RESEARCH ARTICLE

Effect of nutrient solution on antioxidant content and yield contributing characteristics in capsicum

M Jahed Rahman[1*], Md Shahjahan Ali[1], Farzana Islami[1], Zannat Zakia[1], Abu Raihani[1], Md Quamruzzamann[2]

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Nutrient solution and its composition can have the effect of capsicum growth and yield. Specific crops have their own particular nutritional necessity for their proper growth in soilless culture. Therefore, it is important to identify nutritional composition for capsicum soilless culture in Bangladesh. In this study, the growth and yield parameter of sweet pepper was investigated by applying different formulations of nutrient solutions. Three nutrient solutions were considered as treatments, *viz.* S1=Hoagland and Arnon, S2=Full strength Rahman and Inden, and S3=¾ strength Rahman and Inden [1]. Vegetative growth, physiological traits and yield contributing characters were measured. The highest plant height (119 cm), number of fruit per plant (20), individual fruit weight (210 g), fruit length (8.7 cm), fruit diameter (7.9 cm), fruit volume (224 cc) and fruits yield (3.99 kg/plant) were found highest when S2 nutrient formulation was applied. But statistically similar results were found in S3. While the ascorbic acid (205.8 mg/100 g FW), leaf area (136.8 cm^2), leaf mass ratio (0.97 $g.g^{-1}$) and net assimilation rate (0.000012 g.cm-2.d-1) were maximum in S3. Therefore, ¾ strength Rahman and Inden, nutrient solution may be used for capsicum culture in the hydroponic system in Bangladesh.

Key Words: Hydroponics; Fruit quality; Soilless culture; Antioxidant; Capsicum

INTRODUCTION

Sweet pepper or capsicum fruits (Capsicum spp.) are among the most widely consumed species in the world. The fruits contain capsaicinoids which give them the distinctive pungent taste. Capsaicin and dihydrocapsaicin, the two main capsaicinoids, are responsible for up to 90 per cent of the pepper fruit's total pungency. Capsaicinoids are commonly used in the food industry, as pharmaceuticals for medical purposes, and also in protective sprays. Sweet pepper fruits are used as vegetables and condiments, and the pungency requirement depends on the purpose of the uses. The degree of pungency depends on Capsicum species and cultivars, and the content of capsaicin may be influenced by various factors such as the fruit developmental stage, environmental stresses and deposition of nutrients in the placental tissue, etc. In hydroponics, it's absolutely essential to begin with a laboratory analysis of nutrient solution. The three main things like alkalinity, Electrical Conductivity (EC) and the concentration of specific elements are important.

Alkalinity is the measurement of the ability of water to neutralize acid. Alkalinity is usually reported in terms of ppm of calcium carbonate equivalents ($CaCO_3$). The increasing the alkalinity in the nutrient solution, the higher the pH of the nutrient solution would continue to rise. Water source alkalinity is much more important to look at than its pH. Hydroponic culture is rapidly popular around the world today. By fact it is highly productive, water and land conserving.

Moreover, the hydroponic culture is environmentally friendly. Hydroponics has proven an excellent alternative method of crop production [1,2]. The cultivation of vegetable crops and the achievement of high yields and high quality are feasible with hydroponics even in saline or acidic soils, or non-arable soils with poor structure, comprising a significant proportion of cultivable land throughout the world. Another advantage of hydroponics is highly precise control of plant nutrition. In addition, soil preparation in hydroponics is avoided, thereby increasing the potential length of cultivation time which is an effective means of increasing the total yield in greenhouses. The rationale for making a shift to hydroponics is increasingly associated with environmental policies as well. A hydroponic system allows for a significant reduction in fertilizer use and a dramatic limitation or even complete elimination of greenhouse leaching of nutrients into the environment [3]. It also offers an immediate and long-term solution to the issue of a household's inability to produce their own vegetables in urban settings. One of the major components for successful hydroponic crops is the nutrient solution. The formulation of nutrient solutions and optimization of nutrition in commercial hydroponics will reduce the cost of fertilizer. Specific formulation of nutrient solutions for the most horticultural species grown in soilless system is required [4]. In addition, in order to obtain high yield and good quality in hydroponically grown commercial crops, the nutrient solution provided to the plants must be appropriate for the particular crop, climatic conditions or hydroponic method used, etc. Improving yield and yield contributing characteristics leading to sweet pepper are important factors for the technique of soilless culture. These can be improved by regulating the supply of external nutrients in growing substrates. Proper combinations of nutrients in the solution will improve crop yield and yield contributing characters. Environmental factors are the limiting factors for a crop yield, and proper management of growing environments can play an important role in increasing the yield and yield contributing characters of sweet pepper. Considering the above-mentioned facts, the aim of the present research work was to identify an optimal dose of nutrient solution for producing higher yield high-quality sweet pepper.

