EVALUATION OF TWO NUTRIENT SOLUTIONS FOR GROWING TOMATOES IN A NON-CIRCULATING HYDROPONICS SYSTEM

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ABSTRACT
A study was conducted to evaluate two prominent nutrient solution recipes of different strengths (½ and full) to grow tomatoes in a non-circulating hydroponics system at Peshawar to evaluate this technology for the peoples living in the congested urban centres of the province to grow fresh vegetables/tomatoes without using soil on their cemented floors, courtyards, verandas or rooftops. For this purpose plants of the tomato variety ‘Rio- Grande’ were grown in 13-litre plastic trash bin type containers using (1) Cooper’s 1988 and (2) Imai’s 1987 nutrient solutions on a randomized complete block design (RCBD) in the greenhouse facility of the Institute of Biotechnology and Genetic Engineering (IBGE), KPK Agricultural University, Peshawar Pakistan during 2006. The tomato crop grown in Cooper’s 1988 recipe (Half (1a) and full strength (1b) solutions respectively) produced flowers significantly earlier (54.78 and 55.45 days of seed sowing), fruits also matured/harvested earlier (98.44 and 96.67 days of seed sowing), plants developed more flower clusters (14.70 and 13.48 plant²), more flowers cluster (10.33 and 8.00), more fruits plant⁻¹ (36.03 and 31.56) the average fruit weight was higher (77.38g and 61.70g), the fruit diameter (4.57cm and 4.27cm), number of leaves plant⁻¹ (72.89 and 64.89), and the fruit yield plant⁻¹ was also better (2.787kg and 1.935kg) than those grown in 2a and 2b solutions, plants consumed more nutrient solution (89.23 and 44.61 litres plant⁻¹), the cost of nutrient solution chemicals was higher (Rs 145.31 and Rs 51.08), but the crop revenues obtained plant⁻¹ were also higher (Rs 97.54 and Rs 67.83) as compared to those plants grown in the corresponding strengths of the Imai’s 1987 recipe solutions. Similarly, the cost benefit ratio (CBR) values on total cost container⁻¹ basis were better (0.96: 1.00 and 0.83:1.00) for ½ strengths solutions grown plants of the Cooper’s 1988 recipe than those obtained in the corresponding strengths of Imai’s 1987 recipe solutions because of the higher cost of chemicals used (Lab grade chemicals). However, CBR values (on solution chemical cost basis) were better for Imai’s 1987 recipe grown plants (1.20: 1.00 and 2.13: 1.00).

Key Words: Hydroponics vegetables / tomatoes, non-circulating hydroponics, soil-less culture, and nutrient solution.


INTRODUCTION
Since the cities and urban centres are fastly expanding, the productive lands are shrinking due to the establishment of new towns, residential colonies, educational campuses, hospitals, industries, roadways and civic facilities etc. It has been estimated that by the year 2030 the population ratio of rural : urban would become 10%: 90% (Abid, 2009). The need of restructuring agriculture sector has been felt seriously to feed the demographically increasing population in our country/province. This could be achieved either through increasing our food production by bringing more and more area under cultivation or through the use of present day improved agricultural technologies (Abid, 2009). The non-circulating hydroponics technology is surely one of the options for growing fresh vegetables for home consumption by the city dwellers (Imai, 1987 and Kratky, 2000). Although the hydroponics technology in the developed world has gone much ahead, however, it is not too late to start the use of this technology, which does not involve much of the initial investment and could be considered as a method of suspended pots in a nutrient solution container for growing fresh vegetables. The entire crop could be grown in a nutrients solution container with a single filling and every one can practice this technique with little care to produce fresh vegetables in his court yard, veranda or on a roof top with out using soil as a growing medium (Imai, 1987 and Kratky, 2002).

