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Performance of soilless cucumbers under partially controlled greenhouse environment in relation to deficit fertigation

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ABSTRACT

An experimental trial was carried out in a split plot design in three replicates to identify the effect of deficit nutrient supply to soilless cucumbers under partially controlled greenhouse environment. The main plots included three levels of fertigation *viz*. F1=100%, F2=85% and F3=70%. The subplots included three cucumber cultivars viz. V1 (Kafka), V2 (Multistar) and V3 (PBRK-4). A total 256.1 mm of water was applied throughout the season. A significant decrease in mean yield was noticed with a decrease in fertigation level from 100% to 70%. Yield was also affected by cultivars, where the mean yield under V2 was statistically higher from that under V3. Among interaction, the yield under F1V2 was significantly higher from that under F3V3. The water and nutrient use efficiencies were also statistically in agreement with yield. The nutrient use efficiency of macro and micronutrients were in orders of S>P>Mg>N>Ca>K and Cu≥Mo>Zn>B>Mn>Fe respectively. The effect of deficit nutrient supply was undoubtedly reflected in the yield with a significant decline from highest to lowest fertigation level. Likewise, the yield was significantly affetcted by the greenhouse microclimate which was partilly under control. Thus, for obtaining higher fruit yield, there is a need to raise the fertigation level within optimal range or maintain optimal microclimatic conditions or the both.

Key words: *Cucumis sativus*, protected environment, nutrient

INTRODUCTION

Cucumber *(Cucumis sativus* L.) belonging to a cucurbitaceae family, is one of the most popular vegetable crops grown extensively throughout the world (Soleimani *et al.,* 11). Cucumber grows best in the temperature range of 22-27°C (Singh *et al*., 8). In India, protective cultivation of vegetable crops in the hilly regions of the country also offers a great scope for use of low cost naturally-ventilated greenhouses because of mild climate (Mishra *et al*., 3). Worldwide, the area under protective cultivation has increased significantly during last few couple of decades (Singh *et al*., 10).

At the early growth stages, the water requirement of cucumber is low with a limited capacity of water uptake by roots (Zotarelli *et al*., 12). There are several growth parameters such as leaf area and leaf area index which significantly affect the water and nutrient requirement of cucumber in relation to progress of growing season (Singh *et al*., 9). Therefore, judicious use of the available water through more efficient methods of water application becomes necessary for higher yield and water use efficiency. Fertigation allows an accurate and uniform application of nutrients directly to the active root system (Rouphael *et al*., 4).

However, the production potential of cucumber has been perilously affected by numerous factors viz. greenhouse microclimatic parameters (temperature, relative humidity, solar radiation, vapour pressure deficit (VPD), carbon-dioxide and transpiration), growing media and soil borne diseases (Singh *et al*., 5; Singh *et al*., 6). VPD, which is linearly related to transpiration even for values >3.0 kPa (Singh *et al*., 8), is one of the key parameters which significantly affect the crop water requirement through its effect of crop evapo-transpiration and absolute air humidity (Singh *et al.,* 6; Singh *et al.,* 7; Singh *et al.,* 8). The soil borne diseases have also significantly limited the protected cultivation of cucumber in soil (Hussain *et al.,* 2). Thus, for improved crop productivity and quality of the produce, the cucumber cultivation in an appropriate soilless growing media subjected to favorable microclimatic conditions under a protected structure is strongly recommended (Singh *et al*., 8).

A soilless media provides a better growing environment compared to soil (Singh *et al*., 5) with more efficient use of water and nutrients (Singh *et al*., 10) offering a better control on plant nutrition and diseases. According to one study, the highest and lowest yields of cucumber were obtained under cocopeat and perlite-cocopeat respectively (Alifar *et al.,* 1). A study was thus, undertaken to determine the effect of deficient nutrient supply to soilless cucumbers under partially controlled environment.