MATERIALS AND METHODS

Experimental site

The experiment was conducted in the polythene shade house at the horticulture farm of Sher-e-Bangla Agricultural University, Dhaka 1207. Bangladesh during April 2015 to March 2016. The site is situated between 23°41/N latitude and 90°22/E longitude.

Plant materials and growing environments: Sweet pepper cv. 'Wonder Bell' of average fruit weight around 180 g is used in this experiment. Seeds of sweet pepper were collected from Siddique Bazar Seed Market, Dhaka.

[1]*Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh*

[2]*Department of Agriculture, Bangladesh*

[*]***Correspondence:*** *M Jahedur Rahman, Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, Tel: +880 1716 590216; E-mail: jrahman04@yahoo.com*

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Experimental environment

The seeds were sown in the seed bed prepared by the media mixture of coco peat, broken brick and rice husk at the ratio of 6:2:2 (v/v). Two-week-old seedlings were transferred into the 250 mL plastic pots. Eight-week old seedlings were transferred 20 cm apart into the cork-sheet boxes containing media mixtures of coco peat, broken brick and rice husk at the ratio of 6:2:2 (v/v). The 150 cm × 25 cm × 30 cm cork sheet boxes were prepared by cork sheets. The boxes were filled with the media mixture of coco peat, brick broken and rice husk at the ratio of 6:2:2 (v/v). Six healthy seedlings were transferred in each box. The pH 6.0 and EC 3.0-3.5 $dS \bullet m^{-1}$, respectively maintained in the nutrient solutions.

Experimental design and treatments

The experiment was conducted in a completely randomized design with three replications. Three nutrient solutions considered as treatments *viz.*:

S1: Hoagland and Arnon nutrient solution

S2: Full strength of Rahman and Inden nutrient solution and

S3: ¾ strength of Rahman and Inden nutrient solution [1].

The nutrient compositions of Hoagland and Arnon solution were NO_3, NH_4, P, K, Ca, Mg, and S of 14.0, 1.0, 3.0, 6.0, 8.0, 4.0 and 4.0 $meq \bullet L^{-1}$, respectively, and Rahman and Inden solution were NO_3-N, P, K, Ca, Mg, and S of 17.05, 7.86, 8.94, 9.95, 6.0 and 6.0 $meq^{\bullet}L^{-1}$, respectively. The rates of micronutrients were Fe, B, Zn, Cu, Mo and Mn of 3.0, 0.5, 0.1, 0.03, 0.025 and 1.0 $mg^{\bullet}L^{-1}$, respectively for both the nutrient solutions. All the treatments were started at half strength from the first day of the seedlings when transferred into the boxes. Full strength of the treatments was started from the second week of the experiment. The pH 6.0 and EC 2.8 $dS^{\bullet}m^{-1}$, respectively were maintained in the nutrient solutions. These solutions were used in different boxes. After one week of capsicum seedlings transplantation 1/2 strength of nutrient solution was used. Treatments were applied from the second week of the transplantation. Nine plants were considered as an experimental unit.

Preparation of nutrient solutions

In this experiment two nutrient solutions at different concentration were used. One nutrient solution was Hoagland and Arnon solution and the other was Rahman and Inden solution [1]. These nutrient solutions were prepared according to their composition. Mg_2SO_4, $NH_4H_2PO_4$, KNO_3, and $Ca(NO_3)_2$ were prepared as macro-nutrient solution and a micro-nutrient stock solution was prepared.

