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Studies on the Influence of Soilless Growing Systems and Nutrient Concentration of Hoagland's Solution on Growth and Development of Paprika Chilli (*Capsicum annuum* L.)

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Abstract

To study the influence of different soilless growing systems and nutrient concentrations of Hoagland's solution on per cent survival of seedlings, plant height, growth rate, leaf area, chlorophyll content, number of flowers per inflorescence, days to flower initiation, days to 50 per cent flowering and days to maturity in paprika chilli at various growth stages, the study was conducted at AICRP on Seed (Crops), UAS, GKVK, Bengaluru during 2021-2023. The results revealed that, among the treatments, paprika chilli crop grown in Dutch buckets (using clay balls as growing medium) with 100 per cent (full strength) Hoagland's solution influenced the performance of chilli plants under greenhouse condition and showed significantly highest per cent survival of seedlings (100%) at 20 DAT, highest plant height (165.38 cm), plant growth rate (0.09 cm), leaf area (1591.79 cm^2), chlorophyll content (56.86) at 180 DAT, number of flowers per inflorescence at 60 DAT (15.67), and took significantly less days to maturity (119.06) which was followed by Dutch bucket with 10 per cent increase in 100 per cent Hoagland's solution for every 20 days compared to control (98.67%, 154.28 cm, 0.06 cm, 1370.92 cm^2, 44.21, 12.66 and 120.94, respectively). Whereas, 50 per cent Hoagland's solution (half strength) showed comparatively less performance both in Dutch buckets and grow bags over control. Paprika chilli grown in Dutch buckets with 100 per cent Hoagland's solution improved the crop performance and seed quality compared to control and other methods. Hence, this could be exploited for commercial soilless seed production of paprika chilli.

Keywords : Soilless growing systems, Hoagland's solution, Paprika chilli

Paprika chilli (*Capsicum annuum*) is an economically important vegetable crop grown worldwide used for food as well as in traditional medicine. It belongs to the family *Solanaceace*, with the chromosome number 2n = 24, and is mainly valued for its high colour, low pungency and high oleoresins. In India it is ranked second among solanaceous vegetable crops after tomato. Presence of pepper-specific secondary metabolites, capsaicinoids, which confer pungency in fruits and have various medicinal effects, made it an important part of diet (Anilkumar and Mohan, 2018). The fruits contain capsaicinoids (Capsaicin and dihydrocapsaicin) which give them the distinctive pungent taste (Berke and Shieh, 2012) and an oil, oleoresin (colouring agent) extracted from these chillies and used in the preparation of nail polish and lipsticks (Veena and Krishnamurthy, 2023). In recent years, soilless growing systems, such as Dutch buckets and grow bags, have gained popularity due to their potential advantages over traditional soil-based cultivation. Additionally, Hoagland's solution, a nutrient-rich hydroponic solution, is commonly used

to supply essential nutrients to plants in soilless systems (Kinoshita *et al.,* 2016 and Rodriguez-Ortega *et al.,* 2017).

Soilless growing systems provide an alternative approach to traditional soil-based cultivation, offering better control over nutrient delivery and water management under controlled environment condition (Sezen *et al.,* 2006). Hoagland's solution, a well-known hydroponic nutrient solution, has been extensively used to support plant growth and development in various soilless systems. However, the optimal combination of soilless growing system and Hoagland's solution concentration for paprika chilli growth remains largely unexplored (Beibel, 1960).

Material and Methods

Experimental Setup : A completely randomized design (CRD) with three replications was employed for this experiment. Paprika chilli plants were grown in two different soilless growing systems: Dutch buckets and grow bags. Additionally, four different Hoagland's solution concentrations were tested: full strength (100%), half strength (50%), higher strength (150%), and a progressive increase in concentration over time (10% increase in 100% concentration every 20 days up to 120 days) along with a control. A comparative group was maintained with traditional soil-based cultivation.

