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Effect of fertigation strategies on growth and production of soilless cucumber (*Cucumis sativus*)

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Soilless cultivation inside the greenhouse has significantly increased during last decade (Mazahreh *et al.* 2015, Singh *et al.* 2019). Cucumber (*Cucumis sativus* L.) is regularly grown in soilless cultivation due to its short growing period and the possibility of year-round cultivation. Cucumber, capsicum and tomato vegetables are mainly produced using organic and inorganic media as cultivation substrates in greenhouses (Grunert *et al.* 2016). However, fertigation in soilless cultivation is the most important, critical and continuous activity, as the crop does not receive nutrients from substrate culture. Furthermore, the rate of fertigation application is affected by a number of factors including crop variety, crop growth stage, climatic conditions, growing season and substrate culture (Sonneveld and Voogt 2009). In soilless cultivation, fertigation schedule is determined using a variety of methods, including a climate model, one or more sensor systems, the physiological response parameter, and any combination of these methods. Thus, many efforts have been made in the past to schedule the fertigation of substrate in soilless cultivation. According to Saha *et al.* (2008) and Chen *et al.* (2016) the automated weight type lysimeter device is the most compact, portable and effective technique, and it also offers direct measurements without the need for calibration. Furthermore Rouphael *et al.* (2016) discovered, fertigation scheduling affects crop growth parameters, water and nutrient use, yield and quality. Keeping in view the above facts, fertigation scheduling based on weight loss criteria was evaluated to study the effects of different levels of fertigation strategies on growth parameters and yield of soilless cucumbers inside the greenhouse and consequently develop an efficient fertigation schedule for soilless cucumbers.

Present study was carried out in greenhouse at the Centre for Protected Cultivation Technology, ICAR-IARI, New Delhi, during October–February (2019 and 2020). The mean daily temperature in the greenhouse was 18–24°C. Coco-peat grow bags (100 cm × 20 cm × 15 cm) were used for cultivation. Cucumber seeds (cv. NAGENE 792 F1) were directly seeded into grows bags at a density of 4 plants per m^2 with plant to plant and row to row spacing of 0.25 × 1 m. Drip laterals (12 mm diameter), with stakes dripper discharge of 2 l/h were used for fertigation. Weight-based sensing system was developed to monitor the combined weight loss of grow bag having four plants and used for fertigation scheduling.

The fertigation treatments were imposed from 15 days after seeding (DAS). The treatments comprised of full replenishment (T1), where 100% of nutrient solution (NS) applied against the weight loss of growing media and plants (by transpiration of crop); T2, T3, and T4, which received 10% less, 20% less, and 20% more amount of nutrient solution, respectively, as compared to full replenishment (T1). The nutrient solution was applied to all treatments at the same time, when full replenishment (T1) treatment got the trigger to start the fertigation by weight-based sensing system. Plants were fertilized by nutrient solution containing macro and micronutrients as suggested by Sonneveld and Voogt (2009) for substrate cucumber with maintaining the EC between 1.5–2.5 dS/m and *p*H in the range of 5.5–6.5. The experiment was laid out in completely randomized design with three replications. During the course of investigation, three sample plants were randomly selected from each treatment to measure the yield and growth parameters.

Measurements of growth and yield parameters: Plant height was measured using a measuring tape. The number of nodes per plant was recorded by a visual count of the nodes. Three plants were chopped into small pieces and packed into brown paper bags from each treatment for

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determination of dry biomass of shoot and root. These samples were first air dried before final drying in a hot air oven at 60°C for 48 h, and then their final constant weight was measured. Before that, the fresh root samples were used for the determination of root parameters using a root scanner. For the calculation of the per cent contribution of fine root parameters over the respective total root parameters, root diameters of less than 0.5 mm were considered fine roots. The number of fruits per plant and the fresh weight of harvested cucumber fruits were recorded after each harvest. The cumulative yield (kg/ha) of the entire harvest and the yield per plant (kg/plant) were calculated. Water use efficiency (WUE) was estimated by dividing the yield (kg/ha) with the amount of water consumed by the crop (mm) during its growth period under different treatments.

The statistical software SPSS (v.16.0) was used for the statistical analysis of different parameters on average data from two seasons without considering the effect of time period. Further, the least significant differences among the different treatments were noted using post-hoc tests.