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METHODS AND MATERIALS

Research trial was conducted inside a naturally ventilated greenhouse located at research farm of department of Soil and Water Engineering, Punjab Agricultural University (PAU). PAU is situated between latitude 30° 56′ N and longitude 75° 52′ E with an altitude of 247 m above mean sea level. The district falls in central part of Indian Punjab and is bounded between latitude 30°33′′ to 31°01′′ N and longitude 75°25′′ to 76°27′′ E having geographical area of 3767 km^2. The greenhouse under experimentation having cover thickness and floor area of 200 μm 560 m^2 respectively was oriented in north-south direction. The entire surface area of the greenhouse floor was covered with weed mat for avoidance of weed emergence. Plastic troughs were laid on the beds above weed mat. The spacing trays were then laid on the troughs, above which the coco-peat slabs were placed.

The nursery of cucumbers was raised in coco-peat media on 6th September, 2016 under a poly net house. The main experimental trial was laid in a split plot design in three replicates with fertigation levels viz. F_1 = 100 %, F_2 = 85 % and F_3 = 70 % in main plots and cultivars viz. V_1 (Kafka), V_2 (Multistar) and V_3 (PBRK-4) in subplots. The slabs were saturated for at least 24 hour before transplanting and a total 648 ready cucumber plants were transplanted at 3-4 leaf stage keeping a plant density of 3 plants m^{-2}. The plants were trained vertically by means of nylon string attached to the roller hooks. Cucumbers were fertigated with nutrient solution for a predetermined time on daily basis as per the schedule throughout the growth period through a semi-automated fertigation system (Fig. 1).

The complete fertigation system included tanks, electric motors, pressure gauges, filters, timers, inverter and pressure compensating emitters (Fig. 1). Three fertigation tanks for three different levels of fertigation, each having a capacity ≥1000 liter were used. The nutrient solution was maintained in the tanks during the entire crop growth season. The fertigation system was run using a 1 hp (0.75 kW) electric motor. An inverter was also provided for running the fertigation system in the absence of electricity. From safety point of view, the system was operated at pressure ≤1.5 kg cm^{-2}. Nutrient solution was passed through filters before its delivery to plants for each supply. The system also included timers for atomization of fertigation. The time to operate fertigation system was set in the timers for a pre-determined time. The timers allowed the application of water and nutrient i.e. nutrient solution for a pre-determined time and automatic closing after the completion of pre-set time.

The emitters were calibrated for their proper working in terms of their discharge rate under variable operating pressure. To ensure that same quantity of nutrient solution is received by each plant, the uniformity coefficient of application of nutrient solution was checked at a regular interval during the entire crop growth period. The uniformity coefficient was calculated using the following equation.