Preparation of growing media for raising seedling

The mixture of coco peat, broken bricks (khoa) and ash at the ratio of 50:30:20% (v/v). Coco peat was soaked in a big bowl for 24 hours. It was washed well with water and spread in a polythene sheet for 3 hours. Then they are mixed with khoa and ash properly. This mixer was placed in a styro foam sheet box for using seedbed.

Data collection

Data on the following parameters were recorded from the plants during the experiment. Six plants were regarded as an experimental unit. Data were collected on different growth and yield components *viz.* plant height at different days after planting, fruit length, fruit diameter, fruit volume, pericarp thickness, number of fruit per plant, individual fruit weight, fruit yield per plant; physiological parameters, *viz.* Leaf Area (LA), Leaf Area Ratio (LAR), Leaf Mass Ratio (LMR), Root Weight Ratio (RWR), Relative Growth Rate (RGR), and Net Assimilation Rate (NAR). However, physiological parameters were recorded at the end of the experiment and antioxidants were measured during the experiment.

Percent dry matter of plant

From the random samples of plants weighing then sun dried for seven days. After drying, plants were weighed. An electric balance was used to record the dry weight of plant and it was calculated on percentage basis. The percentage of dry matter of plant was calculated by the following formula.

% Dry matter of plant=(Constant dry weight of plant/Fresh weight of plant) × 100

Measurement of ascorbic acid

Ascorbic acid content in capsicum was measured from Bangladesh Council of scientific and Industrial Research (BCSIR).

Growth parameter analysis

Growth parameters (dry weights of stem, leaf and root), and different physiological parameters [Leaf area (LA), leaf area ratio (LAR), leaf mass ratio (LMR), root weight ratio (RWR), relative growth rate (RGR), and net assimilation rate (NAR)] were determined in the experiments. Leaf area was measured by Photoshop program. The parameters were measured as described below (Equations 1-5):

$$LAR = \frac{LA}{PDW} (1)$$

Where, LAR=leaf area ratio; LA=Leaf Area (cm^2); PDW=Plant Dry Weight (g).

$$LMR = \frac{LDW}{PDW} (2)$$

Where, LMR=leaf mass ratio; LDW=Leaf Dry Weight (g).

$$RWR = \frac{RDW}{PDW} (3)$$

Where, RWR=root weight ratio; RDW=Root Dry Weight (g).

$$RGR = \frac{PDW_2 - PDW_0}{(t_1 - t_0) \times PDW_0} (4)$$

Where, t=time; Subscripts 0 and 1 refer to the transplanting and final harvest (days), respectively.

$$NAR = \frac{RGR}{LAR} (5)$$

Statistical analysis of data

The data obtained for different characters were statistically analysed with SPSS version 21.0 and means separation were done by Tukey's test at $p \leq 0.05$.

RESULTS AND DISCUSSION

Plant height

There was no significant difference in plant height at 0 and 30 days after transplanting (DAT), but significant increases in plant height among the three concentrations of nutrient solutions were observed at 60, 90, 120, 150 and 180 DAT (Table 1). The longest plants were found at DAT 150, and DAT 180, when ¾ strength of Rahman and Inden applied [1]. This could be due to the proper proportion of nutrient supply in the plants. In the case of a closed hydroponic system, proper nutrient solution control in the root zone is the first concern for plant adoption. Bloom et al. reported that the growth of sweet pepper was influenced by specific nutrient solutions strengths [5]. The present finding consisted of the Bloom et al. observations [5]. In this study, S3 can provide the plants with a proper amount of nutrients resulting in a higher plant height.

TABLE 1: Effect of nutrient solution on plant height at different days after transplanting in sweet pepper.

Treatment	Plant height (cm) at different Days After Transplanting (DAT)						
	0 DAT	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	180 DAT
S1	29^{az}	49^{b}	61^{b}	73^{b}	82^{b}	95^{b}	102^{b}
S2	31^{a}	64^{a}	77^{a}	95^{a}	106^{a}	115^{a}	119^{a}
S3	27^{a}	61^{a}	75^{a}	91^{a}	103^{a}	112^{a}	117^{a}
p	0.1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	NS	**	**	**	**	**	**

Note: ^{z}Means with different letter (s) is significantly different by Tukey's test at p ≤ 0.05. P represents the level of significance of one-way ANOVA. NS means non-significant at p ≤ 0.05. **Significant at p ≤ 0.01. DAT–Days after transplanting. S1: Hoagland and Arnon, S2: Full strength Rahman and Inden, S3: ¾ strength Rahman and Inden.