Plant height and Number of nodes per plant: The results revealed that plant height was highest (184 cm) under the 100% replenishment treatments, which at par with 10% less and 20% more replenishment treatment (Table 1). A significantly lower plant height was observed under 20% less replenishment treatments. The number of nodes per plant was statistically different among the fertigation treatments. Highest number of nodes per plant (29.33) was recorded under the full replenishment (T1) treatment and it was at par with the 20% more replenishment (T4) treatment. Number of nodes per plant was observed lowest under 20% less replenishment treatment and it was at par with 10% less replenishment against weight loss (T2). It was found that sufficient nutrients were available in the full and 20% more replenishment levels of fertigation for vegetative growth. Singh *et al.* (2019) also observed a similar trend in response to fertigation strategies for plant height and number of nodes per plant.

Dry matter of shoot and root: Dry matter of shoot and root was significantly ($P<0.05$) affected under different treatment of fertigation strategies. In full replenishment treatment (T1), dry matter of the shoot was observed higher whereas it was lower in the 20% less replenishment (T3) treatment. Moreover, it was at par with the 10% less (T2) and 20% more (T4) replenishment treatment (Table 1). The highest dry matter of root was recorded under the full replenishment (T1) treatment followed by in 20% less (T3) and 20% more (T4) replenishment, though they were at par (Table 1). This indicates that more root growth occurred as a result of search for water and nutrients, whereas in 20% less replenishment treatment, dry matter of shoots was decreased because there was less nutrient available during growth. Ghehsareh *et al.* (2011) found that reducing fertigation levels resulted in significant reductions in plant development.

Root parameter: Root length, projected area and surface area of cucumber plants were not significantly ($P<0.05$) affected by the fertigation strategies (Table 2). While root volume, average diameter and the percent contribution of fine root length to total root length, and fine root surface area to total root surface area were found to be significantly different between fertigation treatments (Fig 1) Moreover, it was found that average root diameter of treatments that received 10% and 20% less replenishment treatments was lower compared with full and 20% more replenishment treatments. Due to less nutrient and water availability under T2 and T3 treatments, the plants allowed the smallest root system to access more water and nutrients from the root zone and this resulted in increased root length and root surface area. As a result, plant growth was more or less

Table 2 Effect of different treatments on root parameters of cucumber

Treatment	Root length (cm)	Projected area (cm^2)	Surface area (cm^2)	Root volume (cm^3)	Average diameter (mm)
T1	5226.9a	247.257a	776.78a	9.1980a	0.4736a
T2	4301.2a	177.276a	556.93a	5.7883ab	0.4091b
T3	4293.7a	170.699a	536.27a	5.3437b	0.3956b
T4	4981.5a	218.742a	687.20a	7.5517ab	0.4384ab
SEM	262.03	14.58	45.806	0.639	0.0114
F value	0.776	1.916	1.916	2.893	4.504

Values within columns followed by different letters are statistically different at $P<0.05$.

Table 1 Effect of different treatments on growth, yield parameters and water use efficiency of greenhouse cucumber

Treatment	Plant height (cm)	Dry biomass of shoot (g)	Dry biomass of root (g)	Number of nodes per plant	Number of fruits per plant	Yield per plant (kg/plant)	Yield (t/ha)	IWUE (kg/ha-mm)
T1	183a	37.02a	0.758a	29.50a	25.17a	2.52a	100.89a	1070.2a
T2	178a	32.08ab	0.425b	23.67b	19.67b	1.92c	76.90c	905.86b
T3	163b	26.60b	0.650ab	24.00b	18.83b	1.90c	76.29c	1010.0a
T4	180a	29.78ab	0.558ab	28.33a	24.33a	2.31b	92.24b	815.21c
SEM	2.892	1.514	0.053	0.849	0.883	0.082	3.296	31.375
F value	4.882	3.563	2.436	13.866	24.350	27.95	27.95	19.691

Values within columns followed by different letters are statistically different at $P<0.05$.