Tsay et al. (1987) evaluated the growth and yield of certain vegetables including tomato in an urban home garden unit of a non-circulating hydroponics system. Their set up included polystyrene containers of size 25 cm (H) x 54 cm (L) x 34 cm (W) for nutrients solution with polystyrene lid cover. Small plastic net bottom pots of 6.5 cm diameter and 7.5 cm height containing the support medium for plants (smoked rice hull) were fixed in the lid of the container. They planted tomatoes in late Oct with growth duration of 167 days and harvested 5.90 kg of tomatoes (box-115 net bottom pots box-1) in a number of harvests.
The information provided by Asian Vegetables Research and Development Centre (AVRDC) (1986) indicated that they harvested 3.1 kg of large fruited tomatoes plant$^{-1}$ in summer having the average fruit weight of 150 g and the maximum 200g. Similarly (Imai, 1987) experienced that tomato cultivation in a non-circulating hydroponics system was far more difficult than cucumbers and melons. In summer 1986 he obtained a yield of 3 kg of tomatoes plant$^{-1}$ with an average fruit weight of 130 g and the largest fruit exceeded 200 g. Like wise, Kratky et al. (1988) also produced tomatoes in a non-circulating hydroponics system. They used polyethylene lined earthen troughs (0.4 m deep x 0.4 m wide) filled with nutrients solution (unto 30 mm of the top of the container) containing N as NO3 173 mg L$^{-1}$, P 63 mg L$^{-1}$, K 213mg L$^{-1}$, Ca 210mg L$^{-1}$, Mg 47 mg L$^{-1}$, Fe 3 mg L$^{-1}$, Mn 1.1mg L$^{-1}$, Cu 0.2 mg L$^{-1}$, Zn 0.4 mg L$^{-1}$, B 0.5 mg L$^{-1}$, and Mo 0.1 mg L$^{-1}$ They obtained 3.5 kg of saleable tomatoes plant$^{-1}$ during Dec-Jan as compared to 3.1 kg plant$^{-1}$ obtained in the soil beds. They further stated that although this non-circulating hydroponics system requires neither mechanical aeration nor circulation of nutrients solution, it offers a simple and inexpensive system with a wide spread acceptance in intensive agricultural systems having yields similar to those obtained from soil beds. While, comparing the results of various vegetables produced in hydroponics (broken brick hydroponicums), with soil grown (control) plants including tomato. Akhtar-Jehan et al. (1994) reported that the control plants were taller (115.3 cm) than the hydroponically grown ones (108.96cm), the number of branches were also more (8.00) than hydroponically grown ones (6.83). However, the number (38.83) , size/circumference (16.83cm) and weight of fruits (57.68g), the number of leaves plant$^{-1}$ (19.50) as well as the total yields in hydroponically grown plants were 1.25 times more than the soil grown control plants.

Cedra et al. (1984) reported the negative effects of high sulphate concentrations on growth/ development of tomato plant, its leaves and stems. Bovine (1990) also worked on the accumulation of some mineral elements especially the sulphates their co-absorption/transport in plants and recommended adjustments made. Likewise, Baars (1992) mentioned that besides sulphates, chlorides and bicarbonates also have the tendency to accumulate and influence crop/ plant growth.

While, Zekki et al. (1996) noticed reduction in fresh weight, dry weight as well as yield (marketable yield 3.86 kg plant$^{-1}$ with average fruit weight of 172.5 g plant$^{-1}$) due to prolong nutrients recycling in Nutrients Film technique (NFT). Similarly, Tuzel et al. (2000) evaluated the closed and open hydroponics systems and noticed variations in tomato yield and water/nutrients consumption in spring and autumn seasons. Similarly, Gul et al. (2000) compared the results of continuous and intermittent solution circulation on tomato growth and yield in NFT hydroponics and did not show much difference in fruit grade and quality parameters in both the systems. Likewise, Kratky (2005) also grew tomatoes in quite similar as well as different kind’s hydroponics systems including the non circulating hydroponics system. Similarly, Kratky (2005) also devised a non-circulating hydroponics system for growing tomatoes. Whereas, Kao (2005) developed and evaluated the dynamic root floating (DRF) hydroponic technique, in which he obtained a yield of 2.7 kg tomatoes panel$^{-1}$. The cost economics of simplified hydroponics tomato bed grower of 2m$^2$ has been calculated by Bradley and Marulanda (2000) as cost US$ 2.84 and US$ 10.06 as net return.

In the present study an attempt has been made to compare two nutrient solution recipes/ formulations for their efficacy with a view to evaluate and promote the technology of non-circulating hydroponics for growing various vegetables including tomatoes in the cemented houses (of the city dwellers/ urban people) with out using soil.

MATERIALS AND METHODS

The studies reported here were undertaken in the greenhouse facilities of the Institute of Biotechnology and Genetic Engineering (IBGE) at Agricultural University, Peshawar, Pakistan during spring 2006. The design of the experiment was randomized complete block design having three replications and four treatments and each treatment comprised of three solution containers (one plant in each container).