Yield contributing characteristics

Number of fruit per plant and individual fruit weight: The maximum number of fruits per plant and individual fruit weight was found when the 3/4 strength nutrient solution was applied (Table 2). This could be due to proper nutrient supply in the plants. Shinohara and Suzuki stated that different intensity of nutrient solutions had affected sweet pepper production. The present finding consisted of findings of Shinohara and Suzuki findings [6].

Fruit length and fruit diameter: The maximum fruit length and diameter were found when ¾ strength Rahman and Inden nutrient solution was applied which was statistically similar when full strength Rahman and Inden was applied (Table 2) [1]. This might be because of proper supply of nutrient in the plants. Shinohara and Suzuki stated that sweet pepper growth was affected by different strength of nutrient solutions. The present finding was consisted with the findings of Shinohara and Suzuki [6].

TABLE 2: Effect of nutrient solution on number of fruit per plant, individual fruit weight, fruit length, fruit diameter, fruit volume and yield of sweet pepper.

Treatment	Number of fruit /plant	Individual Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Fruit volume (cc)	Yield/plant (Kg)
S1	16^{b}z	170^{b}	7.2^{b}	5.8^{b}	183^{b}	2.73^{c}
S2	19^{a}	210^{a}	8.7^{a}	7.9^{a}	224^{a}	3.89^{b}
S3	20^{a}	220^{a}	9.1^{a}	8.1^{a}	238^{a}	4.42^{a}
p	0.020	<0.001	<0.001	<0.001	<0.001	<0.001
	*	**	**	**	**	**

Note: ^{z} Means with different letter is significantly different by Tukey's test at p ≤ 0.05; p represents the level of significance of one-way ANOVA. *significant at p ≤ 0.05. **significant at p ≤ 0.01. S1:Hoagland and Arnon (1940), S2:Full strength Rahman and Inden, S3: ¾ strength Rahman and Inden.

Fruit volume: The fruit volume in the plants was significantly higher when 3⁄4 strength Rahman and Inden were applied (Table 2). In the meantime, the lowest volume of fruit was observed in the plant grown in treatment of S1 [1].

Yield: Nutrient solution formulations have influenced marketable yield (Table 2). S3 noticed the highest yield which was statistically similar to that of S2. This could be attributed to the better performance of yield-contributing characters in S3 and S2 resulting in the higher yield in the same treatments. In the present study, S3 can supply proper amount in available forms of nutrients to the plants resulting higher fruit yield per plant.

Fresh weight: Significant increase in growth was observed among the three concentrations of nutrient solution, where the samples showed greater fresh weights in S3 (Table 3). In fact, plants were able to grow shoot and roots with at ¾ strength Rahman and Inden (2012) nutrient solution in a closed hydroponic system. Physiological quality of fruiting horticultural crops such as capsicum, tomato, strawberry, etc. can be improved at high Electrical Conductivity (EC), also stated that EC levels above 2.0 and 2.6 dS m^{-1} reduced fresh yield and plant growth, respectively in sweet pepper [7-9]. In the present experiment, EC of ¾ strength Rahman and Inden nutrient solution was greater than 2 dS m^{-1} and it might have contributed to supply proper amount of nutrients in available form [1].

TABLE 3: Effect of nutrient solutions on plant fresh and dry weights in sweet pepper.

Treatment	Plant dry weight (g/ plant)		Plant fresh weight (g/plant)
	Leaf	Root	
S1	1.58^{bz}	0.33^{a}	42.37^{b}
S2	1.45^{b}	0.20^{b}	33.41^{c}
S3	2.35^{a}	0.37^{a}	51.61^{a}
p	0.012	0.011	0.001
	**	**	**

Note: ^{z} Means with different letter is significantly different by Tukey's test at p ≤ 0.05. p represents the level of significance of one-way ANOVA. **significant at p ≤ 0.01. S1:Hoagland and Arnon, S2:Full strength Rahman and Inden (2012), S3:¾ strength Rahman and Inden (2012).

