Biological Forum – An International Journal **15(10): 929-937(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

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

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(Received: 15 August 2023; Revised: 08 September 2023; Accepted: 30 September 2023; Published: 15 October 2023)
(Published by Research Trend)

ABSTRACT: The experiment was conducted at AICRP on Seed (Crops), UAS, GKVK, Bangalore during 2022-2023. Two different soilless growing systems (Dutch buckets and Grow bags) and four different nutrient concentrations of Hoagland's solution (50%, 100%, 150% and 10% increase in 100% solution for every 20 days) were evaluated by keeping soil as control to study their influence on growth and yield of paprika chilli. The results revealed that, among the treatments, crop grown in Dutch buckets with 100% Hoagland's solution (T_1) had significantly highest seedling survival (100%) at 20 DAT, plant height (165.38cm), leaf area (1591.79cm^2), chlorophyll content (56.86), number of branches (28.67), net assimilation rate (0.00083 mgcm^{-2} day^{-1}) and shows early maturity (119.06) compared to control (98.67%, 144.18cm, 1110.87cm^2, 44.28, 23.67, 0.00058 mgcm^{-2} day^{-1} and 120.94, respectively). It is also observed that, 100% Hoagland's solution in Dutch bucket showed maximum fruit length and diameter (17.15 and 1.60cm), total number of fruits per plant (67.27), fruit weight (6.46g), fruit yield (379.01 g/plant and 58.75 q/ha), number of seeds per fruit (51.00), seed weight (3.17g/fruit), seed yield (16.42 g/plant and 254.51 kg/ha), seed to fruit recovery percentage (4.35%), total biomass (120.82g/plant), and harvest index (3.14) over control (15.69cm, 1.41cm, 55.73, 4.84g, 258.50g/plant, 40.07q/ha, 41.27, 1.61g/fruit, 10.42g/plant, 161.51kg/ha, 3.98%, 91.10g/plant and 2.84, respectively). Whereas, 50% Hoagland's solution performed comparatively less in both Dutch buckets and Grow bags over control. Chilli crop grown in Dutch buckets with 100 % Hoagland's solution improved the crop performance, fruit and seed yield compared to control and other soilless treatments. Hence, this could be exploited for commercial seed production of chilli.

Keywords: Soilless Growing Systems, Hoagland's Solution, Dutch buckets, Grow bags, Paprika Chilli.

INTRODUCTION

Paprika chilli (*Capsicum annuum* L.) is a major vegetable and spice crop which is native to Hungary. It is distributed across the world, used for food as well as in traditional medicine and it belongs to the family *Solanaceace*, with the chromosome number 2n = 24. Paprika chilliis mainly valued for its high colour, low pungency and high oleoresins and is ranked second among solanaceous vegetable crops after tomato. The species Capsicum originated in Mexico with centre of diversity in South America. Presence of pepper-specific secondary metabolites, capsaicinoids, confers pungency in fruits and have various medicinal effects and these made it an important part of diet (Anilkumar and Mohan 2018).

Paprika chilli is having abundant source of vitamin C (175 mg/100 g), vitamin A and E and reported to have antioxidant, anti-carcinogenic, anti-mutagenic, anti-aging and antibacterial properties (Chu *et al.*, 2002). It is typically dried and ground to make the powdered spice. The paprika chilli is fairly large red pepper and quite long, growing up to 8 inches, and lends a unique spiciness to paprika powder. The fruits contain capsaicinoids which give them the distinctive pungent taste. Capsaicin and dihydrocapsaicin, the two main capsaicinoids which are usually lower in paprika than in other plants of the same genus (Berke and Shieh 2012) and an oil, oleoresin (colouring agent) extracted from these chillies which is used in the preparation of nail polish and lipsticks (Veena and Krishnamurthy 2023).

In world, the production of paprika is around 4.03M mt. The major paprika producers in the world are India (42.24 %), followed by Thailand (8.01 %), China (7.63 %), Ethiopia (7.35 %), Bangladesh (3.91 %), Pakistan (3.51 %), Myanmar (3.5 %), Benin (2.7 %) and Ghana (2.69 %). In India, currently, the production of paprika is 1.70M mt (Anon., 2022) and the major paprika producing states are Andhra Pradesh, Telangana, Madhya Pradesh, Karnataka, West Bengal, Orissa, Gujarat, Assam, *etc.*

Paprika chillies (*Capsicum annuum* L.) are highly sensitive to environmental conditions; therefore, most of the peppers are grown in greenhouses with soilless

culture systems, where the microclimate can be precisely controlled (Sezen *et al.,* 2006). Currently, about 3.5 per cent of the world wide area depends ontunnels and greenhouses for vegetables production by adopting soil-less technique based on hydroponic principle such as floating systems, wick system, nutrient film technique or aeroponics (Hickman, 2016). Increasingly greenhouse farming and urban agriculture are being looked at as more efficient and cost-effective way to produce vegetables (Kinoshita *et al.,* 2016; Rodriguez-Ortega *et al.,* 2017).