Preparation of Nutrient Solution: Different concentrations (505, 1005, 1505 and 10% increase to 100% for every 20 days) of Hoagland's solution (Hoagland and Arnon, 1950) were prepared and after the preparation, pH was adjusted to 5.5 to 6.5. The pH of nutrient solution was measured using pH meter for every 6 days interval. Following is the nutrient composition:

- Full-strength Hoagland's solution (100%) (ppm): N-210, P-31, K-234, Ca-200, Mg-34, S-64, Na-0.02, Cl-0.14, Fe-2.5, Mn-0.5, Zn-0.1, B-0.5, Cu-0.02, Mo-0.04
- Half strength Hoagland's solution (100% - 50 % N, P, K and Ca) (ppm): N-105, P-15.5, K-117, Ca-100, Mg-17, S-64, Na-0.02, Cl-0.14, Fe-2.5, Mn-0.5, Zn-0.1, B-0.5, Cu-0.02, Mo-0.04
- Higher strength Hoagland's solution (100% + 50 % N, P, K and Ca) (ppm): N-315, P-46.5, K-351, Ca-300, Mg-51, S-64, Na-0.02, Cl-0.14, Fe-2.5, Mn-0.5, Zn-0.1, B-0.5, Cu-0.02, Mo-0.04
- 10 per cent increase in concentration of Hoagland's solution for every 20 days after transplanting (ppm): 20 DAT- 100% + 10 %, 40 DAT- 100% + 20 %, 60 DAT- 100% + 30 %, 80 DAT- 100% + 40 %, 100 DAT- 100% + 50 %

Seed Source and Raising of Seedlings : Fresh seeds of paprika chilli variety OAL-1 was obtained from Omni Activa Private Limited, Bengaluru and were used for various studies. Fresh seeds of paprika chilli variety OAL-1 were treated with carbendazim (2g kg^{-1} of seeds) (Anonymos, 2022) by dry dusting method before sowing in protrays to protect the seedlings from diseases. The treated seeds were sown on coco-peat in portrays and necessary seedling protections were taken and watered regularly for twenty eight days until transplanting.

Table 1

Treatment details of the experiment

Control	Soilless growing systems	Different nutrient concentrations
Soil	Dutch buckets	• Full strength (100 %) Hoagland's solution (Control)
		• Half strength (50 %) Hoagland's solution (Control – 50 % N, P, K, Ca and Mg).
	Grow bags	• Higher strength (150 %) Hoagland's solution (Control +50 % N, P, K, Ca and Mg).
		• 10 % increase in 100 % Hoagland's solution concentration for every 20 days after transplanting (Up to 120 days)

TABLE 2
Treatment combinations of the experiment

Treatments	Soilless growing systems	Different nutrient concentrations
T_0	-	Recommended dose of fertilizer (RDF) a/c to UHS, Bagalkot
T_1	Dutch buckets	Full strength (100%) Hoagland's solution (Control)
T_2	Dutch buckets	Half strength (50%) Hoagland's solution (Control – 50% N, P, K, Ca and Mg).
T_3	Dutch buckets	Higher strength (150%) Hoagland's solution (Control +50% N, P, K, Ca and Mg).
T_4	Dutch buckets	10 % increase in 100% Hoagland's solution concentration for every 20 days after transplanting (Up to 120 days)
T_5	Grow bags	Full strength (100%) Hoagland's solution (Control)
T_6	Grow bags	Half strength (50%) Hoagland's solution (Control – 50% N, P, K, Ca and Mg).
T_7	Grow bags	Higher strength (150%) Hoagland's solution (Control +50% N, P, K, Ca and Mg).
T_8	Grow bags	10% increase in 100% Hoagland's solution concentration for every 20 days after transplanting (Up to 120 days)

Transplanting: In soil system (control), pots were filled with soil and were used to transplant twenty-eight days old paprika chilli seedlings with recommended dose of fertilizer (RDF) (60:30:30 NPK/acre) as per the package of practices of UHS, Bagalkot. This soil based method was used as control and maintained in the same poly house. While in Soilless growing systems *viz.,* Dutch buckets and Grow bags were used for soilless paprika chilli seed production by using clay balls and coco peat as growing medium, respectively and used for transplanting of seedlings. After transplanting, different concentrations of Hoagland's solution was given regularly until the harvest.