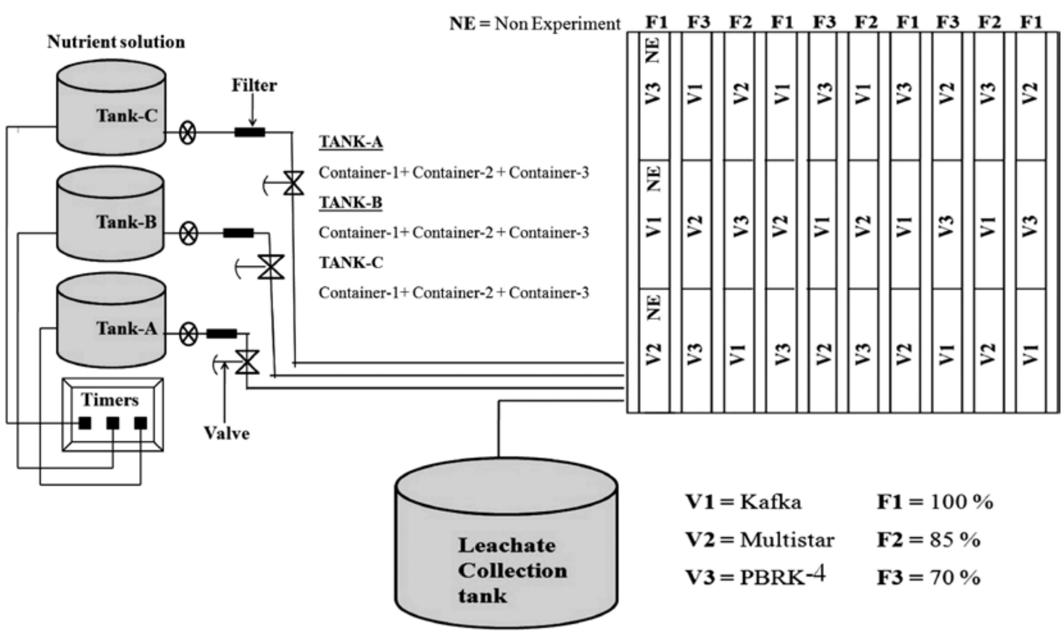

Fig. 1. Schematic of experimental trial along with fertigation system.

Uniformity coefficient, $U_{ceff} = \left(\frac{\Sigma\ |q - \bar{q}|}{n \times q} \right) \times 100$

Where, q = Individual emitter discharge (liter hr^{-1})
$\bar{q}$ = Mean emitter discharge (liter hr^{-1})
$\Sigma\ (q - \bar{q})$ = Deviation of emitter discharge from mean value
n = Number of emitters

Having known, the discharge rate of individual emitter, volume (V_{13}) of nutrient solution applied to cucumber in a given time (t) was calculated using the relationship.

$V_{13} = n \times q \times t$
Where,
n = Total number of drippers operating
q = Dripper discharge (liter hr-1)
t = Time to irrigate or fertigate (hr)

For safe drainage of the leachate coming out of the slabs, a slope of 1% in North-South direction was given to the greenhouse floor from north to south direction to allow a free gravity flow. Two cuts, each at an angle of 45° on two opposite faces of coco-peat slabs along length nearly at bottom, were given for safe drainage. The leachate reaching to the end of trough was expelled through an underground pipeline system and collected in a tank outside greenhouse.

Macronutrients (N, P, K, Ca, Mg and S) and micronutrients (Fe, Zn, Mn, Cu, B and Mo) were used for preparation of nutrient solution. The three basic elements *viz.* carbon (C), hydrogen (H) and oxygen (O), which are essentially required by the plants, are obtained from water or air. Calcium free fertilizers were dissolved in container-1, while phosphate and sulphate free fertilizers were dissolved in container-2. Phosphoric acid (86 %) was contained in container-3. Thereafter, nutrient solution was prepared in the following manner.

Tank A (100%) = Water (1000 L) + Container-1 + Container-2 + Container-3
Tank B (85%) = Water (1000 L) + Container-1 + Container-2 + Container-3
Tank C (70%) = Water (1000 L) + Container-1 + Container-2 + Container-3

The measurement pH and electrical conductivity (EC) of nutrient solution was done using a digital waterproof tester (HI 98130). The EC of coco-peat media was determined using a different digital waterproof tester a product of HANNA instruments. The pH and EC values of the nutrient solution were kept in the ranges 6.0-6.40 and 2.5-3.0 dSm^{-1}. Phosphoric acid (86 %) was used to adjust pH (lowering) of nutrient solution.

RESULTS AND DISCUSSION

The microclimatic parameters viz. air temperature, relative humidity, radiation and plant root zone temperature during crop growth period are depicted in Fig. 2. The greenhouse microclimate was partially controlled having optimum day air temperature 20-30 °C between 10:30 a.m. to 17:30