Plant dry weight: Plant dry weights of sweet pepper significantly varied by three nutrient solutions (Table 3). The highest dry weights of leaf and root were found in S3 as compared to S2 and S1. This might be due to proper supply of nutrition due to application of S3 solution containing higher Ca^{2+} compared to the others, which contributed to higher dry weights. On the contrary, nutrient solution of S1contains the lowest amount of Ca^{2+} compared to the other treatments. Epstein and Bloom reported that Ca^{2+} increased the root dry weight and calcium content in plant tissues [5]. Bar-Tal et al. found that the shoot and root dry weights decreased with increasing Ca^{2+} in sweet pepper [10]. The present findings consisted with the other findings.

Ascorbic acid content: In Figure 1 the effect of treatments on the ascorbic acid content was observed. Ascorbic acid content increased markedly with the increasing levels of nutrient solution. Ascorbic acid content was higher in the plants grown in ¾ strength of Rahman and Inden [1]. Shinohara and Suzuki reported that ascorbic acid content increased when grown in ¼ strength nutrient solutions compared to the ½ strength nutrient solutions. In the present experiment, ascorbic acid content increased with increased concentration which was not consistent with the others findings [6].

However, it was significant that ascorbic acid content increased in the same treatment with higher yield. On the other hand, when the plants were grown in low nutrient concentrations, leaf constituents implied not to be metabolized sufficiently under low concentration of nutrient solution because of insufficient supply of inorganic matter from roots [6]. The present result was consistent with their findings. Fanasca et al. stated that the total antioxidant activity increased in tomato with increased supply of Mg^{2+} and K^{+} in the nutrient solution [5]. In the present study, S3 contained the higher amount of Mg and K which enhanced the biosynthesis of higher amount of ascorbic acid in sweet pepper.

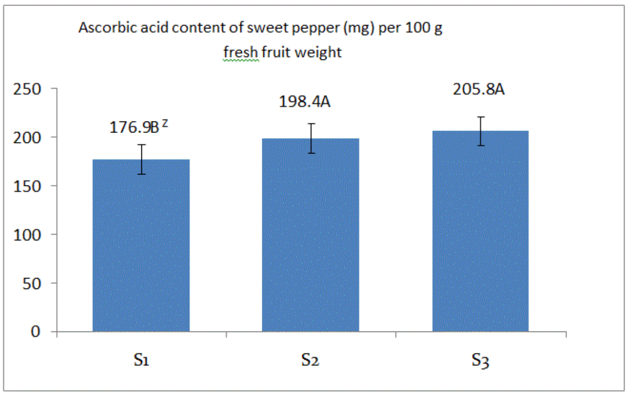

Figure 1) Effect of nutrient solutions on ascorbic acid content in sweet pepper. ^{z} Means with different letter is significantly different by Tukey's test at $p \leq 0.05$. S1:Hoagland and Arnon, S2:Full strength Rahman and Inden, S3: ¾ strength Rahman and Inden. Vertical bars represent standard errors of means.

Physiological growth traits

Leaf Area (LA): Leaf area increased markedly with rising concentrations of nutrient solution (Table 4). The leaf area was higher in the plants grown in ¾ strength Rahman and Inden nutrient solution than those grown in S1 and S2 nutrient solution. The area of plant leaves is an important determinant of light interception and therefore of transpiration, photosynthesis and productivity of plants [11]. The area of the leaf can be calculated by either destructive or non-destructive methods. Accurate, non-destructive measurements enable repeated sampling of the same plants over time, and have the benefit of preventing biological variance. Non-destructive measures are of great value especially when using specific plants, for example in genetically segregating populations. A common approach to the non-destructive estimation of leaf areas is to develop ratios and regression estimators using easily measured leaf parameters such as length and width [12]. In the course of development, plants produce many forms of leaves. The first few true leaves produced are usually smaller, simpler and anatomically distinct from the leaves developed later. Zeigerand Taiz showed that in lettuce this ratio of individual leaves decreased with time and eventually became constant. Comparable results were found in red spruce. Consequently, the ratio between leaf area and the product of length and width changes with plant age [13].

