

Effect of Different Nutrient Solutions on Growth, Yield, and Quality of Hydroponic Capsicum Varieties

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ABSTRACT

Nutrient solution and its composition may have the effect of growth and yield of capsicum varieties. Individual crop has its specific nutrition requirement for its proper growth in soilless culture. Therefore, it is important to identify specific nutritional composition in capsicum / sweet pepper varieties in Bangladesh. In this study, growth and yield parameter in different varieties of sweet pepper by applying different nutrient solution formulations were investigated. Four levels of nutrient solution concentrations, viz., S₁: Full strength Hoagland and Arnon (1940) nutrient solution, S₂: $\frac{3}{4}$ strength Hoagland and Arnon (1940) nutrient solution, S₃: Full strength Rahman and Inden (2012) nutrient solution and S₄: $\frac{3}{4}$ strength Rahman and Inden (2012) nutrient solution and four varieties of capsicum, viz., V₁: California Wonder, V₂: Wonder Bell, V₃: Capsicum F1 and V₄: Capsicum F1 were treated as treatments. Vegetative growth, physiological, yield contributing characters and antioxidant content were measured. In case of nutrient solution, the highest plant height (119cm), number of fruits per plant (20), individual fruit weight (210g) and fruits yield (3.99 kg/plant) were found highest when S₃ nutrient formulation was applied. But statistically similar results were found in S₄ V₄ which was similar to that of S₃. While the ascorbic acid (205.8 mg/100g FW), leaf area

(136.8 cm²), leaf mass ratio (0.97g.g⁻¹) and net assimilation rate (0.000012 g.cm⁻². d⁻¹) were maximum in S₄. In varieties, the highest plant height (119cm), number of fruits per plant (20), individual fruit weight (210g) and fruits yield (3.99 kg/plant) were found in V₄ which was similar to that of V₃. The highest plant height number of fruits/plants, individual fruit weight, yield/plant were found in S₃V₃ which was similar to S₄V₄. Therefore, ³/₄ strength Rahman and Inden, (2012) nutrient solution can be used for sweet pepper cv. California Wonder in hydroponic system in Bangladesh.

Key words: antioxidant, capsicum, fruit quality, hydroponics and soilless culture.

INTRODUCTION

Fruits of sweet pepper or capsicum (*Capsicum annuum*) among the most consumed species throughout the world. The fruits contain capsaicinoids that give them the characteristic pungent taste. Capsaicin and dihydrocapsaicin, the two major capsaicinoids, are responsible for up to 90% of the total pungency of pepper fruits. Capsaicinoids are currently used in the food industry, for medical purposes as pharmaceuticals, and in defensive sprays. Sweet pepper fruits are used as vegetable and condiments, and the requirement of pungency levels depend on the purpose of the uses. The degree of pungency depends on Capsicum species and cultivars, and the capsaicin contents may be affected by different Vectors such as the developmental stage of fruits, environmental stresses, and nutrient accumulation in the placental tissue and so on.

In hydroponics, it's absolutely essential to begin with a laboratory analysis of nutrient solution. The three main things are important as the alkalinity, the electrical conductivity (EC) and the concentration specific elements. Alkalinity is a measure of water's ability to neutralize acid. Alkalinity is usually reported in terms of ppm of calcium carbonate equivalents (CaCO₃). The greater nutrient solution's alkalinity, the more the pH will tend to rise in the nutrient solution. Water source alkalinity is a much more important to look at than its pH. Nowadays, hydroponics culture is becoming increasingly popular all over the world. It is highly productive in nature, conservative of water and land. Moreover, hydroponics culture is protective to the environment. Hydroponics has proved to be an excellent alternative crop production system (Savvas, 2003). The cultivation of vegetable crops and the achievement of high yields and high quality are possible with hydroponics even in saline or acidic soils, or non-arable soils with poor structure, which represent a major proportion of cultivable land throughout the world. A further advantage of hydroponics is the precise control of plant nutrition. Furthermore, the preparation of the soil is avoided in hydroponics, thereby increasing the potential length of cultivation time, which is an effective means of increasing the total yield in greenhouses. The reason, imposing a switch over to hydroponics is increasingly associated with environmental policies as well. A hydroponic system enables a considerable reduction of fertilizer application and a drastic restriction or even a complete elimination of nutrient leaching from greenhouses to the environment (Avidan, 2000). Moreover, it provides an instant as well as long term solution to the problem of inability of a household to produce its own vegetables under urban settings.

The nutrient solution is one of the major components for successful hydroponic crop production. The composition of nutrient solutions and the optimization of nutrition in

commercial hydroponics can reduce fertilizer costs. Specific formulation of nutrient solution compositions is required for the most horticultural species grown in soilless culture (De Kreij *et al.*, 1999). Moreover, to obtain high yield and good quality in commercial crops grown hydroponically, the nutrient solution supplied to the plants must be specific for the particular crop, the climatic conditions, or hydroponic system used etc.