Seeds are the pivotal hub of agriculture and quality seed is a key component for the successful agriculture, where the main objective is each seed should germinate and produce a vigorous seedling which ensures higher seed yield. As a rule of thumb, the soil is usually the most available growing medium for plants, where it provides anchorage, nutrients, air, water, *etc.* for successful plant growth and for microorganisms (Sepehri *et al.,* 2018). Since, the traditional soil culture employed in paprika chilli seed production lacks robust and economic viability under the diverse and un predictable climatic factors, recurrent disease *viz.*, powdery mildew, anthracnose, chilli leaf curl, pepper mild mottle, bacterial spot, alternaria, *etc.*, which could cause yield loss up to 10-15 per cent. Pest outbreak (Aphids, Thrips, Heliothis bollworm) and nematodes in soil also causes stunted growth, wilting and turns the plant into yellow colour. Hence, it is necessary to conduct soil treatments using either chemical or thermal methods that are not environmentally friendly.

Therefore, soilless culture techniques have been developed and it involves the techniques of cultivation of plants without using soil (Beibel, 1960) or by using an inert medium, such as coco peat, peat moss, wood chips, clay balls (hydrotons), bark, sand, gravel, perlite, vermiculite, rice hull, rock wool, pumice, zeolite, volcanic tuff, *etc.* (Sevgican, 1999). This system helps to avoid plant growing problems such as soil salinity, lack of fertile soil and soil–borne diseases (Alan, 1990) and contributes to the improvement of plant growth, earliness, yield (Grangvist, 1981) and finally increases crop quality, which results in higher competitiveness and economic incomes (Tuzel *et al*., 2006) and also helps in saving water up to 85-90 per cent. Therefore, with the review of above points, a comprehensive investigation is envisaged to study the impact of different soilless systems on plant growth and yield of paprika chilli.

MATERIAL AND METHODS

The present investigation was carried out in the AICRP on Seed (Crops), University of Agricultural Sciences, Gandhi Krishi Vigyan Kendra, Bangalore during 2022 to 2023 which was situated between 13° 05' N latitude and 77° 34' E longitude at an altitude of about 924 m above mean sea level (MSL). The experiment was conducted in poly house under controlled condition and the objective of this study was to study the impact of different soilless systems on plant growth and yield of paprika chilli. The experiment was laid out using Completely Randomized Design (CRD) with three replications and nine treatments. Seeds of paprika chilli variety OAL-1 were sown in pro trays. Two types of growing media *viz*., clay balls and coco peat were tested in dutch buckets and in grow bags, respectively by supplying Hoagland's nutrient solution. The treatments included in the experiment were mentioned below

Treatment details of the experiment.

Treatments	Growing systems	Different nutrient concentrations
T_0	Soil	-
T_1	Dutch buckets	Full strength Hoagland's solution (100%)
T_2	Dutch buckets	Half strength Hoagland's solution (100% – 50 % N, P, K, Mg and Ca).
T_3	Dutch buckets	Higher strength Hoagland's solution (100% +50 % N, P, K, Mg and Ca).
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 Hoagland's solution (100%)
T_6	Grow bags	Half strength Hoagland's solution (100% – 50 % N, P, K, Mg and Ca).
T_7	Grow bags	Higher strength Hoagland's solution (100% +50 % N, P, K, Mg and Ca).
T_8	Grow bags	10 % increase in 100 %Hoagland's solution concentration for every 20 days after transplanting (Up to 120 days)

— Nutrient composition of Full strength Hoagland's solution (100%) in ppm:

N-210, P-32, K-234, Ca-200, Mg-48, 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

— Nutrient composition of Half strength Hoagland's solution (100%-50 % N, P, K and Ca) in ppm:

N-105, P-15.5, K-117, Ca-100, Mg-24, 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

— Nutrient composition of Higher strength Hoagland's solution (100%+50 % N, P, K and Ca) in ppm:

N-315, P-46.5, K-351, Ca-300, Mg-72, 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

— Nutrient composition of 10 % increase in concentration of 100 % Hoagland's solution for every 20 days after transplanting in ppm:

20 DAT- 100% + 10 %, 40 DAT- 100% + 20 %, 60 DAT- 100% + 30 %, 80 DAT- 100% + 40 %, 100 DAT- 100% + 50 %

Seed source. For the present study, fresh seeds of paprika chilli variety OAL-1 were obtained from Omni Activa Private Limited, Bangalore. The collected seeds of OAL-1 variety were fresh and untreated, and were used for various studies.

Seed treatment and seedling preparation. The healthy, fresh and bold seeds of paprika chilli variety OAL-1 were treated with carbendazim (2g kg^{-1} of seeds) by dry dusting method before sowing in protrays to protect the seedlings from diseases and were dried in shade. The treated seeds were sown on coco-peat in protrays. Necessary seedling protections were taken and watered regularly until transplanting.

Preparation of nutrient solution. Different concentrations (50%, 100%, 150% and 10 % increase to 100% for every 20 days) of Hoagland's nutrient solutions (Hoagland and Arnon. 1950) were prepared. After the preparation, pH was adjusted to 5.5 to 6.5 and the pH of nutrient solution was measured using pH meter for every 6 days interval.

Transplanting

Soil system (Control). In soil system (control), pots were filled with red lateritic soil which was collected from AICRP on Seed (Crops), UAS, GKVK, Bangalore and was used to transplant twenty-eight days old paprika chilli seedlings with recommended dose of fertilizer (RDF) as per the package of practices of UHS, Bagalkot (60:30:30 NPK kg/acre). This soil based method was used as control and maintained in the same poly house (Plate 1a).

