (Veg. and Flori.), Bihar Agricultural College, Bihar Agricultural University, Sabour-813210, Bhagalpur, Bihar, India. The experiment was laid out in Factorial Randomized Block Design (FRBD) with three replications and nine treatment combinations. These treatment combinations were formulated with three spacing *viz.* 60 cm × 35 cm (S_1), 60 cm × 35 cm (S_2) and 60 cm × 55 cm (S_3) with three levels of fertigation *viz.* 80% RDF (F_1) ,100% RDF (F_2) and 120% RDF (F_3). Cucumber seedlings were transplanted on 1st January 2019 and all the recommended cultural practices were carried throughout the growing season in the polyhouse. The recommended dose of fertilizer (100: 50: 75 NPK kg/ha) was applied through water soluble fertilizers viz. NPK (19:19:19), MAP (12: 61: 0), SOP (0:0:50) and urea (46:0:0) during growing period of the plant as per the treatments. The available nitrogen was determined by Kjeldhal method (Subbiah and Asija 1956) [3], available phosphorus content by the Olsen method through using the instrument spectrophotometerand available potassium content by flame photometer (Jackson1973) [4].

Results

Vegetative growth, flowering, yield and quality parameters

The data revealed that there was significant difference in treatments with respect to Vegetative growth, flowering, yield and quality parameters. Significantly, the maximum vine length (320.91cm) was obtained in S_3 treatment, whereas minimum vine length (278.47 cm) in S_1 treatment. The vine length at final harvest was also significantly influenced by different levels of fertigation. The maximum vine length (308.71 cm) was obtained in F_2 treatment i.e. 100% RDF which was at par with F_3 (307.84 cm), whereas minimum vine length (284.80 cm) was noted in F_1 treatment. The interaction betweendifferent spacing and levels of fertigation was found to be non- significant regarding vine length at final harvest.

Significant difference was observed in treatments with respect to first flower appearance. Significantly, earliest first flower appeared in S_3 treatment (29.47 days), whereas delayed in treatment S_1 (32.47 days). The first flower appearancewas also significantly influenced by different levels of fertigation. The minimum days taken to first flower appearance (30.13 days) was recorded in F_2treatmenti.e.100% RDF whereas, maximum days taken for first flower appearance (32.29 days) in F_1treatment which was at par with F_3 (30.49 days). A perusal of the data revealed that the interaction between different spacing and levels of fertigation was found to be non-significant regardingfirst flower appearance.

First picking of fruits was significantly affected by spacing. Significantly, the minimum days to first picking was noted in plants placed at 60 cm x 55 cm spacing (37.73 days) while, maximum days to first picking (40.60 days) was recorded in S_1treatment. It is evident from data that the significantly days to first picking influenced by different levels of fertigation. The minimum days to first picking (38.42 days) was noted in F_3 treatment which was at par with F_2 (38.73days) whereas, maximum days to first picking (40.76 days) was recorded in F_1 treatment. The interaction betweendifferentspacing and levels of fertigation was found to be non-significant regarding days to first picking.

There was significant difference in treatments with respect to number of fruits per vine. Significantly, the maximum number of fruits per vine (34.69) was recorded in S_3, whereas minimum number of fruits per vine (29.18) was recorded in S_1 treatment. The number of fruits per vine was also significantly influenced by different levels of fertigation. The maximum number of fruits per vine (34.00) was obtained in F_3 treatment i.e. 120% RDF whereas; minimum number of fruits per vine (30.11) recorded in F_1 treatment. The interaction between different spacing and levels of fertigation was found to be significant regarding number of fruits per vine. Significantly, higher number of fruits per plant (37.67) was noted in S_3F_2 which was at par with S_2F_3 whereas; minimum number of fruits per plant (26.87) was noted in S_1F_1.

It is clear from the data that different spacing significantly affected the fruit length. The maximum fruit length (16.53 cm) was recorded in S_3 which was at par with S_2 (16.35 cm), while minimum fruit length (15.66 cm) was recorded in S_1 treatment. The fruit length was significantly influenced by different levels of fertigation. The maximum fruit length (16.53 cm) was obtained in F_2 treatment which was at par with F_3 (16.44cm) whereas, minimum fruit length (15.58 cm) noted in F_1 treatment. The interaction between different spacing and levels of fertigation was found to be significant regarding fruit length. Significantly higher values for fruit length (17.13 cm) was recorded in S_3F_2 which was at par with S_3F_3 (17.05 cm) and S_2F_2 (16.92 cm).