Seeds of tomato cv. Rio-Grande were sown (on Feb 28, 2006. Seeds germinated in 3-5 days) in disposable plastic cups (the upper diameter of plastic cup was 6.5 cm, while the lower diameter was 3.5 cm and length/height of the cup was 9.5 cm with multi-holes at the lower portion for emerging roots) having smoked rice hull as the growing medium. The pots/cups were fixed in a 2.5 cm thick polystyrene lid placed on a plastic trash bin of 13 liters capacity (25 cm L x 21 cm W x 33 cm H). Cooper’s nutrient solution at full strength consisted of (mg L$^{-1}$) N-236, P 60.0, K 300, Ca 185, Mg 50, S 68, FE (EDTA) 12, Mn 2.0, Zn 0.1, Cu 0.1, B 0.3, Mo 0.2. At half strength Cooper’s solution consisted of (mg L$^{-1}$) N 118, P 30, K 150, Ca 92.5, Mg 25, S 34, Fe 6, Mn 1.0, Zn 0.1, Cu 0.1, B 0.15, Mo 0.2. Imai’s solution at full strength consisted of (mg L$^{-1}$) NO3-N 140.0, P 35.05, K 360.22, Ca 160.16, Mg 48.60, Fe (EDTA) 3.0, Mn 0.5, Cu 0.02, Zn 0.05, B 0.5, Mo 0.01. The $\frac{1}{2}$ strength solution of this recipe consisted of (mg L$^{-1}$) NO3-N 70.0, P 17.52, K 180.06, Ca 80.08, Mg 24.18, Fe (EDTA) 3.0, Mn 0.5, Cu 0.02, Zn 0.05, B 0.5 and Mo 0.01.Seedlings were transplanted into the individual plastic cups (on March 7,2006) fixed into the lid of solution containers. The solution containers were placed on
greenhouse benches. The initial pH of Cooper’s 1988 solution of full strength was 6.65 while, that of half strength was 6.77. Whereas, the initial pH of Imai’s 1988 solution of full strength was 9.05, while, that of half strength was 8.97. Before planting the individual plants in plastic cups, the pH of both the solutions of Imai’s 1988 recipe were adjusted/reduced to 6.66 with the addition of acid. The first harvest was taken from the plants grown in full strength solution of Cooper’s recipe on June 07, 2006, while from half strength grown plants in this recipe solution on June 05, 2006. The temperature, relative humidity conditions, as well as the fluctuations/adjustments made in pH and EC of the solutions is shown in Figures 1-8.

The data on various parameters as given below were collected and analyzed statistically using M State-C software and LSD test as described by Gomez and Gomez (1984).

i. Number of days to first flowering.
ii. Number of days to first harvest.
iii. Number of staminate flowers plant\(^{-1}\).
iv. Number of flowers cluster\(^{-1}\).
v. Number of flowers cluster\(^{-1}\).
vi. Number of fruits plant\(^{-1}\).
vii. Number fruit weight (g).
viii. Fruit diameter (cm).
ix. Fruit yield plant\(^{-1}\)/container\(^{-1}\) (kg).
x. Plant height/ stem length (m).
xii. Amount of nutrients solution consumed plant\(^{-1}\) (Liters).
xiii. Crop revenues obtained container\(^{-1}\) (Rs).
xiv. Cost-benefit- ratio container\(^{-1}\) based on chemicals cost container\(^{-1}\) only (in Rs).
xv. Cost-benefit-ratio container\(^{-1}\) based on average total costs container\(^{-1}\) (in Rs).

**RESULTS AND DISCUSSION**

The results of various parameters studied in this experiment during the 16 weeks crop duration are presented in Table I, Fig 1-8 and discussed under parameter-wise headings in the following paragraphs.
Number of Days to First Flowering

As indicated in Table I, the number of days taken by tomato plants from seed sowing to the first flowering ranged from 54.78–61.52 (in full-strength Cooper’s 1988 solution and ½ strengths Imai’s 1987 solution respectively). First flowers opened about a week earlier in plants grown in Cooper’s 1988 solution than those grown in the Imai’s 1987 solution. However, the differences days to first flowering due to solution strengths (full and ½ strengths) were almost statistically non-significant (Table I). These non-significant differences regarding the number of days to first flowering between the two strengths (full and half) of both the solution recipes (Cooper’s 1988 and Imai’s 1987) could be attributed to the favorable temperatures of the nutrients solution during the months of Feb and March (Fig. 3) at which the dissolved oxygen contents has not been a problem, thus the plant roots and shoot growth remained almost similar resulting in statistically negligible variations in first flower opening.

![Fig. 3. Temperature conditions during the growth period of tomato crop inside the green-house.](image)

Number of Days to First Harvest

Data regarding the average number of days to first harvest in tomatoes grown in different strengths of the two hydroponics nutrients solution recipes are given in Table I.

Results showed that the tomatoes matured approximately 12-16 days earlier when grown in either strengths of the Cooper’s 1988 nutrients recipe as compared to the Imai’s 1987 recipe. The average number of days taken to first harvest after sowing of seed in tomato plants grown in Cooper’s 1988 nutrients solution recipe were almost statistically equal (98.44 days in full strength & 96.67 days in ½ strength solutions). Whereas, in the full and ½ strength solutions of the Imai’s 1987 recipe, these days were 108.60 and 115.00 respectively (Table I).

The delay of 12-16 days in first harvest as noticed in the different strengths of the Imai’s 1987 recipe was mainly due to varietals difference as well as the solution pH range fluctuation (Fig. 2) which slowed down the vegetative growth, survival of the plants and ultimately resulted in a delay in flowering, fruit development and even fruit maturity/harvest. Non the less tomato flowers are highly self pollinated but certain kind of environments (the greenhouse environment) and physiological conditions do influence the fruit set, fruit growth and maturity and it was observed in this experiment that very few flowers did set fruit.