Soilless growing systems

In soilless growing systems, Dutch buckets (Plate 1b) and Grow bags (Plate 1c) were used for soilless paprika chilli seed production by using clay balls and coco peat as growing medium, respectively. These Dutch buckets (Plate 1b) and Grow bags (Plate 1c) were used for transplanting of twenty-eight days old paprika chilli seedlings. After transplanting, different concentrations [full strength (100%), half strength (50%), higher strength (150%) and 10 % increase to 100% for every 20 days] of Hoagland's solution was given regularly until the harvest.

Data analysis: The treatments were laid out in a Completely Randomized Design (CRD) with three replications and nine treatments. The overall significance of difference among the treatments was tested using critical differences (C.D.) at 5% level of significance. The data were recorded from five selected plants which were tagged from each treatment and the average for every growth and yield parameter was worked out. The influence of soilless growing systems on plant growth and yield of paprika chilli was recorded. The raw data was subjected to appropriate statistical procedure as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Plant Growth parameters

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

Per cent survival of seedlings: The results showed significant variations in per cent survival of seedlings among the 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).

Plant height: The results revealed that, there is a significant variation in plant height among the different treatments and growth stages. At 180 DAT, the plants grown in Dutch bucket with full strength (%) Hoagland's solution (165.38 cm) and Dutch bucket with 10% increase in concentration (159.37 cm) outperformed over control (144.18 cm) (Table 1 and Fig. 2).

Leaf area: Leaf area measurements exhibited significant differences among treatments and growth stages. The highest leaf area (1591.79 cm^2) was observed in the Dutch bucket with full strength (100 %) Hoagland's solution, while the lowest leaf area (466.65 cm^2) was found in the grow bag with half strength (50 %) Hoagland's solution (Table 1).

Chlorophyll content: Chlorophyll content varied among different treatments. Plants grown in Dutch bucket with full strength (100 %) Hoagland's solution consistently having the highest chlorophyll levels (56.86 SPAD value) at 180 DAT. However, the lowest (43.66 SPAD value) was recorded in Grow bags with half strength (50 %) Hoagland's solution (Table 1).

Number of branches: The data recorded on number of branches per plants as influenced by soilless growing systems is presented in Table 1. Number of branches was recorded from the day of transplanting up to 180 days at 30, 60, 90, 120 and at 180 days after transplanting. Significant difference was observed in number of branches per plants among different treatments. At 180 DAT, the higher number of branches per plants (28.67) was recorded in Dutch bucket with full strength Hoagland's nutrient solution (T_1) and the lower number of branches per plants (21.33) was noticed in plant grown in Grow bags with 50 % Hoagland's nutrient solution (T_6).

Net assimilation rate: The result (Table 1) showed that, significantly higher (0.00083) net assimilation rate was noticed in Dutch bucket with full strength Hoagland's nutrient solution (T_1) and the lowest (0.00053) was observed in Grow bags with 50 % Hoagland's nutrient solution (T_6).

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 (119.06) for maturity compared to control (Table 1).

Yield parameters

The data on influence of soilless growing systems on yield parameters *viz.*, fruit length (cm), fruit diameter (cm), fruit length to diameter ratio (cm), number of fruits per plant, fruit weight (g), fruit yield (g/plant), fruit yield (q/ha), number of seeds per fruit, seed weight (g/fruit), seed weight (g/plant), seed yield (kg/ha), seed to fruit recovery (%), total biomass (g/plant) and

harvest index are presented in Table 2-5 and discussed in the following paragraph.

Fruit length and diameter: The data on fruit length and diameter is given in the Table 2. The result showed that, significantly higher fruit length and diameter was recorded in T_1 (17.15 cm and 1.60 cm) which was followed by T_4 (16.79 cm and 1.55 cm) and the lowest fruit length and diameter was recorded in T_6 (14.29 cm) and T_0 (control) (1.41 cm), respectively.

Fruit length to diameter ratio: The data on fruit length to diameter ratio as influenced by soilless growing systems is present in the Table 2. There was no significant difference observed among the different treatments for fruit length to diameter ratio. This might be due to increase in both length and diameter, correspondingly among the treatments. However, the result showed that, higher fruit length to diameter ratio was recorded in T_0 (control) (11.09 cm) which was followed by T_4 (10.95 cm) and the lowest fruit length to diameter ratio was recorded in T_6 (9.98 cm).

Number of fruits and Fruit weight: The observations on total number of fruits per plant and fruit weight as influenced by soilless growing systems are depicted in Table 3. There was a significant difference observed among the different treatments for total number of fruits per plant and fruit weight. The result revealed that, among the different treatments significantly higher number of fruits per plant was recorded in T_1 (67.27) which was followed by T_4 (66.33) and the lowest number of fruits per plant was recorded in T_6 (43.07). Whereas, significantly higher fruit weight was noticed in T_1 (6.46 g) which was followed by T_5 (6.01 g) and the less fruit weight was observed in T_6 (4.46 g).