There was significant difference in various spacing treatments with respect to fruit girth. Significantly, the maximum fruit girth (11.14 cm) was recorded in S_3, whereas, minimum fruit girth (10.20 cm) was recorded in S_1 treatment. The fruit girth was significantly influenced by different levels of fertigation. The maximum fruit girth (10.89 cm) was obtained in F_2 treatment whereas, minimum fruit girth (10.27 cm) in F_1. The interaction between different spacing and levels of fertigation was found to be significant regarding fruit girth. Significantly, maximum fruit girth was noted in S_3F_2 (11.57 cm) which was at par with S_3F_3 (11.20 cm).

Significant difference was found in treatments with respect tofruit yield per vine. Significantly, the maximum fruit yield per vine (3.82 kg) was recorded in S_3 which was at par with S_2 (3.68 kg). The fruit yield per vine was significantly influenced by different levels of fertigation. The maximum fruit yield per vine (3.75 kg) was obtained in F_3 treatment which was at par with F_2 (3.63 kg). The interaction between different spacing and levels of fertigation was found to be significant regarding fruit yield per vine. Significantly, maximum yield per plant was noted in treatment S_3F_2 (4.20 kg) which was at par with S_2F_3 (3.95 kg) and S_3F_3 (3.77 kg).

The data revealed that there was significant difference in treatments with respect to TSS. Significantly, the maximum TSS (3.27 ºBrix) was recorded in S_3, whereas minimum TSS (2.96 ºBrix) was recorded in S_1 treatment. The TSS was significantly affected by various levels of fertigation. The maximum TSS (3.25 ºBrix) was recorded in F_3 treatment which was at par with F_2 (3.16 ^{0}Brix). The interaction between different spacing and levels of fertigation was found to be non-significant regarding TSS.

Soil analysis

The data observed that there was significant difference in treatments with respect to available nitrogen. Significantly, the maximum amount of available N (208.28 kg/ha) was recorded in S_3, whereas minimum available N (199.69 kg/ha) was recorded in S_1 treatment. The available N was significantly influenced by different levels of fertigation. The

maximum available N (214.33 kg/ha) was obtained in F_3 treatment whereas minimum available N (193.41 kg/ha) in F_1 treatment. The interaction between spacing and levels of fertigation was found to be significant regarding available N. Significantly higher amount of available nitrogen was recorded in treatment combination S_3F_3 (218.67 kg/ha) which was at par with S_2F_3 (213 kg/ha).

Significant difference was observed in treatments with respect to available phosphorus. Significantly, the maximum amount of available P (15.67 kg/ha) was recorded in S_3 which was at par with S_2(15.28 kg/ha). The available phosphorus was significantly influenced by different levels of fertigation. The maximum available P (16.00 kg/ha) was obtained in F_3 treatment whereas minimum available P (14.50 kg/ha) in F_1 treatment. The interaction between different spacing and levels of fertigation was found to be significant regarding available P. Significantly maximum amount of available phosphorus was found in S3F3 (16.67 kg/ha) which was at par with S_2F_3, S_3F_2, S_3F_1, S_1F_2 and S_2F_1.

The data revealed that there was significant difference in treatments with respect to available K. Significantly, the maximum amount of available K (111.89 kg/ha) was recorded in S_3 which, was at par with S_1 (109.87 kg/ha) minimum available K (109.87 kg) was recorded in S_1 treatment. The available K was significantly influenced by different levels of fertigation. The maximum available K (114.22 kg/ha) was obtained in F_3 treatment whereas, minimum available K (105.12 kg/ha) in F_1 treatment. The interaction between differentspacing and levels of fertigation was found to be significant regardingavailable K. Significantly, maximum available K was recorded in S_3 F_3 (116 kg/ha) which was at par with S_3F_2, S_2F_3 and S_1F_3.

Economics of cultivation

Cost of cultivation of cucumber under polyhouse condition was calculated for the best treatment combination regarding different spacing and fertigation levels. The economics involved in cucumber production are presented in table-6. While evaluating the cost of production for different treatment combinations, it was observed that the treatment combination S_3F_2 (60 cm ×55 cm with 100% RDF) resulted maximum benefit cost ratio (2.90) followed by S_3F_1 (2.67) whereas, minimum benefit cost ratio (1.65) was observed with S_1F_3 treatment.

Discussion

Cucumber (*Cucumis sativu*s L.) is receiving a great attention among horticulture crops for its high content of water and minerals.Among several factors affecting growth and production of fruits in cucumber, plant spacing and fertigation are important aspects. Under suitable agro-climatic condition, fertigation is one of the main factors, which influences the growth and high yield of cucumber. Application of fertigation has been found beneficial to improve the growth and yield of cucumber. However, the secret of success for commercial cultivation is to have good fertilizer application and proper plant geometry.