Most of the greenhouse tomato growers’ often use some other practices to increase the fruit setting, fruit enlargement and hastening maturity. Specific varieties are bred for greenhouse/hydroponics cultivation (mostly the indeterminate types) and a few trusses are kept on plant and by Logendra et al. (2001). as long as the lower truss is there and not harvested; the upper one does not grow fully and even matures very late. And similar kind of pruning and truss management practice for increasing tomato yield has been reported.

Number of Flower Clusters Plant$^{-1}$

Data pertaining to the average number of flower clusters plant$^{-1}$ in tomatoes plants grown in different strengths of the two hydroponics nutrients solution recipes are given in Table I.

Significant variations were observed in number of flower clusters plant$^{-1}$ in tomatoes grown in different strengths of the two hydroponics nutrient solution recipes. More number of flower clusters (14.70 plant$^{-1}$) were
formed on plants grown in full strength Cooper’s 1988 solution followed by the ½ strength solution of Imai’s 1987 recipe (13.48 plant\(^{-1}\)). While, the minimum number of flower clusters (12.14 plant\(^{-1}\)) were counted on plants grown in ½ strength solution of Imai’s 1987 recipe. The differences in number of flower clusters plant\(^{-1}\) between the ½ strength solution of Cooper’s 1988 recipe and full strength Imai’s 1987 recipe as well as between both the solution strengths of the Imai’s 1987 recipe were almost non-significant (Table I).

Flower clusters development on a tomato plant occurs progressively with the increase in plant/branch length. The more vegetative growth occurs, the more number of flower clusters are formed. However, these phenomena could definitely be influenced genetically and physiologically. Certain tomato varieties are indeterminate; some are semi-determinate, while others are determinate. The side shoots pinching/pruning practices also influence the flower clusters pattern in tomato. Slight variations in clusters number in our studies could be attributed to the nutrients availability and uptake by plants in different kind and strengths of the solutions. Cooper’s 1988 recipe appeared to be better than Imai’s 1988 recipe probably due to its balanced ingredients and solution pH range.

**Number of Flowers Cluster\(^{-1}\)**

The results indicated in Table I revealed that the differences in average number of flowers cluster\(^{-1}\) for plants grown in different strengths of Cooper’s 1988 solution were significant where as, for those grown in Imai’s 1987 solution were non-significant.

Significantly higher number of flowers cluster\(^{-1}\) (10.33) were counted for the plants which were grown in full strength solution of the Cooper’s 1988 recipe followed by (8.00 cluster\(^{-1}\)) those grown in ½ strength solution of this recipe while, the average number of flowers cluster\(^{-1}\) for those plants which were grown in either strength solution of Imai’s 1987 recipe was 6.37 plant\(^{-1}\) (Table I). Statistically the significant variations observed among the recipes with regards to the flower clusters plant\(^{-1}\) could be attributed to the recipes/solution nutrients contents and their pH values (Fig.4) at which the plants growth occurred verily causing these variations.

![Fig. 4. Relative humidity (%) during the growth period of tomato crop inside the greenhouse.](image)

**Number of Fruits Plant\(^{-1}\)**

Data concerning the average number of fruits plant\(^{-1}\) in tomatoes grown in different strengths of the two hydroponics nutrients solution recipes are presented in Table I, revealed significant differences among tomato plants grown in either kind of the nutrient solution recipes as well as their different strengths. Significantly higher number of fruits (36.03 plant\(^{-1}\)) were harvested from tomato plants grown in full strength solution of the Cooper’s 1988 recipe (31.56 plant\(^{-1}\)) and by full strength of Imai’s 1987 recipe (27.00 fruits plant\(^{-1}\)) whereas, lowest number of fruits (22.25 plant\(^{-1}\)) were harvested from plants grown in ½ strength solution of the Imai’s 1987 recipe (Table-I) Our results for the Cooper’s 1988 recipe grown plants are highly in accordance with those of Akhtar-Jehan et al. (1994) who after failing two times ultimately grew tomatoes successfully in a hydroponics system using Knops’ and Hoagland solutions and obtained an average fruit number of 38.83 plant\(^{-1}\) as compared to 29.50 plant\(^{-1}\) from soil grown plants. The Imai’s 1987 recipe tested in our experiment remained poor in many growth and yield parameters probably due to its ingredients contents and lack of skills to adjust the solution pH and EC up to an appropriate range which is needed to maintain an optimum plant growth rate.
Chemicals/solutions as well as a portable dual purpose device (digital pH of EC meter) is must which we were lacking throughout these studies and we relied on non-portable pH and EC monitoring devices.