Fruit yield: Significantly higher fruit yield per plant and per hectare was recorded in T_1 (379.01 g/plant and 58.75 q/ha) which was followed by T_4 (284.03 g/plant and 44.02 q/ha). Whereas, the lower fruit yield per plant and per hectare was recorded in T_6 (161.78 g/plant and 25.08 q/ha). The results pertaining fruit yield is presented in the Table 3.

Number of seeds and Seed weight: The observations related to number of seeds and seed weight as influenced by soilless growing systems is presented in the Table 4. More number of seeds per fruit was noticed in T_1 (51.00) and the less number of seeds per fruit was recorded in T_6(26.60). However, higher seed weight per fruit was noticed in T_1 (3.17 g/plant) which was on par with T_4 (3.00 g/plant) the lower seed weight per fruit was recorded in T_6(0.95 g/plant).

Seed yield and Seed to fruit recovery: Significantly higher seed yield per plant and per hectare (Table 4 and 5) was recorded in T_1 (16.42 g/plant and 254.51 kg/ha) which was followed by T_4 (12.16 g/plant and 188.48 kg/ha). The lower seed yield per plant and per hectare was recorded in T_6 (6.59 g/plant and 102.15 kg/ha). However, the result showed that, higher seed to fruit recovery percentage was recorded in T_1 (4.35 %) which was followed by T_4 (4.29 %) and the lower percentage was recorded in T_6 (3.75 %).

Total biomass and Harvest index: The result related to total biomass of plant and harvest index is presented in the Table 5. There was a significant difference obtained among the different treatments for to total biomass and for harvest index. Among the different treatments significantly higher to total biomass and harvest index was recorded in T_1 (120.82 g/plant and 3.14) which was followed by T_4 (98.54 g/plant and 2.93). Whereas, the lower total biomass and harvest index was recorded in T_6 (81.15 g/plant and 2.00).

DISCUSSION

The present study indicated that all the growth and yield parameters were significantly influenced by different growing media and concentrations of Hoagland's nutrient solution. Almost all the soilless treatments significantly increased the performance of paprika chilli compared to control (soil).Highest per cent survival of seedlings in soilless system was due the use of clay balls and coco peat as growing media, which increases the porosity and amount of oxygen in the growing medium, which further increase vegetative and reproductive growth. Whereas, more seedlings mortality under soil condition (control) was primarily because, soil has less aeration, porosity and drainage required for the plant growth and development (Aslanpour *et al.*, 2019). Highest plant height in soilless growing system was mainly 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); Dysko *et al*. (2015). This further 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). 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; Hesami *et al*., 2012).

Similarly, more number of branches and increased net assimilation rate in soilless system might be due to the availability of all the necessary nutrients to the growing plants. It was also found that, the variation in the vegetative growth (plant height, plant growth rate, leaf area, chlorophyll content, number of branches, *etc.*) may be due to the properties of different materials used as growing substrates, which exhibit direct and indirect effects on plant vegetative growth (Verdonck *et al.,* 1981). Kamal *et al.* (1974) in his study stated that, half and full strength Hoagland nutrient solution significantly increased relative growth rates of stem and root, dry matter accumulation which ultimately leads to the increased net assimilation rate in tomato. 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 increased fruit length, diameter, length to diameter ratio, number of fruits and fruit weight might be due to

increased photosynthetic rate, higher source to sink movement's which had direct relation on fruit size and fruit yield characters as reported by Massantini *et al.* (1988); Gruda (2009) in different vegetable crops, Alan *et al.* (1994); Kanneh *et al.* (2017) in tomato and Kaddi *et al.* (2014) in cucumber. Thapa *et al.* (2016) in his study on the standardization of growing media stated that, sweet pepper (*capsicum annuum* L) when grown under soilless culture showed highest fruit size along with other growth and yield parameters. Total fruit number per plant under soil-less culture is positive as the result of the precise control of the growth elements to the plants such as nutrition, pH, light and temperatures under protected cultivation (Gungor and Yildirim 2013). Similar results for the increase of fruit size and yield parameters under soilless culture were also noticed by Maboko *et al.* (2008); Kanneh *et al.* (2017); Kaur *et al.* (2017) in tomato, Singh *et al.* (2009) in pumpkin, Caguiat and Hautea (2014) in eggplant, Treftz and Omaye (2015) in strawberry and Kaddi *et al.* (2014) in cucumber. Under protected cultivation with soil-less agriculture system, nutrients were available to plants at right time and proportion leading to increased photosynthesis, thus in turn maternal plants could produce more number of seeds which leads to higher seed weight, seed yield, total biomass and harvest index as reported by Muyekho (1993) in cucumber. Singh *et al.* (2009), Bennett *et al.* (2012); Kaddi *et al.* (2014) in cucumber and Paneru *et al.* (2017) in wheat also reported similar results of higher seed yield parameters under soilless cultivation system.

Plate 1: Different growing systems used for the seed production of paprika chilli.