In Dutch bucket Hydroponics, plants were placed in individual Dutch buckets and the growing medium (clay balls) was filled around the roots to provide stability. Then, the water pump circulates the nutrient solution from the reservoir through the distribution lines into the Dutch buckets. The nutrient solution was delivered to the root zone of the plants via drip emitters or drip lines. Excess nutrient solution not absorbed by the plants drains through the drainage holes at the bottom of the Dutch buckets and returns to the reservoir. This ensures that, the growing medium and roots do not become waterlogged. The nutrient solution was continuously recirculated from the reservoir through the Dutch buckets, ensuring a constant supply of nutrients to the plants. Constant monitoring of pH and nutrient levels of the solution was done regularly to maintain the proper nutrient balance for optimal plant growth. Additionally, periodic flushing of the system also helped to prevent nutrient buildup and maintain system health.

In Grow Bag Cultivation, the grow bags were filled with the cocopeat growing medium, which was pre-moistened to ensure proper hydration. Then, the seedlings were placed in the grow bags and their roots were nestled into the growing medium. Proper spacing between plants was maintained to allow for optimal growth. Then, the nutrient solution was supplied to the plants through the irrigation system. Drip emitters or hand watering cans deliver the nutrient solution directly to the root zone of the plants. Excess nutrient solution that is not taken up by the plants drains through the permeable walls of the grow bags. This ensures that the growing medium and roots do not become waterlogged. Constant monitoring of the moisture levels of the growing medium and pH and nutrient levels of the solution was done regularly to maintain the proper nutrient balance for optimal plant growth. Periodic flushing of the system also helped to prevent nutrient buildup and maintain system health.

Data analysis: Plant height was recorded at 30, 60, 90, 120 and 180 days after transplanting (DAT). Plant

growth rate was calculated as the change in plant height per day. Leaf area was measured using a leaf area meter at the same time points. Chlorophyll content was assessed using a chlorophyll meter. The number of flowers per inflorescence was counted at 30 and 60 DAT. The data were subjected to appropriate statistical procedure as suggested by Gomez and Gomez (1984).

Results and Discussion

The data on influence of soilless growing systems on growth parameters *viz.,* per cent survival of seedlings, plant height (cm), plant growth rate (cm), leaf area (cm^2), chlorophyll content, number of flowers per inflorescence, days to flower initiation, days to 50 per cent flowering and days to maturity are presented in Table 1-5, Fig. 1-4 and discussed in the following paragraph.

Per cent Survival of Seedlings: The results showed significant variations in per cent survival of seedlings across different treatments. Highest (100%) per cent of seedlings were survived under soilless growing systems and the lowest was recorded in control (98.7%) (Fig. 1).

Highest per cent survival of seedlings in soilless system was due the use of clay balls and cocopeat as growing media, which increases the porosity and