**Fruit Weight (g)**

The data for average fruit weight of tomatoes grown in different strengths of the two hydroponics nutrients solution recipes are presented in Table I, revealed significant differences in the average fruit weight of tomatoes grown in different strengths of the two nutrients solution recipes. Relatively heavier fruits of 77.38 g were harvested from plants grown in full strength solution of Cooper’s 1988 recipe followed by those grown in ½ strength solution of this recipe (60.70 g) and in full strength Imai’s 1987 solution (57.83 g). While, the lighter weight fruits of 48.75 g were harvested from plants grown in ½ strength solution of Imai’s 1987 nutrients recipe (Table I).

Although, AVRDC (1986); Imai (1987); Zekki et al. (1996) and Gul et al. (2000) reported an average fruit weight of 130 g, 91 g, 157.9 g and 113 or 114 g who applied different techniques with the exception of AVRDC (1986) which was more similar to ours but they had more experience of hydroponics cultures and solution maintenance. Nonetheless, our results are in close conformity with those of Imai (1987) and Akhtar-Jehan et al. (1994) who obtained an average fruit weight 91.0 g and 57.68 g respectively, while the early attempts of the later one to grow tomatoes hydroponically in Knops’ and Hoagland solution ended on failures.

**Fruit Diameter (cm)**

The data for the average fruit diameter (which was measured with the help of Vernier Caliper) of tomatoes grown in different strengths of the two hydroponics nutrients solution recipes as given in Table I, showed that the fruit diameter had been significantly influenced by different strengths of both the solution recipes. Maximum average fruit diameter (4.57 cm) was recorded in fruits obtained from plants grown in Cooper’s 1988 full strength solution. While, the minimum (3.30 cm) fruit diameter was measured in fruits harvested from plants grown in ½ strength solution of Imai’s 1987 solution recipe. The results of the ½ strength Cooper’s 1988 solution and full strength Imai’s 1987 solution recipes with regards to the average fruit diameter were 4.2 cm and 3.63 cm respectively.

Many of the reports in our literature reviewed do not mention about their results regarding this parameter. However, from the data on fruit circumference provided in a paper by Akhtar-Jehan et al. (1994), it appears that the average fruit diameter of tomatoes they grew (who did not mention the name of the cultivar) in Knops’ or Hoagland solutions hydroponics remained around 5.35 cm. Our results obtained in Cooper’s 1988 recipe of either strengths (full or half) apparently seems closer to their findings.

**Fruit Yield of Tomatoes (kg plant$^{-1}$/kg container$^{-1}$)**

Data concerning the average fruit yield of tomato plants grown in different strengths of the two hydroponics nutrient solution recipes is given in Table I, which revealed that the average fruit yield was maximum (2.787 kg plant$^{-1}$) in full strength solution grown plants of the Cooper’s 1988 recipe which was 1.935 kg plant$^{-1}$ in half strength solution grown plants of the same recipe and 1.560 kg plant$^{-1}$ from Imai’s 1987 full strength solution grown plants. Where as, the average fruit yield was minimum (1.081 kg plant$^{-1}$) from the plants grown in ½ strength solution of Imai’s 1987 recipe.

Our results to certain extents are nearer to those of AVRDC (1986) who obtained 3.1 kg of large fruited tomatoes plant$^{-1}$ in a non-circulating hydroponics system. Like wise, Kratky (2005) in a suspended pot method (non-circulating hydroponics system obtained almost the similar yields (24.79 kg from 12 plants) of tomato but his nutrients solution formula were patented and kept secret. Kratky (1988) has also shown the similar yield of tomato cultivar “Vendor” little higher (3.1 kg plant$^{-1}$) than avers (2.78 kg plant$^{-1}$ in Cooper’s (1988) full strength solution) but his technique was a little different than ours. Bradley and Marulanda (2000) also obtained 3.1 kg tomato yield plant$^{-1}$ while, Zekki et al. (1996) mentioned 3.80 kg marketable yield of tomatoes grown in hydroponics and these results could be considered much closer to ours.

**Number of Leaves Plant$^{-1}$**

Significant differences were observed in number of leaves plant$^{-1}$ for the tomatoes grown in different strengths of the two hydroponics nutrients recipes (Table-I). Maximum average number of leaves (72.89 plant$^{-1}$) was counted for the plants grown in full strength Cooper’s 1988 solution, followed by (64.89 plant$^{-1}$) ½ strength solution grown plants of the same recipe. The average number of leaves plant$^{-1}$ was comparatively low in plants grown in Imai’s 1987 solution as compared to Cooper’s 1988 solution. In the full strength solution grown plants of the Imai’s 1987 recipe the average number of leaves were 41.11 plant$^{-1}$ as compared to the minimum number (33.33 plant$^{-1}$) noticed in ½ strength solution grown tomato plants in the same recipe (Table I). None of the reports in literature exists pertaining to this parameter of study with the exception of Akhtar-Jehan et al. (1994).
The authors of this exceptional research paper themselves admitted of their early failures regarding of the cultivation of tomatoes in hydroponics system. Our results in this regards are far better than theirs, who mentioned of 19.50 leaves plant\(^{-1}\). There could have been a difference of the genotype also but in our lowest category of treatment (\(\frac{1}{2}\) strength Imai’s 1987 recipe) the plant size and leaves number was much higher 33.33 plant\(^{-1}\). This indicates that the Cooper’s 1988 recipe formulae were much better than that of Imai’s 1987 recipe formulae.