Vegetative growth parameters like vine length at final harvest, first flower appearance and days to first picking were found to be non- significant effect. The maximum fruit length was observed in maximum spacing 60 cm × 55 cm. It might be due to decreasing plant density which was resulted minimum competition for space. These results are in conformity with the results of Kapuriya *et al*. (2017) [5] and Lata *et al*. (2017) [6]. Maximum fruit length was observed in optimum fertigation level at 100% RDF due to efficient uptake of fertilizer. This may be due to fertilizers supplied in fertigation in the required form that has helped in efficient uptake resulting in increased length of the fruits. The results are in conformity with the results of Choudhari and More (2002) [7], Jilani *et al*. (2009) [8], Sharma *et al*. (2009) [9] and Shinde *et al*. (2010) [10].

The maximum fruit girth was observed in S_3 treatment (60 cm ×55 cm) and applied high dose of fertigation level at 100% RDF which helped in efficient uptake of fertilizer resulting increasing girth of the fruits. Due to increasing fertilizer dose, plant got optimum nutrients for growth and yield. The results are in opinion with Choudhari and More (2002) [7], Sharma *et al*. (2009) [9] and Shinde *et al*. (2010) [10].

The spacing 60 cm ×55 cm showed the maximum fruit yield per vine due increasing number of flowers in the plants and percent of fruit set. The similar results are found by Kapuriya *et al*. (2017) [5] and Lata *et al*. (2017) [6]. The higher levels of fertilizer increased the number of fruits per vine in the plants because of increasing in the production of flowers in the plant. The similar results are reported by Sharma *et al*. (2009) [9] and Sikarwar and Hardaha (2016) [11].

TSS was found to be non- significant effect. It was found that available nitrogen in soil increased with increase in spacing of plant. Cucumber planted at spacing 60 cm ×55 cm showed significantly higher available nitrogen in the soil. The minimum available nitrogen in soil was observed in crop planted at closer spacing (60 cm x 35 cm). This might be due to the consequence of more vegetative growth and less number of plants at wider spacing which resulted in depletion ofmore soil nitrogen in closer plant spacing as compared to wider plant spacing. Similar results were reported by Sharma *et al*. (2018) [12].

Maximum available phosphorus was observed in maximum spacing 60 cm ×55 cm due to the consequence of more vegetative growth and less number of plants at wider spacing which resulted in depletion ofmore soil nitrogen in closer plant spacing as compared to wider plant spacing. Similar results were reported by Sharma *et al*. (2018) [12]. Maximum available potassium was observed in maximum spacing 60 cm ×55 cm due to the consequence of more vegetative growth and less number of plants at wider spacing which resulted in depletion ofmore soil nitrogen in closer plant spacing as compared to wider plant spacing. Similar results were reported by Sharma *et al*. (2018) [12].

The higher fruit yield and benefit cost ratio (2.90) were observed in maximum spacing of 60 cm × 55 cm and optimum fertigation levels at 100% RDF due to higher production of fruits by applying required amount of fertilizer for growth and yield of the plant. This similar result was observed by Chand (2014) [13].

Table 1: Effect of spacing and fertigation levels onvine length (cm) at final harvest andfirst flower appearance.

Treatment	Vine length at final harvest(cm)				First flower appearance(day)			
Spacing	Fertigation levels				Fertigation levels			
	F_1(80% RDF)	F_2(100% RDF)	F_3(120% RDF)	Mean	F_1(80% RDF)	F_2(100% RDF)	F_3(120% RDF)	Mean
S_1(60 cm x 35 cm)	263.93	276.07	295.40	278.47	33.47	32.73	31.20	32.47
S_2(60 cm x 45 cm)	286.27	310.33	309.33	301.98	32.47	29.53	30.93	30.98
S_3(60 cm x 55 cm)	304.20	339.73	318.80	320.91	30.93	28.13	29.33	29.47
Mean	284.80	308.71	307.84		32.29	30.13	30.49	
	S	F	S* F		S	F	S* F	
C.D. at 5%	18.49	18.49	NS		1.33	1.33	NS	

Table 2: Effect of spacing and fertigation levels on days to first picking and number of fruits per vine.