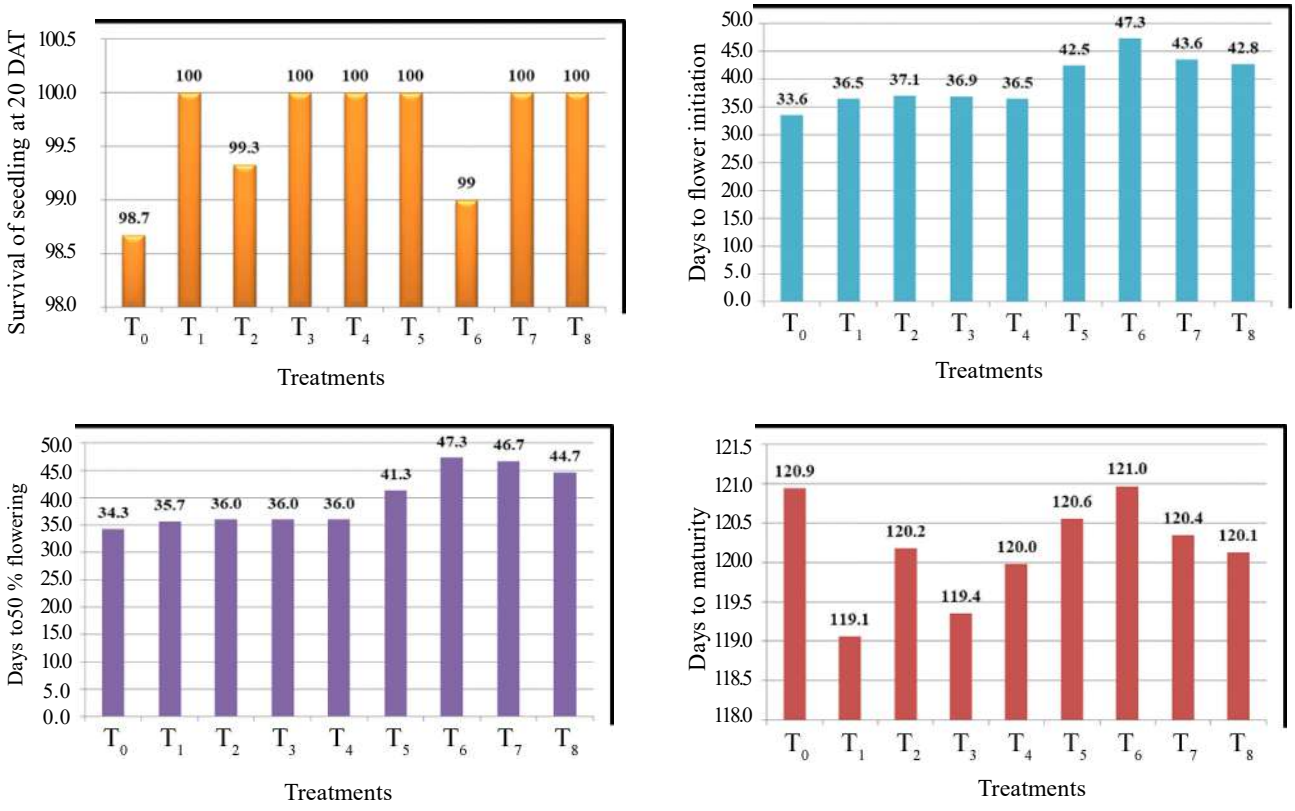

Fig. 1: Influence of soilless growing systems and nutrient concentration of Hoagland's solution on per cent survival of seedlings at 20 DAT, days to flower initiation, days to 50 % flowering and days to maturity in paprika chilli

Treatments: [T_0: Control (soil), T_1: Dutch bucket with full strength Hoagland's solution (100 %), T_2: Dutch bucket with half strength Hoagland's solution (50 %), T_3: Dutch bucket with higher strength Hoagland's solution (150 %), T_4: Dutch bucket with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days), T_5: Grow bag with full strength Hoagland's solution (100 %), T_6: Grow bag with half strength Hoagland's solution (50 %), T_7: Grow bag with higher strength Hoagland's solution (150 %), T_8: Grow bag with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)]. DAT: Days after Transplanting

amount of oxygen in the growing medium, which can increase vegetative and reproductive growth. Whereas, more seedlings mortality under soil condition (control) was primarily because soils has less aeration, porosity and drainage required (Aslanpour *et al.,* 2019).

Plant Height: The results showed significant variations in plant height across different treatments and growth stages. At 30 DAT, the highest plant height was recorded in the Dutch bucket with full strength Hoagland's solution (62.34 cm), while the control group had the lowest height (52.53 cm). However, at 180 DAT, the plants in the Dutch bucket with full strength Hoagland's solution (165.38 cm) and Dutch bucket with 10 per cent increase in concentration (159.37 cm) outperformed over control (154.28 cm) (Table 3).

Plant Growth Rate: The plant growth rate data indicated that the Dutch bucket with full strength Hoagland's solution resulted in the highest growth rate at all throughout crop growth period, followed by the Dutch bucket with a 10 per cent increase in concentration. The control had the lowest growth rate throughout the experiment (Table 4).

Highest plant height and plant growth rate in soilless growing systems were due to the better maintenance of plant nutrition in soil-less culture (Hoagland's) with optimum pH of 5.5-6.5 as stated by Wan *et al*. (1994), Gericke (2007), Singh (2013), Hojhabrian (2014) and Dysko *et al*. (2015), which enhances the root growth in turn leads to absorption of nutrients more efficiently leading to higher plant height and plant growth rate under soil-less system (Shah *et al*., 2011).