**Plant Height/ Stem Length (m)**

The average plant height/ stem length was significantly more (2.41 m and 2.31 m) in full and \(\frac{1}{2}\) strength solutions grown plants of the Cooper’s 1988 recipe as compared to the less plant height (1.75 m and 1.59 m) found in full and \(\frac{1}{2}\) strength solutions grown plants of the Imai’s 1987 recipe (Table I). The different strengths of both the solution recipes did not show any significant variations regarding the average plant height; however, the differences between the recipes (Cooper’s 1988 and Imai’s 1987 recipes) were significant with regards to their influence on average plant height (Table I)

Our results seem far better than Akhtar-Jehan et al. (1994) who measured the tomato plants height up to 108.96 cm in their experiment of hydroponics vegetable production. These variations might be due to a different genotype they used. However, it is evident that the Cooper’s 1988 recipe out performed than Imai’s 1987 recipe with regards to its influence on plant growth/stem length which was probably due to the recipe’s nutrients combination/ratio as well as the pH, especially when the solution was prepared with an ordinary tap water (the pH of which was 7.2-7.4).

**Amount of the Nutrients Solution Consumed (litres plant\(^{-1}\))**

Data pertaining to the average amount of the nutrients solution consumed by tomato plants grown in different strengths of the two hydroponics nutrients solution recipes are given in Table I. The results indicated that the plants grown in full strength solution of the Cooper’s 1988 recipe consumed maximum average amount of the nutrients solution (89.23 liters) followed by \(\frac{1}{2}\) strength grown plants in the same recipe (44.61 liters). While, the amount of the solution consumed by plants grown in Imai’s 1987 recipe (being statistically equal in both strengths) was relatively very low (26.87 liters in full strength and 22.25 liters in \(\frac{1}{2}\) strength).

Since, the Imai’s 1987 solution recipe has been observed to have relatively higher pH in which plants growth and performance remained poor as compared to Cooper’s 1988 recipe, hence the consumption of the nutrients solution too was less.

Tuzel et al. (2000) mentioned that in an open system the tomatoes (Cv Gokce F1) consumed 51.1-69.8 litres of solution / water, while, in a closed system 91.2-119.0 litres of solution plant\(^{-1}\). Likewise, Kraty (2005) in a suspended pot method mentioned that tomato plant utilizes 25-40 liters of water/nutrients solution for producing 1 kg of fruit. Our results could be considered with in the same range for Cooper’s 1988 solution recipe, however, for Imai’s 1988 recipe probably the solution pH fluctuation might have influenced the plant growth, fruit development and nutrient solution consumption/ utilization.

**Cost of the Nutrients Solution Consumed (Rs)**

Significant differences have been observed in the average cost of the nutrients solution consumed by tomato plants grown in different strengths of both the recipes (Table I). The highest cost was spent on plants grown in full strength solution of Cooper’s 1988 recipe (Rs.145.31 container\(^{-1}\)) which was followed by \(\frac{1}{2}\) strength grown plants of the same recipe (Rs.51.08 container\(^{-1}\)) while, the cost of growing tomatoes in full strength solution of Imai’s 1987 recipe was Rs. 32.59 container\(^{-1}\) and Rs.12.69 container\(^{-1}\) for its \(\frac{1}{2}\) strength solution which was extremely low as compared to that of Coopers 1988 recipe grown plants. The higher costs observed in Cooper’s 1988 recipe were due to the reason that the nutrients chemicals were of lab grade and were of foreign origin which were costly while, those used for Imai’s 1987 recipe were partly of local origin and had lower cost. Moreover, the nutrients chemicals used for \(\frac{1}{2}\) strength solutions of both the recipes were halved and hence their cost was also lower than their corresponding full strength solutions.