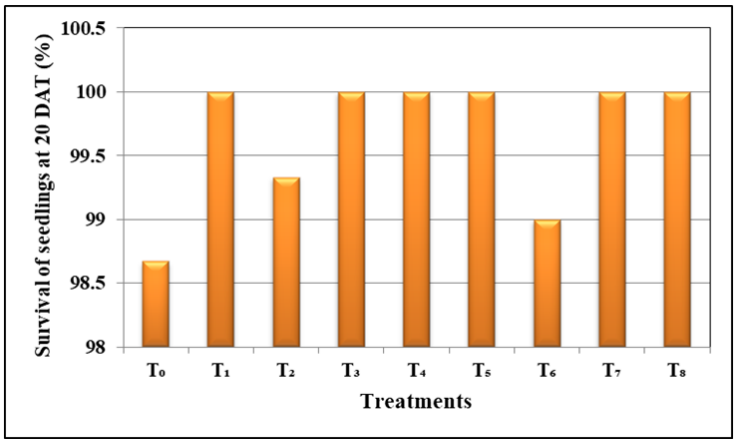

Fig. 1. Influence of soilless growing systems and nutrient concentration of Hoagland's solution on survival of seedlings (%) of paprika chilli.

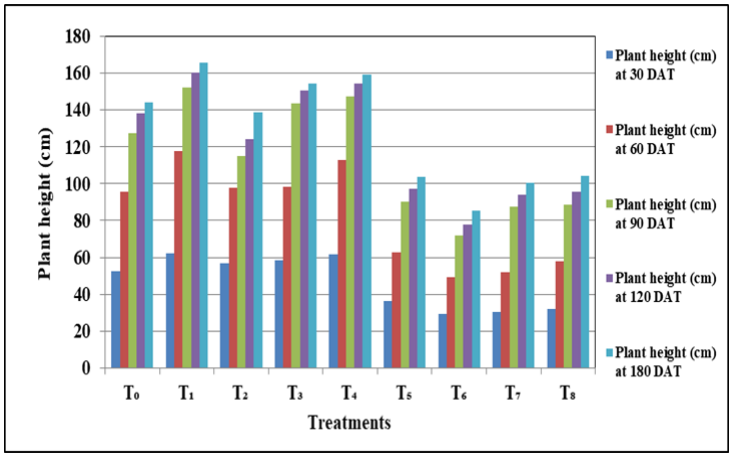

Fig. 2. Influence of soilless growing systems and nutrient concentration of Hoagland's solution on plant height (cm) of paprika chilli.

Table 1: Influence of soilless growing systems and nutrient concentration of Hoagland's solution on plant growth of paprika chilli.

Treatments	Plant height (cm)	Leaf area (cm^2)	Chlorophyll content (SPAD value)	Number of branches	Net assimilation rate ($mg\ cm^{-2}day^{-1}$)	Days to maturity
T_0: Control	144.18	1110.87	44.28	23.67	0.00058	120.94
T_1: Dutch bucket with full strength Hoagland's solution (100 %)	165.38	1591.79	56.86	28.67	0.00083	119.06
T_2: Dutch bucket with half strength Hoagland's solution (50 %)	138.59	781.29	44.21	23.00	0.00054	120.18
T_3: Dutch bucket with higher strength Hoagland's solution (150 %)	154.28	1370.92	56.33	26.33	0.00070	119.35
T_4: Dutch bucket with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	159.37	1449.75	56.81	27.00	0.00074	119.98
T_5: Grow bag with full strength Hoagland's solution (100 %)	103.52	1292.44	55.57	26.00	0.00066	120.56
T_6: Grow bag with half strength Hoagland's solution (50 %)	85.36	466.65	43.66	21.33	0.00053	120.97
T_7: Grow bag with higher strength Hoagland's solution (150 %)	100.20	666.60	53.42	24.33	0.00061	120.35
T_8: Grow bag with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	104.40	1118.71	54.11	25.00	0.00063	120.13
Mean	**128.37**	**1094.34**	**51.72**	**25.04**	**0.00065**	**120.17**
S.Em±	**1.28**	**63.24**	**2.86**	**0.42**	**0.000013**	**0.56**
CD (P=0.05)	**3.83**	**189.35**	**8.56**	**1.25**	**0.000037**	**NS**
CV (%)	**1.72**	**10.01**	**9.58**	**2.88**	**3.36**	**0.81**

Table 2: Influence of soilless growing systems and nutrient concentration of Hoagland's solution on fruit length (cm), fruit diameter (cm) and fruit length to diameter ratio (cm) in paprika chilli,

Treatments	Fruit length (cm)	Fruit diameter (cm)	Fruit length to diameter ratio (cm)
T_0: Control	15.69	1.41	11.09
T_1: Dutch bucket with full strength Hoagland's solution (100 %)	17.15	1.60	10.78
T_2: Dutch bucket with half strength Hoagland's solution (50 %)	15.29	1.42	10.77
T_3: Dutch bucket with higher strength Hoagland's solution (150 %)	15.75	1.52	10.34
T_4: Dutch bucket with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	16.79	1.55	10.95
T_5: Grow bag with full strength Hoagland's solution (100 %)	16.33	1.54	10.57
T_6: Grow bag with half strength Hoagland's solution (50 %)	14.29	1.43	9.98
T_7: Grow bag with higher strength Hoagland's solution (150 %)	15.68	1.49	10.58
T_8: Grow bag with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	16.33	1.52	10.77
Mean	**15.92**	**1.50**	**10.65**
S.Em±	**0.44**	**0.03**	**0.34**
CD (P=0.05)	**1.32**	**0.08**	**NS**
CV (%)	**4.79**	**3.15**	**5.48**

Table 3: Influence of soilless growing systems and nutrient concentration of Hoagland's solution on total number of fruits per plant, fruit weight (g), fruit yield (g/plant) and fruit yield (q/ha) in paprika chilli.