Leaf Area : Leaf area measurements exhibited significant differences among treatments and growth stages. The highest leaf area was observed in the Dutch bucket with full strength Hoagland's solution, while the lowest leaf area was found in the grow bag with half strength Hoagland's solution (Table 5).

Chlorophyll Content: Chlorophyll content varied among treatments, with the Dutch bucket with full strength Hoagland's solution consistently having the highest chlorophyll levels at most of the crop growth

TABLE 3

Influence of soilless growing systems and nutrient concentration of Hoagland's solution on plant height (cm) at 30, 60, 90, 120 and at 180 DAT in paprika chilli

Treatments	Plant height (cm)				
	30 DAT	60 DAT	90 DAT	120 DAT	180 DAT
T_0: Control	52.53	95.69	143.49	150.47	154.28
T_1: Dutch bucket with full strength Hoagland's solution (100 %)	62.34	117.60	152	160.27	165.38
T_2: Dutch bucket with half strength Hoagland's solution (50 %)	56.83	97.63	114.78	123.92	138.59
T_3: Dutch bucket with higher strength Hoagland's solution (150 %)	58.22	98.56	127.35	137.99	144.18
T_4: Dutch bucket with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	61.70	112.65	147.34	154.41	159.37
T_5: Grow bag with full strength Hoagland's solution (100 %)	36.58	62.83	87.47	95.73	103.52
T_6: Grow bag with half strength Hoagland's solution (50 %)	32.07	49.30	71.79	77.97	85.36
T_7: Grow bag with higher strength Hoagland's solution (150 %)	30.27	57.90	90.21	93.79	100.20
T_8: Grow bag with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	29.42	51.93	88.56	97.23	104.40
Mean	46.66	82.68	113.67	121.31	128.37
S.Em±	0.92	0.95	1.18	1.34	1.28
CD (P=0.05)	2.74	2.84	3.53	4.01	3.83
CV (%)	3.40	1.99	1.80	1.91	1.72

TABLE 4

Influence of soilless growing systems and nutrient concentration of Hoagland's solution on plant growth rate (cm) at 30, 60, 90, 120 and at 180 DAT in paprika chilli

Treatments	Plant growth rate (cm)				
	30 DAT	60 DAT	90 DAT	120 DAT	180 DAT
T_0: Control	1.15	1.44	1.59	0.23	0.06
T_1: Dutch bucket with full strength Hoagland's solution (100 %)	1.48	1.84	0.92	0.28	0.09
T_2: Dutch bucket with half strength Hoagland's solution (50 %)	1.29	1.36	0.57	0.30	0.08
T_3: Dutch bucket with higher strength Hoagland's solution (150 %)	1.34	1.35	0.96	0.36	0.10
T_4: Dutch bucket with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	1.46	1.70	1.16	0.24	0.08
T_5: Grow bag with full strength Hoagland's solution (100 %)	0.62	0.88	0.82	0.28	0.13
T_6: Grow bag with half strength Hoagland's solution (50 %)	0.47	0.57	0.75	0.21	0.12
T_7: Grow bag with higher strength Hoagland's solution (150 %)	0.41	0.92	1.07	0.28	0.14
T_8: Grow bag with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	0.38	0.75	1.22	0.29	0.12
Mean	0.96	1.20	1.01	0.27	0.10
S.Em±	0.03	0.04	0.04	0.02	0.01
CD (P=0.05)	0.09	0.11	0.13	0.05	0.03
CV (%)	5.53	5.15	7.22	11.41	18.52

TABLE 5

Influence of soilless growing systems and nutrient concentration of Hoagland's solution on plant leaf area (cm^2) at 30, 60, 90, 120 and at 180 DAT in paprika chilli