Treatment	Days to first picking				Number of fruits per vine			
Spacing	Fertigation levels				Fertigation levels			
	F_1(80% RDF)	F_2(100% RDF)	F_3(120% RDF)	Mean	F_1(80% RDF)	F_2(100% RDF)	F_3(120% RDF)	Mean
S_1(60 cm x 35 cm)	41.47	41.27	39.07	40.60	26.87	28.80	31.87	29.18
S_2(60 cm x 45 cm)	40.87	39.00	38.87	39.58	30.60	35.00	36.60	34.07
S_3(60 cm x 55 cm)	39.93	35.93	37.33	37.73	32.87	37.67	33.53	34.69
Mean	40.76	38.73	38.42		30.11	33.82	34.00	
	S	F	S* F		S	F	S* F	
C.D. at 5%	1.86	1.86	NS		1.12	1.12	1.94	

Table 3: Effect of spacing and fertigation levels on fruit length and fruit girth

Treatment	Fruit length(cm)				Fruit girth(cm)			
Spacing	Fertigation levels				Fertigation levels			
	F_1(80% RDF)	F_2(100% RDF)	F_3(120% RDF)	Mean	F_1(80% RDF)	F_2(100% RDF)	F_3(120% RDF)	Mean
S_1(60 cm x 35 cm)	15.34	15.55	16.10	15.66	9.87	10.14	10.60	10.20
S_2(60 cm x 45 cm)	15.98	16.92	16.17	16.35	10.31	10.95	10.70	10.65
S_3(60 cm x 55 cm)	15.42	17.13	17.05	16.53	10.65	11.57	11.20	11.14
Mean	15.58	16.53	16.44		10.27	10.89	10.83	
	S	F	S* F		S	F	S* F	
C.D. at 5%	0.35	0.35	0.61		0.23	0.23	0.40	

Table 4: Effect of spacing and fertigation levels onfruit yield per vine and TSS

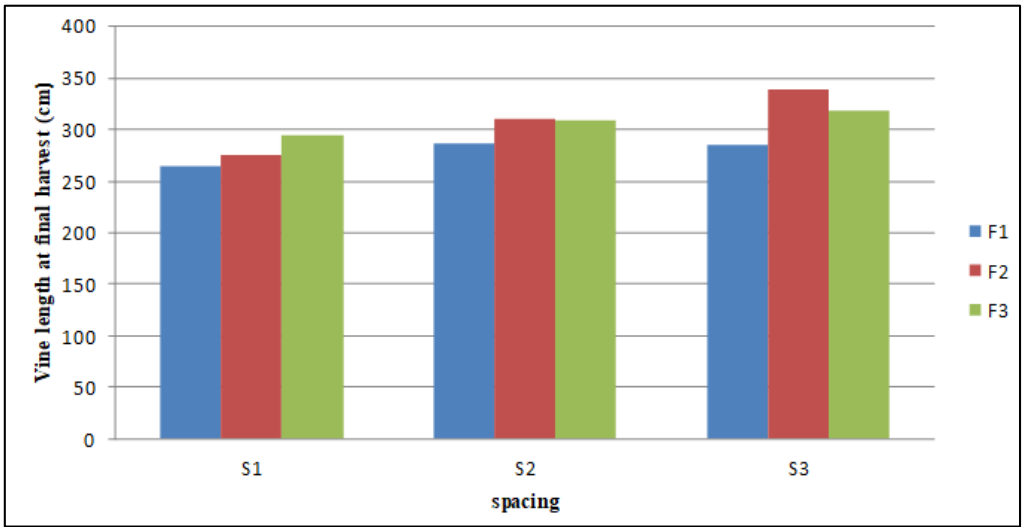
Treatment	fruit yield per vine(kg)				TSS (ºBrix)			
Spacing	Fertigation levels				Fertigation levels			
	F_1(80% RDF)	F_2(100% RDF)	F_3(120% RDF)	Mean	F_1 (80% RDF)	F_2 (100% RDF)	F_3 (120% RDF)	Mean
S_1(60 cm x 35 cm)	2.68	3.05	3.53	3.09	2.82	2.98	3.08	2.96
S_2(60 cm x 45 cm)	3.48	3.60	3.95	3.68	2.92	3.13	3.27	3.11
S_3(60 cm x 55 cm)	3.49	4.20	3.77	3.82	3.05	3.37	3.40	3.27
Mean	3.21	3.62	3.75		2.93	3.16	3.25	
	S	F	S* F		S	F	S* F	
C.D. at 5%	0.26	0.26	0.45		0.09	0.09	NS	