Treatments	Total number of fruits per plant	Fruit weight (g)	Fruit yield (g/plant)	Fruit yield (q/ha)
T_0: Control	55.73	4.84	258.50	40.07
T_1: Dutch bucket with full strength Hoagland's solution (100 %)	67.27	6.46	379.01	58.75
T_2: Dutch bucket with half strength Hoagland's solution (50 %)	54.87	4.80	247.67	38.39
T_3: Dutch bucket with higher strength Hoagland's solution (150 %)	63.60	5.94	278.23	43.13
T_4: Dutch bucket with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	66.33	6.01	284.03	44.02
T_5: Grow bag with full strength Hoagland's solution (100 %)	59.33	5.50	276.91	42.92
T_6: Grow bag with half strength Hoagland's solution (50 %)	43.07	4.46	161.78	25.08
T_7: Grow bag with higher strength Hoagland's solution (150 %)	57.13	4.94	263.82	40.89
T_8: Grow bag with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	59.07	5.37	273.91	40.07
Mean	**58.49**	**5.37**	**269.32**	**41.48**
S.Em±	**1.51**	**0.30**	**15.73**	**1.94**
CD (P=0.05)	**4.52**	**0.90**	**47.10**	**5.81**
CV (%)	**4.47**	**9.70**	**10.12**	**10.12**

Table 4: Influence of soilless growing systems and nutrient concentration of Hoagland's solution on total number of seeds per fruit, seed weight (g/fruit), seed yield (g/plant) and seed yield (kg/ha) in paprika chilli.

Treatments	Number of seeds per fruit	Seed weight (g/fruit)	Seed yield (g/plant)	Seed yield (kg/ha)
T_0: Control	41.27	1.61	10.42	161.51
T_1: Dutch bucket with full strength Hoagland's solution (100 %)	51.00	3.17	16.42	254.51
T_2: Dutch bucket with half strength Hoagland's solution (50 %)	32.60	1.55	9.18	142.29
T_3: Dutch bucket with higher strength Hoagland's solution (150 %)	48.60	2.98	11.38	176.39
T_4: Dutch bucket with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	50.73	3.00	12.16	188.48
T_5: Grow bag with full strength Hoagland's solution (100 %)	46.53	2.85	11.32	175.46
T_6: Grow bag with half strength Hoagland's solution (50 %)	26.60	0.95	6.59	102.15
T_7: Grow bag with higher strength Hoagland's solution (150 %)	44.57	1.62	10.48	162.44
T_8: Grow bag with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	45.13	2.09	11.02	170.81
Mean	**42.97**	**2.20**	**11.00**	**170.45**
S.Em±	**1.23**	**0.14**	**0.42**	**5.13**
CD (P=0.05)	**3.68**	**0.42**	**1.24**	**15.35**
CV (%)	**4.96**	**11.00**	**6.54**	**6.54**

Table 5: Influence of soilless growing systems and nutrient concentration of Hoagland's solution on seed to fruit recovery (%), total biomass (g/plant) and harvest index in paprika chilli.

Treatments	Seed to fruit recovery (%)	Total biomass (g/plant)	Harvest index (HI)
T_0: Control	3.98	91.10	2.84
T_1: Dutch bucket with full strength Hoagland's solution (100 %)	4.35	120.82	3.14
T_2: Dutch bucket with half strength Hoagland's solution (50 %)	3.79	86.92	2.78
T_3: Dutch bucket with higher strength Hoagland's solution (150 %)	4.28	97.93	2.93
T_4: Dutch bucket with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	4.29	98.54	2.93
T_5: Grow bag with full strength Hoagland's solution (100 %)	4.15	97.25	2.89
T_6: Grow bag with half strength Hoagland's solution (50 %)	3.75	81.15	2.00
T_7: Grow bag with higher strength Hoagland's solution (150 %)	4.11	93.20	2.84
T_8: Grow bag with 10 % increase in 100% Hoagland's solution concentration for every 20 days (up to 120 days)	4.14	93.79	2.85
Mean	**4.15**	**95.63**	**2.80**
S.Em±	**0.25**	**5.42**	**0.15**
CD (P=0.05)	**NS**	**16.24**	**0.45**
CV (%)	**10.70**	**9.82**	**9.23**

CONCLUSIONS

In conclusion, the above findings revealed that, when the Hoagland's solution was used as nutrient medium and clay balls and coco peat were used as growing medium for soilless cultivation, chilli plants produced higher vegetative growth, providing that the concentration of Hoagland's solution and quality of growing substrates greatly matters when crops are grown under controlled condition. The chilli crop grown in 100 % concentration of Hoagland's solutions and better water holding capacity of clay balls medium in Dutch bucket influenced the performance of chilli plants under polyhouse condition and significantly showed overall crop performance in terms of highest plant growth, fruit yield and seed yield characters.

FUTURE SCOPE

In future, to avoid the nutrient precipitation, the nano-nutrients can be used which have high stability in the nutrient solution with increased bio-efficiency and also to work out the cost. We can also investigate how soilless cultivation influences the genetic and epigenetic characteristics of paprika chilli and other vegetable crops. This technique allow us to study the seed's tolerance to abiotic stresses, such as drought, salinity, or extreme temperatures.