Treatments	Leaf area (cm^2)				
	30 DAT	60 DAT	90 DAT	120 DAT	180 DAT
T_0: Control	453.19	1369.14	1635.54	1839.44	1370.92
T_1: Dutch bucket with full strength Hoagland's solution (100 %)	856.64	2228.59	2410.28	2484.92	1591.79
T_2: Dutch bucket with half strength Hoagland's solution (50 %)	646.29	949.32	1141.68	1272.40	781.29
T_3: Dutch bucket with higher strength Hoagland's solution (150 %)	701.07	1319.46	1404.57	1632.01	1110.87
T_4: Dutch bucket with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	766.77	1728.96	1782.11	1841.84	1449.75
T_5: Grow bag with full strength Hoagland's solution (100 %)	697.60	957.65	1196.60	1623.21	1292.44
T_6: Grow bag with half strength Hoagland's solution (50 %)	308.13	469.18	724.34	930.51	466.65
T_7: Grow bag with higher strength Hoagland's solution (150 %)	365.40	641.53	1140.29	1237.41	666.60
T_8: Grow bag with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	441.22	883.40	1177.21	1515.37	1118.71
Mean	581.81	1171.92	1401.40	1597.46	1094.34
S.Em±	42.41	42.68	57.93	54.70	63.24
CD (P=0.05)	126.97	127.79	173.44	163.79	189.35
CV (%)	12.62	6.31	7.16	5.93	10.01

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TABLE 6

Influence of soilless growing systems and nutrient concentration of Hoagland's solution on chlorophyll content at 30, 60, 90, 120 and at 180 DAT in paprika chilli

Treatments	Chlorophyll content (SPAD value)				
	30 DAT	60 DAT	90 DAT	120 DAT	180 DAT
T_0: Control	50.70	61.84	58.87	47.87	44.21
T_1: Dutch bucket with full strength Hoagland's solution (100 %)	52.43	65.81	71.99	59.16	56.86
T_2: Dutch bucket with half strength Hoagland's solution (50 %)	50.24	55.05	53.99	47.82	44.28
T_3: Dutch bucket with higher strength Hoagland's solution (150 %)	50.48	57.56	54.98	58.40	53.42
T_4: Dutch bucket with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	50.81	62.36	64.21	58.62	56.81
T_5: Grow bag with full strength Hoagland's solution (100 %)	48.63	53.69	58.97	57.78	56.53
T_6: Grow bag with half strength Hoagland's solution (50 %)	43.19	45.04	48.23	45.09	43.66
T_7: Grow bag with higher strength Hoagland's solution (150 %)	45.83	47.46	56.74	54.95	54.11
T_8: Grow bag with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	48.24	50.40	58.61	55.40	55.57
Mean	48.95	55.47	58.51	53.90	51.72
S.Em±	1.02	1.89	1.24	3.42	2.86
CD (P=0.05)	3.05	5.65	3.70	10.25	8.56
CV (%)	3.60	5.90	3.66	11.00	9.58

stages. However, the lowest was recorded in Grow bags with half strength Hoagland's solution (Table 6).

Under soilless cultivation, highest leaf area and chlorophyll content were observed because of the use of different organic and inorganic substrates in appropriate proportion which optimizes water and oxygen holding and allows the plants better nutrient uptake for sufficient growth and development (Ayesha *et al*., 2011 and Hesami *et al*., 2012). Nourizadeh (2003) and Raja *et al*. (2018) also reported that, inert media (clay balls, cocopeat, perlite) used in soilless cultivation to be effective due to better interchange of the elements especially cations inside the substrate and proper moisture distribution that improves root system and finally plant and leaf characteristics. Whereas, less leaf area and chlorophyll content in T_6 (Grow bag with 50% Hoagland's solution) might be due to the non-availability of sufficient nutrients (Shah *et al*., 2011) to the growing plants and also due to aeration problem in case of grow bags which might negatively affect the plant vegetative growth during crop growth period (Aslanpour *et al*., 2019).

Number of Flowers per Inflorescence: The number of flowers per inflorescence was significantly affected by the treatments. The Dutch bucket with full strength Hoagland's solution and the Dutch bucket with a 10 per cent increase in concentration exhibited the highest number of flowers per inflorescence at 30 and 60 DAT (Table 7).

Days to flower initiation: The data on number of days for flower initiation indicated that, least number of days taken for flower initiation was noticed in control (33.6), which was on par with Dutch bucket with full strength Hoagland's solution (36.5) (Fig. 1).