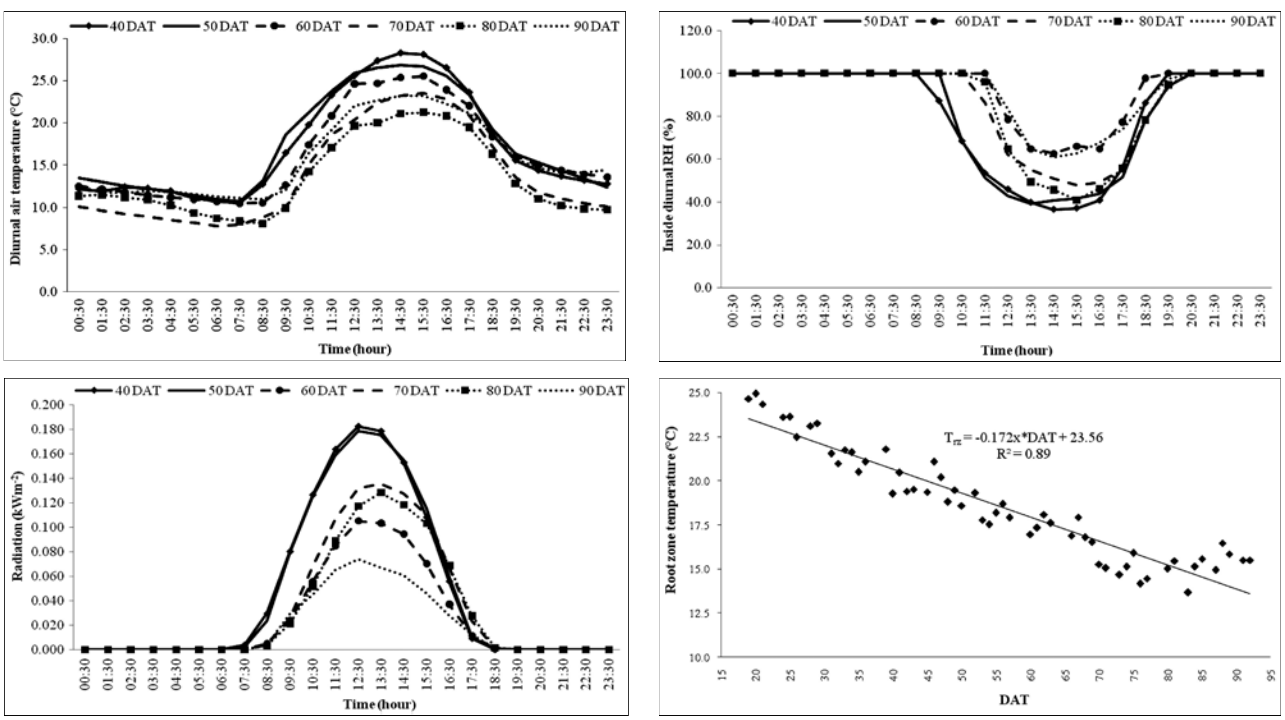

Fig. 2. Variation of a) air temperature, b) relative humidity, c) radiation and d) plant root zone temperature.

p.m. Inside, average maximum and minimum air temperatures during growing season, were 24.4 °C and 14.0 °C, respectively at 19 and 67 DAT. The relative humidity was in the range of 39.1-77.4 % during growth period.

During growing season, the five days averaged incident solar radiation decreased as the season progressed with maximum and minimum values of 106.8 and 54.1 $Wm^{-2}day^{-1}$ in the months of October and December respectively. The plant root zone temperature in soilless media was negatively correlated (R^2=0.89) with time (DAT) and decreased linearly with the progress of the season. However, the minimum root zone temperature was in the range of 13.7-24.9 °C with lowest and highest at 83 and 20 DAT respectively.

The sources of macro and micronutrients were calcium nitrate, potassium nitrate, monopotassium phosphate, potassium sulphate, magnesium sulphate, iron chelate, mangnese sulphate, zinc, Borax, copper sulphate and ammonium molybdate. The water soluble fertilizers and their respective amounts used (kg ha^{-1} or g $plant^{-1}$) are specified in Table 1.

The order of quantity of macro and micronutrients applied was K>Ca>N>S>Mg>P>Fe>Mn>B>Zn>Cu≥Mo respectively (Table 2).