Author contributions: Conceptualization, investigation, data analysis and original manuscript preparation- Seema A. N; Conceptualization, supervision, review, resources mobilization and editing manuscript- Vishwanath Koti.

Acknowledgements. The authors are highly thankful to Rashtriya Krishi Vikas Yojana (RKVY) scheme for the financial support to conduct the project 'Development of demonstration and business model for soil less agriculture production system' at AICRP on seed (Crops), National Seed Project, UAS, GKVK, Bangalore during the course of investigation.

Conflict of Interest. None.

REFERENCES

Alan, R. (1990). Characteristics of some of the growth media used in greenhouse. Turkey 5. Greenhouse Symposium, October 17- 19, Izmir, Turkey. pp., 401-410.

Alan, R., Zulkadir, A. and Padem, H. (1994). The influence of growing media on growth, yield and quality of tomato grown under greenhouse conditions. *Acta Hort*iculturae, *366*, 429-436.

Anilkumar, C. and Mohan, R. A. (2018). Genetics of Fruiting Habit Traits in Chilli (*Capsicum annuum* L.) *Mysore Journal of Agricultural Sciences*, *52*(2), 293-299.

Anonymous (2022). Global production of paprika. pp., 1.

Aslanpour, M., Shoor, M., Ghalekahi, B., Sharifi, A. and Kharazi, M. (2019). Effects of growing medium type on growth and flowering of saintpaulia (*Saintpaulia ionanthawendi*). *International Transaction Journal of Engineeding, Management and Applied Sciences and Technologies*, *10*(5), 597-606.

Ayesha, R., Fatima, N., Ruqayya, M., Faheem, H, Qureshi, K. M., Hafiz, I. A., Khan, K. S. and Kamal, A. (2011). Influence of different growth media on the fruit quality and reproductive growth parameters of strawberry (*Fragaria* × *ananassa*). *Journal of Medicinal Plant Research*, *5*(26), 6224-6232.

Beibel, J. P. (1960). Hydroponics- The science of growing crops without soil, Florida Department of Agric. *Bull.*, pp., 180.

Bennett, E. and Roberts, J. A. (2012). Wagstaff C. Manipulating resource allocation in plants. *Journal of Experimental Botany*, *63*(9), 3391-3400.

Berke, T. G. and Shieh, S. C. (2012). Handbook of herbs and spices, *Food Science and Nutrition Technology, 1*(2), 116-130.

Caguiat, X. G. I. and Hautea, D. M. (2014).Genetic diversity analysis of eggplant (*Solanum melongena* L.) and related wild species in the Philippines using morphological and SSR markers. *Sabrao Journal of Breeding and Genetics*, *46*(2),183-201.

Chu, Y. F., Sun, J., Wu, X. and Liu, R. H. (2002). Antioxidant and anti-proliferative activities of common vegetables. *Journal of Agricultural and Food Chemistry, 50*, 6910-6916.

Dysko, J., Kaniszewski, S. and Kowalczyk, W. (2015). Lignite as a new medium in soilless cultivation of tomato, *Journal of Elementology*, *20*(3), 559-569.

Gericke, W. F. (2007). Soilless Gardening. Biotech Books, Delhi.pp., 285.

Gomez, K. A. and Gomez, A. A. (1984). *Statistical procedures for agricultural research* (2 ed.). *John wiley and sons*, New York.pp., 680.

Grangvist, G. (1981). Recent experience in the use of substrates for vegetable production under glass in Sweden. *Acta Horticulturae*, *126*, 259-262.

Gruda, N. (2009). Do soilless culture systems have an influence on product quality of vegetables. *Journal of Applied Botany and Food Quality*, *82*(2), 141-147.

Gungor, F. and Yildirim, E. (2013). Effect of different growing media on quality, growth and yield of pepper (*Capsicum annuum* L.) under greenhouse conditions. *Pakistan Journal of Botany*, *45*(5), 1605-1608.

Hesami, A., Khorami, S. S. and Kashkooli, A. B. (2012). Date-peat as an alternative in hydroponic strawberry production. *African Journal of Agricultural Research*, *7*(23), 3452-3458.

Hickman, G. (2016). International greenhouse vegetable production – Statistics. USA: Cuesta *Roble Greenhouse Consulting.*

Hoagland, D. R. and Arnon, D. I. (1950). The water-culture method for growing plants without soil. University of California, Berkeley, *347*, 1-32.

Hojhabrian (2014). Effect of different soil pHs on the growth and proceeds of Tomatoes. *Journal of Novel Applied Sciences*, *3*(2),145-147.

Kaddi, G., Tomar, B. S., Singh, B. and Sanjay, K. (2014). Effect of growing conditions on seed yield and quality of cucumber (*Cucumis sativus* L.) hybrid. *Indian Journal of Agricultural Sciences*, *84*, 624-627.

Kamal, A. N. Y., Aung, L. H. and Solomon, S. (1974). Growth and carbohydrates content of tomato seedlings in nutrient solutions. *Horticultural Science*, *9*(6), 547-548.