Leaf Mass Ration (LMR): The growth parameters of different nutrient solutions varied significantly (Table 4). Results revealed an increase in LMR in S3 as compared to S1 and S2. One important criterion for producing higher metabolites is higher LMR. Prieto et al. stated that increased LMR provided an increased ability to intercept light to the plants. We found higher LMR in sweet pepper due to application of S3 which may be able to produce higher metabolites [14].

TABLE 4: Effect of nutrient solutions on physiological growth of sweet pepper.

Treatment	Leaf area (cm^2)	Leaf Mass Ration (LMR) ($g.g^{-1}$)	Leaf area Ratio (cm^2g^{-1})	Root Weight Ratio (RWR) ($g.g^{-1}$)	Net Assimilation Rate (NAR)	Relative Growth Rate (RGR)
S1	$128.7^{a}z$	0.85^{c}	72.92^{a}	0.175^{a}	0.0000079^{b}	0.00059^{b}
S2	117.6^{b}	0.89^{b}	65.82^{b}	0.124^{c}	0.0000071^{c}	0.00051^{c}
S3	136.8^{a}	0.97^{a}	63.97^{b}	0.139^{b}	0.0000119^{a}	0.00079^{a}
p	<0.001	<0.001	0.002	0.003	<0.001	<0.001
	**	**	**	**	**	**

Note: ^{z} Means with different letter is significantly different by Tukey's test at $p \leq 0.05$. p represents the level of significance of one-way ANOVA. **significant at $p \leq 0.01$. S1:Hoagland and Arnon (1940), S2:Full strength Rahman and Inden (2012), S3: ¾ strength Rahman and Inden (2012).

Leaf Area Ratio (LAR): Growth parameters varied significantly by different nutrient solution (Table 4). Results revealed that LAR decreased in S3 compared with S2 and S1. Lower LAR is one of the key criteria for producing higher metabolites. Prieto et al. stated that increased LAR provided an improved ability to intercept light to the plants. We observed lower LAR in sweet pepper due to application of S3, which may have the ability to produce higher metabolites [14]. Starck observed reduced LAR in tomatoes, which coincided with our results because of the use of the nutrient solution in sweet pepper [15].

Root Weight Ratio (RWR): Growth parameters varied significantly by different nutrient solution (Table 4). Results revealed that RWR decreased from S1 in S3, but increased to S2 in S3. Higher RWR is one of the important criteria for higher metabolite production. Prieto et al. reported that increased RWR has enabled the plants to intercept light [14]. We found lower RWR in sweet pepper due to application of S3, which may have the ability to produce higher metabolites. Starck observed reduced RWR in tomatoes, which coincided with our results because of the use of a nutrient solution in sweet pepper [15].

Net Assimilation Rate (NAR): Growth parameters varied significantly by different nutrient solution (Table 4). Results revealed that NAR increased in S3 compared to S1 and S2. Higher NAR is one of the important criteria for producing higher metabolites. Prieto et al. [14] reported that increased NAR gave the plants an increased ability to intercept light. We found higher NAR due to application of S3 that may have the ability to produce higher metabolites in sweet pepper.

Relative Growth Rate (RGR): Growth parameters varied significantly by different nutrient solution (Table 4). Results revealed that RGR increased in S3 compared to S1 and S2. Higher RGR is one of the important criteria for producing higher metabolites. Prieto et al. reported that increased RGR gave the plants an increased ability to intercept light [14]. We found higher RGR due to application of S3 that may have the ability to produce higher metabolites in sweet pepper. The plants growth analyses data suggested that S3 provided better nutrition to the plants, followed by the control. This was most relevant in higher RGR and NAR due to application of S3. However, plant growth parameters indicated that application of ¾ strength of Rahman and Inden with a higher level of plant growth [1].

CONCLUSION

In conclusion, the different strengths of nutrient solutions have affected vegetative production, yield, ascorbic acid concentration and physiological traits. The maximum number of fruit, plant height, fruit volume, NAR, RGR and ascorbic acid content was found in S3. Thus, sweet pepper can be grown in the greenhouse using ¾ strength of Rahman and Inden nutrient solution in Bangladesh with higher yield.

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