**Crop Revenues obtained Container\(^{-1}\) (Rs)**

Data concerning the average total crop revenues obtained from the tomatoes grown in different strengths of the two hydroponics nutrients solution recipes on gross marginal return basis are presented in Table I. The variations in the average revenues obtained were significant in both kinds of solutions grown produce. At market price of Rs.35/- kg\(^{-1}\), the maximum average revenues obtained from tomatoes grown in full strength solution of Cooper’s 1988 recipe were Rs.97.54 solution container\(^{-1}\) and Rs.67.83 were bagged from the produce harvested from \(\frac{1}{2}\) strength solution grown plants of the same recipe because of the better fruit grade/size. Whereas, the revenues obtained from plants grown in Imai’s 1987 recipe were almost equal to less than half of
those obtained from plants grown in Cooper’s 1988 recipe because of a lower fruit grade the price of which was Rs.25/kg⁻¹ (i.e., Rs.39.00 from full strength and Rs.27.01 from ½ strength solution) grown plants. More revenues obtained in certain cases were due to better grade fruits and better production obtained from those plants/containers.

Bradley and Marulanda (2000) analyzed the income/revenues obtained from each tomato crop grown in a simplified hydroponics system equals to US$ 2.01 and our revenues obtained from Cooper’s 1988 recipe full strength solution grown plants come almost near to this on currency conversion basis.

Cost Benefit Ratio (CBR) of Growing Tomatoes Container⁻¹(Rs) (Based on Solution Chemicals Cost Only)

The CBR values presented in Table I, demonstrate the returns obtained for every Rupee spent. These values were derived/calculated with the help of formulae reported by Kapp and Vasta (2003), which states that “CBR or BCR = Benefits ÷ Coat. The CBR values are considered as feasible/acceptable when these are greater than one (>1), while, these are not accepted when fall less than one (<1). The guidelines of Sugden and Williams (1985) were also kept in view while calculating these values.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Cooper’s 1998 recipe</th>
<th>Imai’s 1987 recipe</th>
<th>LSD</th>
<th>Full strength</th>
<th>½ strength</th>
<th>Full strength</th>
<th>½ strength</th>
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<td>Number of days to flowering</td>
<td>54.78 c</td>
<td>55.45 bc</td>
<td>60.24 ab</td>
<td>61.52 a</td>
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<td>Number of days to harvest</td>
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<td>96.67 c</td>
<td>108.60 b</td>
<td>115.00 a</td>
<td>3.662</td>
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<td>Number of flower clusters plant⁻¹</td>
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<td>13.48 b</td>
<td>12.70 bc</td>
<td>12.14 c</td>
<td>0.871</td>
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<td>Number of flowers cluster⁻¹</td>
<td>10.33 a</td>
<td>8.00 b</td>
<td>6.37 c</td>
<td>6.37 c</td>
<td>0.852</td>
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<td></td>
<td></td>
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<tr>
<td>Number of fruits plants⁻¹</td>
<td>36.03 a</td>
<td>31.56 b</td>
<td>27.00 c</td>
<td>22.25 d</td>
<td>3.328</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit weight (g)</td>
<td>77.38 a</td>
<td>61.70 b</td>
<td>57.83 b</td>
<td>48.75 c</td>
<td>5.149</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit diameter (cm)</td>
<td>4.57 a</td>
<td>4.27 b</td>
<td>3.63 c</td>
<td>3.30 d</td>
<td>0.268</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruits Yield (kg plant⁻¹)</td>
<td>2.787 a</td>
<td>1.935 b</td>
<td>1.560 c</td>
<td>1.081 d</td>
<td>0.253</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of leaves plant⁻¹</td>
<td>72.89 a</td>
<td>64.89 b</td>
<td>41.11 c</td>
<td>33.33 d</td>
<td>5.707</td>
<td></td>
<td></td>
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<tr>
<td>Plant height/stem length (m)</td>
<td>2.41 a</td>
<td>2.31 a</td>
<td>1.75 b</td>
<td>1.59 b</td>
<td>0.2895</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount of nutrients solution consumed plant⁻¹ (litres)</td>
<td>89.23 a</td>
<td>44.61 b</td>
<td>26.87 c</td>
<td>22.25 c</td>
<td>11.470</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of nutrient solutions consumed by tomatoes plant⁻¹ (Rs)</td>
<td>145.31 a</td>
<td>51.08 b</td>
<td>32.59 c</td>
<td>12.69 d</td>
<td>5.640</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop revenues obtained container⁻¹ (Rs)</td>
<td>97.54 a</td>
<td>67.83 b</td>
<td>39.00 c</td>
<td>27.01 d</td>
<td>8.219</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost benefit ratio of growing tomatoes</td>
<td>0.67 c</td>
<td>1.34 b</td>
<td>1.20 b</td>
<td>2.13 a</td>
<td>0.1998</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>container⁻¹ based on nutrient chemicals cost (Rs)</td>
<td>0.59 c</td>
<td>0.96 a</td>
<td>0.74 b</td>
<td>0.83 b</td>
<td>0.1054</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