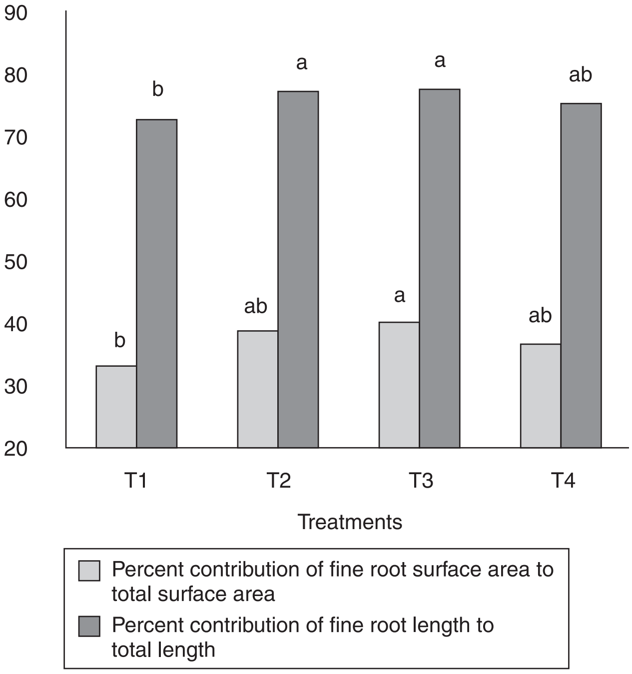

Fig 1 Effect of different fertigation strategies on per cent contribution of fine root length to total root length and per cent contribution of fine root surface area to total root surface area (Bars graph with different letters are statistically different at P<0.05).

similar between all treatments. However, it may also create nutrient balance in the root zone. Consistent with findings by Saha *et al.* (2008), improved root growth was observed with treatments having minimum nutrient leaching and also plants having more fine roots as compared to high fertigation treatments.

Yield parameters: Fertigation treatments significantly (P<0.05) affected the cucumber yield parameters. The maximum cucumber yield (96.88–104.89 t/ha), number of fruits per plant (25–25.33) and yield per plant (2.42–2.62 kg/plant) was obtained under the full replenishment (T1) treatment (Table 1). The lowest yield parameters were observed in the 20% less fertigation treatments (T3) as compared to treatment T1. Water use efficiency was found highest in full replenishment treatment (T1) (1069.1–1071.2 kg/ha mm) and lowest was 811.38 kg/ha mm in case of 20% more replenishment (T4) treatment. Singh *et al.* (2019) reported yield of 2.5–4.4 kg/plant for cucumber cultivated in coco-peat grows bag culture inside a greenhouse. The results of yield (Table 1) from the experiment were similar with the report of Singh *et al.* (2018b) who found decreased yield of crops by reducing the fertigation levels. The yield of cucumbers increased due to the fact that nutrients were more easily available in full replenishment and 20% more replenishment treatments, which received more nutrient solutions.

This study revealed that cucumber growth can be supported by the weight-based application of fertigation and farmers will be confident in applying the fertigation based on the water loss. Moreover, the addition of fertigation levels, such as full replenishment and 20% more replenishment of fertigation strategies, could be adopted to increase the water availability and reduce the occurrence of nutrient imbalances, thus allowing more nutrients to be available to the plant root zone area. The full replenishment fertigation strategy reduces the nutrient loss and improves the crop production and related crop parameters. Hence, it should be used as a fertigation strategy to promote the weight-based fertigation scheduling for cucumber production in soilless grow bag systems.

SUMMARY

Weight-based fertigation scheduling strategies optimized for cucumber production in coco-peat grow bag under greenhouse conditions. The experiment was conducted using treatments comprised of four different levels of nutrient solution replenishment based on weight loss of growing bags along with plants, viz. full replenishment, 10% and 20% less replenishment and 20% more replenishment. Significantly, maximum cucumber yield (96.88–104.89 t/ha), number of fruits per plant (25–25.33) and yield per plant (2.42–2.62 kg/plant) were observed under full replenishment of nutrient solution against weight loss. It was also at par with treatment, which received 20% more nutrient solution as compared to full replenishment. The physiological attributes, viz. plant height (184 cm), number of nodes per plant (29.33), dry biomass and root parameters were observed higher in the full replenishment strategy which received 100% fertigation against the weight loss. Water use efficiency was found higher in the full replenishment followed by 20% less replenishment and lowest (811.38 kg/ha-mm) in 20% more replenishment of nutrient solution. Fertigation strategy which received the 100% nutrient solution against the weight loss, allowed the plant to grow fully with maximum yield and water use efficiency (WUE). Hence, 100% and more replenishment of nutrient solution against weight loss were found to be highly suitable strategies for controlling the fertigation scheduling through the weight-based sensing system.

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