The plants were fertigated 4-5 times a day for duration of 8-10 minutes taking crop growth stage under consideration. Nutrient solution was monitored on regular basis for EC, pH value and deficiency of micronutrients. Measurement of water applied per plant on daily basis was done by installing measuring cylinders each having capacity ≥2.0 liters. Surplus emitters were installed for collection of water applied to an individual plant. The coefficient of uniformity of emitter discharge was ≥90.0 %. The water for irrigation coupled fertigation was supplied directly from the ground water through a bore well. The optimal gauge pressure and emitter discharge for safe application of nutrient solution were 1.25 to 1.5 kg cm^{-2} and 1.7 to 2.0 liter per hour respectively. The amount of irrigation water applied per plant during complete growing season was 91.0 liters. The irrigation water use per plant during growing season is presented in Fig. 3. The total water applied was computed to be 2559.4 m^3 ha^{-1} (256.1 mm).

Among all the treatments, the fruit yield per plant was recorded in the range of 3.1-4.7 kg (88.2-131.6 t/ha) having lowest and highest under F3V3 and F1V2, respectively. Since, F3 represents the lowest fertigation level i.e. 70 % and F1 represents the

Table 2. Nutrient use balance.

Nutrient	Nutrient applied (kg ha^{-1})
N	429.0
P	112.0
K	696.1
Ca	432.1
Mg	155.9
S	354.3
Fe	1.7
Mn	1.2
Mo	0.11
Cu	0.11
Zn	0.26
B	0.57

Table 1. Water soluble fertilizers with their nutrient composition.

Straight/binary fertilizer	Primary macronutrient			Secondary macronutrient			Micronutrients						
	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Cu	Mo	kg ha^{-1}
Calcium nitrate	15.5	-	-	18.8	-	-	-	-	-	-	-	-	2298.2
Potassium nitrate	13	-	37.4	-	-	-	-	-	-	-	-	-	559.5
Monopotassium phosphate	-	22.7	28.2	-	-	-	-	-	-	-	-	-	493.8
Potassium sulphate	-	-	41.5	-	-	17	-	-	-	-	-	-	837.9
Magnesium sulphate	-	-	-	-	9.6	13	-	-	-	-	-	-	1624.2
Iron chelate	-	-	-	-	-	-	12	-	-	-	-	-	14.5
Mangnese sulphate	-	-	-	-	-	17	-	30.5	-	-	-	-	3.9
Zn EDTA	-	-	-	-	-	-	-	-	12	-	-	-	2.2
Borax (boron)	-	-	-	-	-	-	-	-	-	10.5	-	-	5.4
Copper sulphate (CuSO4)	-	-	-	-	-	12	-	-	-	-	24	-	0.45
Ammonium molybdate	-	-	-	-	-	-	-	-	-	-	-	52	0.21

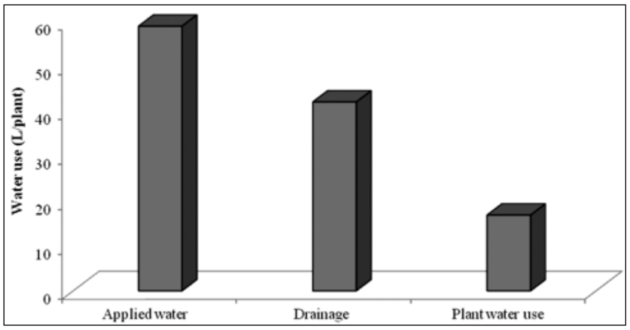

Fig. 3. Plant water use.