Improving the yield and yield contributing characteristics in sweet pepper are important factor for soilless culture technique. These may be improved by managing external nutrient availability in the growing substrates. Proper nutrient combinations in the solution may improve the yield and yield contributing characters in the crop. Environmental factors are the limiting factors for the yield of a crop, and proper management of growing environments may play an important role to increase in the yield and yield contributing characters of sweet pepper.

Considering the above-mentioned facts, the present research work was aimed to modify a simple nutrient solution for producing higher yield and high quality of capsicum in Bangladesh

MATERIALS AND METHODS

Experimental Site

The experiment was conducted in the polythene house (treated as semi-greenhouse) at the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka 1207. Bangladesh during July 2018 to March 2019. The site is situated between 23 ° 41' N latitude and 90 ° 22' E longitude.

Plant Materials and Growing Environments

sweet pepper/capsicum varieties of average fruit weight around 180g were used in this experiment. Seeds of sweet pepper were collected from Siddique Bazar Seed Market, Dhaka.

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 30-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 $\cong$ 6.0 and EC $\cong$ 3.0 – 3.5 dS·m⁻¹, respectively maintained in the nutrient solutions.

Experimental Design and Treatments

The experiment was conducted in a two factors Randomized Completely Block Design (RCBD) with three replications. The factors were nutrient solution concentrations denoted as NS and varieties of capsicum denoted as V.

Factor - A: Four levels of nutrient solution concentrations denoted as NS, viz., S₁: Full strength Hoagland and Arnon (1940) nutrient solution, S₂: $\frac{3}{4}$ strength Hoagland and Arnon (1940)

nutrient solution, S₂: Full strength Rahman and Inden (2012) nutrient solution and S₃: $\frac{3}{4}$ strength Rahman and Inden (2012) nutrient solution. Factor - B: Four varieties of capsicum denoted as V, viz., V₁: California Wonder, V₂: Wonder Bell, V₃: Capsicum F1 and V₄: Capsicum F1.

The nutrient compositions of Hoagland and Arnon (1940) solution were NO₃, NH₄, P, K, Ca, Mg, and S of 14.0, 1.0, 3.0, 6.0, 8.0, 4.0 and 4.0 meq·L⁻¹, respectively, and Rahman and Inden (2012) solution were NO₃-N, P, K, Ca, Mg, and S of 17.05, 7.86, 8.94, 9.95, 6.0 and 6.0 meq·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·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 $\cong$ 6.0 and EC $\cong$ 2.8 dS·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 (1940) solution and the other was Rahman and Inden (2012) solution. These nutrient solutions were prepared according to their composition. Mg₂SO₄, NH₄H₂PO₄, KNO₃, and Ca (NO₃)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 styrofoam sheet box for using seedbed.

Seed Sowing

The seeds were soaked in water for 24 hours and then wrapped with piece of thin cloth. The soaked seed were then spread over polythene sheet for 2 hours to dry out the surface water. After those seeds were shown in plastic tray and covered with newspaper under room temperature for rising seedlings.

Transplanting of Capsicum Seedling

Two-week old capsicum seedlings were transferred into the plastic pots containing the mixture of coco peat, khoa and rice husk. Rahman and Inden (2012) solution were given to the seedlings regularly along with fresh water (Plate 1). After that, six-week-old seedlings were transplanted to the main boxes. The seedlings were transplanted in the afternoon carefully to minimize transplanting shock. After transplanting of capsicum seedlings in the boxes, light watering was done with water can.

DATA COLLECTION

Different data on the growth and physiological growth parameters were recorded during the experiment. Data were collected from each plant described below.

Plant Height

Plant height was measured in centimeter (cm) by a meter scale at 0, 30, 60, 90, 120, 150 and 180 DAT (days after transplanting) from the point of attachment of growing media up to the tip of the longest leaf.

Individual Fruit Weight

The individual fruit weights were measured by electric balance at the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka 1207.

Number of Fruits per Plant

Number of fruits per plant were counted at 75 (First harvesting), 120 (Second harvesting) and 180 (Third harvesting) DAT. All the fruits of each plant were counted separately. Only the smallest young fruits at the growing point of the plant were excluded from the counting and the average number was recorded.

Dry Weight of Stem, Leaf and Root

Stem, leaf and root was dried by sun for 2 days separately, after that these were transferred to oven of central laboratory, Sher-e-Bangla Agricultural University for 72 hours at 105°C.

Yield per Plant

Yield per plant was determined with the following formula.

$$\text{Yield per plant (g)} = \text{Individual fruit weight (g)} \times \text{Number of fruits per plant}$$

Yield per Hectare

Yield per hectare was determined with the following formula.

$$\text{Yield per hectare (kg)} = \frac{\text{Yield / plant (g)} \times 50000}{1000}$$

where, 50000 = number of plant / hectares, and 1000 g = 1 kg

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.