The cost benefit ratio was much better (Rs.2.13: Rs.1.00) for ½ strength grown plants of Imai’s 1987 recipe, which was followed by full strength solution grown plants of the same recipe (Rs.1.20: Rs.1.00) and those grown in ½ strength Cooper’s 1988 solution (Rs 1.34: Rs 1.00). However, the lowest ratio (Rs.0.67: Rs.1.00) was calculated for the plants grown in full strength solution of the Cooper’s 1988 recipe. The better costs benefits ratios obtained in case of Imai’s 1987 recipe solutions grown plants were mainly due to the lower cost of the nutrients solution chemicals. Because, some of the solutions ingredients used were of local origin and their cost was comparatively low. While, the ingredients used for Cooper’s 1988 recipe solution were of an imported origin (the prices were higher due to their transactions in a foreign currency). Looking upon the costs benefit ratio of Bradley and Marulanda (2000) which comes to 3.53:1.00, it could be clearly said that we need to improve benefits through standardizing our techniques and to reduce our costs by using the locally made chemicals/fertilizers. Since, it was a preliminary academic type study having many constraints, nonetheless, it was a new study for us, and possibilities of improvement are there.

Cost Benefit Ratio (CBR) of Growing Tomatoes Container⁻¹(Rs) (Based on Average Total Cost Container⁻¹)

Data for this parameter are based on actual total costs (which includes the nutrient chemicals costs as well as the cost of other materials such as containers their lids pots, filling material/media and the seeds) and were derived with the help of formulae reported by Kapp and Vasta (2003), which states that “ CBR or BCR = Benefits ÷ Coat. The CBR values are considered as feasible/acceptable when these are greater than one (>1), while, these are not accepted when fall less than one (<1). The guidelines of Sugden and Williams (1985) were also kept in view while calculating these values. As indicated in Table I, the better cost benefits ratios were seen for plants grown in ½ strengths Cooper’s 1988 recipe (Rs 0.96: Rs 1.00) followed by those obtained from Imai’s
1987 solution recipe (Rs.0.83: Rs.1.00 and Rs.0.74: Rs.1.00) for ½ strength and full strength solutions respectively) however, both the strengths of this solution (Imai’s 1987) were statistically at par with regards to cost benefits ratios. Whereas, the CBR value for the plants grown in full strength solution of the Cooper’s 1988 recipe was significantly lower one amongst all the treatments (Rs.0.59 : Rs.1.00). The chemicals which were used for making Cooper’s 1988 recipe solutions were of the lab grade and their cost was more because of their foreign origin and as result the cost benefits ratio was lower for this recipe’s, full strength solution grown plants, however, the cost could be reduced by using the locally manufactured chemicals/fertilizers and relatively better and cheaper containers of Styrofoam which could perform well and even lost longer. Moreover, in the ½ strength solution grown plants half of the nutrients chemicals were used, hence their production costs were lower and values for cost benefits ratios were higher. Very few researchers have commented on this aspect of the study because they have gone further now, however, looking upon the results of Bradley and Marulanda (2000) in which they got much higher values of cost benefits analysis (US$3.53:US$1.00) of simplified hydroponics to reduce global hunger. It could be inferred that their study was a UN project, their precision/expertise were more, while, we were lacking facilities of even a dual-purpose portable electronic pH and EC meter.

Fig.5. Photograph showing the experimental set up during the early days of tomato plants growth.

Fig.6. Photograph showing the tomato plants in the early days of tomato plants growth period.
CONCLUSION AND RECOMMENDATIONS

For growing tomato crop in a non-circulating hydroponics system, Cooper’s 1988 nutrients solution recipe of full strength proved better than the Imai’s 1987 solution recipe because of early development of flowers on plant, early fruit maturity, development of more number of flower clusters plant$^{-1}$, more number of flower clusters$^{-1}$ plant$^{-1}$, more number of fruits plant$^{-1}$, better average fruit weight, fruit diameter, more number of leaves plant$^{-1}$, more plant height/stem length, more fruit yield plant$^{-1}$, better average crop revenues and better CBR values (based on solution chemical’s cost). The better results obtained with the use of Cooper’s 1988 recipe were mainly due to the recipe’s ingredients/ that helped to maintain the solution pH and EC with ordinary tap water with in the permissible range at which tomato plants grew more vigorously. The CBR values could be improved enormously with the use of locally manufactured standard quality chemicals/ fertilizers instead of the expensive imported chemicals.

Since, the tomato is a long duration crop; hence the nutrient solutions need constant monitoring for pH, EC and appearance of symptoms of certain micro-nutrients deficiency. Because, in $\frac{1}{2}$ strength solutions of both the recipes these deficiency symptoms appear frequently which need correction and even sometime need solution replacement? Moreover, during high summer temperatures the development of mucilaginous moss on the surface of the nutrients solution could appear that usually masks the oxygen absorbing roots which may lead to plants death.
REFERENCES