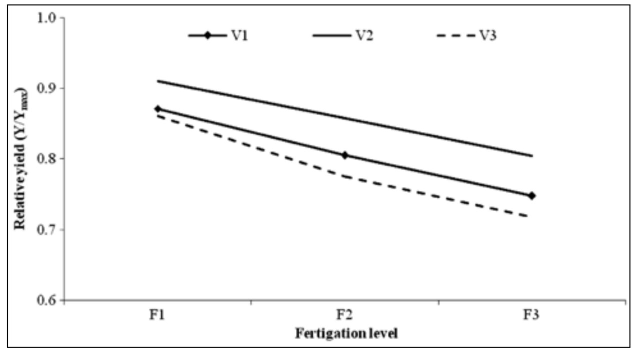

Fig. 4. Relative yield of cucumber under the effect of fertigation and cultivars.

highest level of fertigation i.e. 100 %, the effect of fertigation was, therefore, obvious along with the effect of cultivars. The interaction F1V2 was observed to be the best treatment. This implies that with reduction in fertigation level, yield was significantly reduced along with reduced water supply. Furthermore, for obtaining higher yield, level of fertigation can be raised even beyond 100 % i.e. F1 which was not in this case. Fig. 4 indicates the relative yield of cucumbers as affected by fertigation and cultivars.

$$\text{Relative yield} = \frac{Y_i \text{ (kg / plant)}}{Y_{max} \text{ (kg / plant)}}$$

Where, Y_i = Yield of individual plant (kg plant^{-1})

Y_{max} = Maximum yield (kg plant^{-1})

The Fig. 4 depicts the reduction in mean yield with decreasing fertigation level as well as effect of cultivars on yield. A significant reduction in mean yield was noticed with a decrease in fertigation level from 100 % to 85%, 100 % to 70% and 85 % to 70 % respectively. Yield was also affected by cultivars, where the mean yield under V2 statistically higher from that under V3. However, among interaction, the yield under F1V2 was significantly higher from that under F3V3. The correlation coefficient (R^2), coefficient of variation (CV) and root mean square error (RMSE) were obtained to be 0.74, 6.7 % and 0.26 kg/plant respectively. Likewise, the yield was also significantly affected by the greenhouse microclimate which was partilly under control. Thus, for obtaining higher fruit yield, there is a need to raise the fertigation level beyond 100% or maintaining optimal microclimatic conditions or both.

The mean consumptive use efficiency $\left(\text{i e } E_a = \frac{W_{cu}}{W_d}\right)$ was 40.0 %. Where, W_{cu} and W_d are the crop water uptake and drainage water respectively. The Irrigation water use efficiency (IWUE) under F1V2 (51.4 kg m^{-3}) was statistically higher from that under F3V3 (34.5 kg m^{-3}) at 5 % level of significance. Similarly, crop water use efficiency (CWUE) under F1V2 (179.9 kg m^{-3}) was statistically higher from that under 120.6 kg m^{-3} under F3V3. WUE which is an indicator of crop yield in relation to water use was also statistically in agreement with yield. Moreover, the nutrient use efficiency (NUE) under V2 was statistically higher from that under V3 for each level of fertigation. However, among fertigation levels, NUE under F3 was statistically higher from that under F1 for each cultivar. This implied that the NUE was certainly affected both by cultivars and fertigation level and increased statistically with decrease in fertigation level. The nutrient use efficiency macro and micronutrients were in orders of S>P>Mg>N>Ca>K and Cu≥Mo>Zn>B>Mn>Fe respectively.

A significant decrease in mean yield was noticed with a decrease in fertigation level from 100 % to 85%, 100 % to 70% and 85 % to 70 % respectively. The highest (4.7 kg plant^{-1}) and lowest (3.1 kg plant^{-1}) fruit yield was recorded under treatments F3V3 and F1V2 respectively. Yield was also affected by cultivars, where the mean yield under V2 was statistically higher from that under V3. However, among interaction, the yield under F1V2 was significantly higher from that under F3V3. The effect of deficit nutrient supply was undoubtedly reflected in the yield with a significant decline from highest to lowest fertigation level. The yield was also significantly affected by the greenhouse microclimate which was partially under control. Thus, for obtaining higher fruit yield, there is a need to raise the fertigation level within the optimal range or maintaining optimal microclimatic conditions or the both.

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