Days to 50 per cent flowering: The number of days for 50 per cent flowering was significantly affected by the treatments. The Dutch bucket with full strength Hoagland's solution took least number of days and grow bag with half strength Hoagland's solution took more days for 50 per cent flowering (Fig. 1).

LECA balls in dutch buckets holds sufficient amount of necessary nutrients required for plant growth. Therefore, more number of flowers per inflorescence

TABLE 7

Influence of soilless growing systems and nutrient concentration of Hoagland's solution on number of flowers per inflorescence at 30 and 60 DAT in paprika chilli

Treatments	Number of flowers per inflorescence	
	30 DAT	60 DAT
T_0: Control	0.82	12.66
T_1: Dutch bucket with full strength Hoagland's solution (100 %)	1.33	15.67
T_2: Dutch bucket with half strength Hoagland's solution (50 %)	0.81	10.73
T_3: Dutch bucket with higher strength Hoagland's solution (150 %)	1.27	12.67
T_4: Dutch bucket with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	1.29	12.89
T_5: Grow bag with full strength Hoagland's solution (100 %)	1.36	12.73
T_6: Grow bag with half strength Hoagland's solution (50 %)	0.75	6.55
T_7: Grow bag with higher strength Hoagland's solution (150 %)	0.94	10.87
T_8: Grow bag with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	1.21	11.55
Mean	1.09	11.81
S.Em±	0.05	0.74
CD (P=0.05)	0.14	2.23
CV (%)	7.24	10.91

were present in Dutch bucket with 100 per cent Hoagland's solution (T_1) due to the availability of all the necessary nutrients to the growing plants during cropping period by 100 per cent Hoagland's solution. Less number of flowers per inflorescence were observed in Grow bags with 50 per cent Hoagland's solution due to the unavailability of the necessary nutrients to the growing plants in 50 per cent Hoagland's solution (Cooper's 1988 and Imai's 1987). However, days to flower initiation and days to 50 per cent flowering is greatly affected by the fluctuation of pH of the nutrient solution (Hoagland's solution) which slowed down the vegetative growth, survival of the plants and ultimately resulted in early or delay in flowering as stated by Shah *et al.,* 2011. However, this was also influenced genetically and physiologically.

Days to maturity: The number of days taken for maturity was not affected by the treatments. However, Dutch bucket with full strength Hoagland's solution took least number of days for maturity compared to control (Fig. 1).

Fruit maturity was found early in soil-less agriculture system compared to soil system as there was early flowering and higher availability of resources while in conventional agriculture plant should invest more energy for withstanding stress. These results are in line with the results of the research conducted by Maboko and Plooy (2009) in tomato and Shah and Shah (2009) in lettuce crop.

The results demonstrated that, the choice of soilless growing system and Hoagland's solution concentration significantly impacts paprika chilli growth and development. The Dutch bucket with full strength Hoagland's solution consistently outperformed other treatments in terms of per cent survival of seedlings, plant height, growth rate, leaf area, chlorophyll content, flower production, days to flower initiation, 50 per cent flowering and maturity.

The highest per cent survival of seedlings, plant height, growth rate, leaf area and chlorophyll content in the Dutch bucket with full strength Hoagland's solution indicated that, the plants received an adequate

and balanced supply of essential nutrients. The progressive increase in Hoagland's solution concentration also had a positive impact on growth, albeit less than the full strength solution. On the other hand, the grow bag with half strength Hoagland's solution showed relatively inferior results compared to the other treatments, suggesting that nutrient limitations affected plant growth.

The days to maturity data did not show significant differences among treatments, indicating that the plants were likely not limited by nutrient availability for maturity.

The study highlights the importance of selecting an appropriate soilless growing system and nutrient concentration to maximize paprika chilli growth and yield. The Dutch bucket with full strength Hoagland's solution emerged as the most favorable treatment in terms of plant height, growth rate, leaf area, chlorophyll content and flower production. The findings contribute to optimizing soilless cultivation practices for paprika chilli and potentially other vegetable crops. Further research could explore additional parameters such as fruit yield, nutritional content and water use efficiency to gain a comprehensive understanding of the interactions between soilless growing systems, nutrient concentrations and crop performance in paprika chilli cultivation.

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