Kanneh, S. M., Quee, D. D., Ngegba, P. M. and Musa, P. D. (2017). Evaluation of tomato (*Solanum lycopersicum* L.) genotypes for horticultural characteristics on the upland in Southern Sierra Leone. *Journal of Agricultural Sciences*, *9*(6), 213-220.

Kaur, S., Jindal, S. K., Dhailwal, M. S., Chawla, N. and Meena. O. P. (2017). Genetic diversity analysis in elite lines of tomato (*Solonum lycopersicum* L.) for growth yield and quality parameters. *Genetika*, *49*(1), 329-344.

Kinoshita, T., Yamazaki, J., Inamoto, K. and Yamazaki, H. (2016). Analysis of yield components and dry matter production in a simplified soilless tomato culture system by using controlled-release fertilizers during summer-winter greenhouse production. *Scientia Horticulturae*, *202*, 17-24.

Maboko, M. M. and Plooy, C. P. (2009). Comparative performance of tomato cultivars in soilless vs. In soil production system. *Acta Horticulturae*, *843*, 314-318.

Maboko, M. M., Du Plooy, C. P. and Bertling, I. (2008). Comparative performance of tomato cultivars in soilless vs. in-soil production systems. *International Symposium on Soilless Culture and Hydroponics*, *843*, 319-326.

Massantini, F., Favilli, R., Magnani, G. and Oggiano, N. (1988). Soilless culture– biotechnology for high quality vegetables. *Soilless Culture*, *4*, 27-40.

Muyekho, F. J. N. (1993). Environmental and agronomic factors affecting seed production in annual medics., *Ph D. Thesis*, Univ. Adelaide, Australia.

Paneru, P., Bhattachan, B. K., Amgain, L. P., Dhakal, S., Yadav, B. P. and Gyawaly, P. (2017). Effect of mother plant nutrition on seed quality of Wheat (*Triticum aestivum* L) in Central Terai Region of Nepal. *International Journal of Applied Science and Biotechnology*, *5*(4), 542-547.

Rodriguez-Ortega, W. M., Martinez, V., Rivero, R. M., Camara-Zapata, J. M., Mestre, T. and Garcia-Sanchez, F. (2017).Use of a smart irrigation system to study the effects of irrigation management on the agronomic and physiological responses of tomato plants grown under different temperature regiments, *Agriculture Water Management, 183*, 158-168.

Sepehri, A. and Sarrafzadeh, M. H. (2018). Effect of nitrifiers community on fouling mitigation and nitrification efficiency in a membrane bioreactor. *Chemical Engineering and Processing Process intensification, 128*, 10-18.

Sevgican, A. (1999). Protected vegetable growing (Soilless Culture). II. Ege University. Agriculture Faculty, Izmir, Turkey, *526*.

Sezen, S. M., Yazar, A. and Eker, S. (2006). Effect of drip irrigation regimes on yield and quality of field grown bell pepper.*Agriculture Water Management, 81*, 115-131.

Shah, A. H. and Shah, S. H. (2009). Cultivation of lettuce in different strengths of the two nutrients solution recipes

in a non-circulating hydroponics system. *Sarhad Journal of Agriculture, 25*(3), 419-428.

Shah, A. H., Munir, S. U., Amin, N. U. and Shah, S. H. (2011). Evaluation of two nutrients solutions for growing tomatoes in a non-circulating hydroponics system. *Sarhad Journal of Agriculture*, *27*(4), 557-567.

Singh, B., Tomar, B. S. and Thakur, S. (2009). Quality seed production of parental lines of Pumpkin under insect proof net house paper presented in 4th International Cucurbitaceae Symposium held at HUNAN, China, September 21-26.

Singh, D. (2013). Hydroponics (Soilless Culture of Plants). *Agrobios*, pp., 185.

Thapa, U., Mondal, R., Mallick, D. and Das, A. (2016). Standardization of growing media for growth, yield and quality of sweet pepper (*Capsicum annuum* L.) under soilless culture. *International Journal of Environmental Sciences, 9*, 395-400.

Treftz, C. and Omaye S. T. (2016). Comparison between hydroponic and soil systems for growing strawberries in greenhouse**.** *International Journal of Agriculture Extension, 3*(3), 195-200.

Tuzel, I. H., Meric, K. M. and Tuzel, Y. (2016). Crop Coefficients in Simplified Hydroponic Systems. *Acta Horticulturae*, *719*, 551-556.

Veena, B. and Krishnamurthy, B. (2023). Profile Characteristics and Economic Performance of Byadagi Chilli Growers in Haveri District of Karnataka. *Mysore Journal of Agricultural Sciences*, *57*(1), 409-420.

Verdonck, O., Vleeschauwer, D. and De Boodt, M. (1981). The influence of the substrates on plant growth. *Acta Horticulturae*, *126*, 251-258.

Wan, W. Y., Cao, W. and Tibbitts, T. W. (1994). Tuber initiation in hydroponically grown potatoes by alteration of solution pH. *Horticultural Science, 29*(6), 621-623.

How to cite this article: Seema A.N. and Vishwanath K. (2023). Studies on the Influence of Soilless Growing Systems and Nutrient Concentration of Hoagland's Solution on Crop Growth and Yield of Paprika Chilli (*Capsicum annuum* L.). *Biological Forum – An International Journal*, *15*(10): 929-937.