Table 5: Effect of spacing and fertigation levels on available NPK

Treatment	Available N(kg/ha)				Available P(kg/ha)				Available K(kg/ha)			
Spacing	Fertigation levels				Fertigation levels				Fertigation levels			
	F_1(80% RDF)	F_2(100% RDF)	F_3(120% RDF)	Mean	F_1(80% RDF)	F_2(100% RDF)	F_3(120% RDF)	Mean	F_1(80% RDF)	F_2(100% RDF)	F_3(120% RDF)	Mean
S_1(60 cm x 35 cm)	191.33	196.40	211.33	199.69	13.33	15.13	14.83	14.43	104.93	112.00	112.67	109.87
S_2(60 cm x 45 cm)	194.40	196.47	213.00	201.29	15.00	14.33	16.50	15.28	105.43	107.33	114.00	108.92
S_3(60 cm x 55 cm)	194.50	211.67	218.67	208.28	15.17	15.17	16.67	15.67	105.00	114.67	116.00	111.89
Mean	193.41	201.51	214.33		14.50	14.88	16.00		105.12	111.33	114.22	
	S	F	S* F		S	F	S* F		S	F	S* F	
C.D. at 5%	3.95	3.95	6.84		0.73	0.73	1.72		2.20	2.20	3.80	

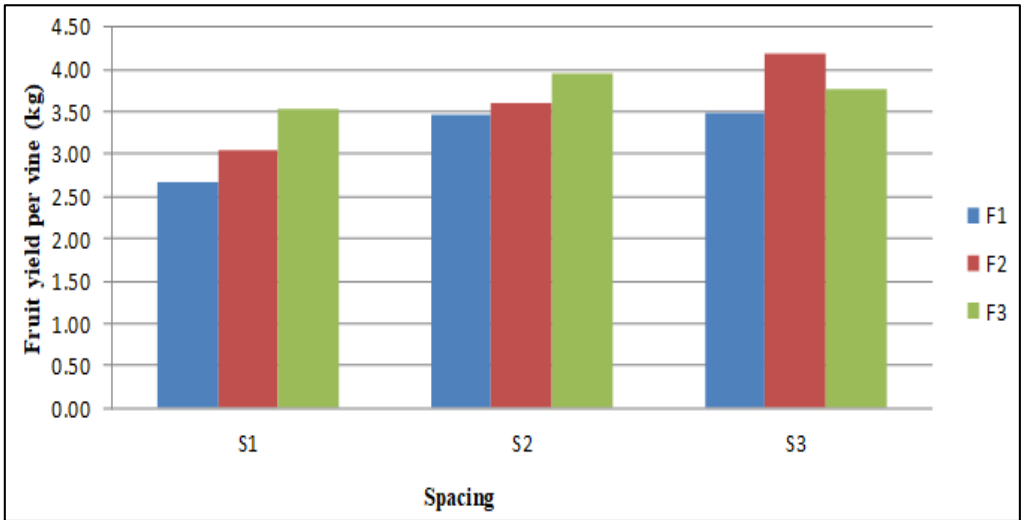
Table 6: Cost of cultivation for cucumber with spacing and fertigation under polyhouse conditions

Treatments	Total yield (kg/550 sqm.)	Total cost of cultivation (Rs.)	Gross return (Rs.)	Net return (Rs.)	B : C ratio
S_1 F_1	4706	40528	112946	72418	1.79
S_1 F_2	4724	40528	113387	72859	1.80
S_1 F_3	4477	40528	107442	66914	1.65
S_2 F_1	6105	40321	146521	106200	2.63
S_2 F_2	5582	40321	133958	93637	2.32
S_2 F_3	5005	40321	120112	79791	1.98
S_3 F_1	6123	40039	146942	106903	2.67
S_3 F_2	6501	40039	156015	115976	2.90
S_3F_3	4772	40039	114537	74498	1.86



S1 –60 cm x 35 cm F1-80% RDF
S2 –60 cm x 45 cm F2-100% RDF
S3 –60 cm x 55 cm F3-120% RDF

Fig 1: Effect ofdifferentspacing and fertigation levels on vine length (cm) at final harvest



S1 –60 cm x 35 cm F1-80% RDF
S2 –60 cm x 45 cm F2-100% RDF
S3 –60 cm x 55 cm F3-120% RDF

Fig 2: Effect of spacing and fertigation levels on fruit yield per vine

Conclusion

On the basis of present investigation, it can be inferred that the variety KPCH-1 of cucumber responded well to different spacing and fertigation levels for growth and yield. Our main objective was to assess the effect of different spacing and levels of fertigation both individually and in combination for growth, yield and quality of cucumber and we found that plant spacing at 60 cm × 55cm and 100% RDF through fertigation increased yield with quality as well as B:C ratio under polyhouse.

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