The parameters were measured as described below:

Leaf Area Index (LAI)

Leaf area index (LAI) was measured using Adobe Photoshop CS-3 program.

Leaf Area Ratio (LAR)

Leaf area ratio (LAR) was determined using the following formula.

$$\text{LAR} = \frac{\text{LA}}{\text{PDW}}$$

Where, LAR = leaf area ratio, LA = Leaf area (cm²), PDW = plant dry weight (g).

Leaf Mass Ratio (LMR)

Leaf mass ratio was determined using the following formula.

$$\text{LMR} = \frac{\text{LDW}}{\text{PDW}}$$

Where, LMR = leaf mass ratio, LDW = leaf dry weight (g).

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

The results of the experiment were presented and discussed under the following headings.

Plant Height (cm)

Plant heights at different days after transplanting (DAT) of sweet pepper were significantly affected by different concentrations of nutrient solutions except 0 DAT (Table 1). The plant heights were measured at 0, 30, 60, 90, 120, 150 and 180. At 0 DAT, the tallest plant (13.13 cm) was found in S₃ and the lowest (13.06 cm) in S₄. At 30 DAT, the tallest plant (33.96 cm) was found in S₃ and the lowest (29.28 cm) in S₁. At 60 DAT, the tallest plant (53.42 cm) was found in S₄ and the lowest (45.78 cm) in S₁. At 90 DAT, the tallest plant (69.11 cm) was found in S₄ and the lowest (58.66 cm) was found in S₁. At 120 DAT, the tallest plant (78.33 cm) was found in S₄ and the lowest (67.27 cm) was found in S₁. At 150 DAT, the tallest plant (84.38 cm) was found in S₄ and the lowest (72.19 cm) was found in S₁. At 180 DAT, the tallest plant (88.55 cm) was found in S₄ and the lowest (76.21 cm) was found in S₁. The results revealed that the maximum plants heights at all dates were found in plants grown in treatment S₄ which was statistically similar to that of S₂. It was revealed that plant heights were increased with advancement of the maturity of the plants. Narkhede *et al.* (2011) found that significant increase in plant height of pepper plants treated with different fertilizer sources.

Plant height was significantly changed by different varieties of capsicum (Table 1). At 0 DAT, the tallest plant (13.17 cm) was found in V₃ and the lowest (13.03 cm) was found in V₁. At 30 DAT, the tallest plant (33.72 cm) was found in V₄ and the lowest (30.05 cm) was found in V₁. At 60 DAT, the tallest plant (53.85 cm) was found in V₄ and the lowest (45.09 cm) was found in V₁. At 90 DAT, the tallest plant (69.50 cm) was found in V₄ and the lowest (57.91 cm) was found in V₁. At 120 DAT, the tallest plant (79.79 cm) was found in V₄ and the lowest (65.43 cm) was found in V₁. At 150 DAT, the tallest plant (85.93 cm) was found in V₄ and the lowest (70.99 cm)

was found in V₁. At 180 DAT, the tallest plant (89.91 cm) was found in V₄ and the lowest (75.41 cm) was found in V₁.

In case of combined effect of liquid organic fertilizer and foliar application, the insignificant variation was found at 0 DAT, whereas the significant variations were found at 30, 60, 90, 120, 150 and 180 DAT (Table 2). The highest plants at all dates were found in S₄V₄ the lowest were found in S₁V₁.

Table 1. Main effects of nutrient solution and variety on plant height of capsicum at different days after transplanting.

Treatments	Plant height at different days after transplanting (DAT) (cm)						
	0 DAT	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	180 DAT
Nutrient solution concentrations (S)							
S ₁	13.08	29.28 c ^z	45.78 c	58.66 c	67.27 c	72.19 c	76.21 c
S ₂	13.09	31.80 b	50.29 b	64.24 b	74.24 b	80.62 b	85.01 b
S ₃	13.13	33.96 a	53.27 a	68.68 a	77.79 ab	83.80 a	87.82 a
S ₄	13.06	34.22 a	53.42 a	69.11 a	78.33 a	84.38 a	88.55 a
Variety (V)							
V ₁	13.03	30.05 c	45.09 c	57.91 c	65.43 c	70.99 c	75.41 c
V ₂	13.05	31.88 b	50.21 b	64.76 b	73.86 b	79.84 b	84.01 b
V ₃	13.17	33.60 a	53.61 a	68.53 a	78.56 a	84.21 a	88.25 a
V ₄	13.12	33.72 a	53.85 a	69.50 a	79.79 a	85.93 a	89.91 a
Level of significance (P)							
S	>0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
V	>0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

^zMeans with different letter (s) is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of two-way ANOVA. DAT – Days after transplanting. S₁: Full strength Hoagland and Arnon (1940) nutrient solution, S₂: ¾ strength Hoagland and Arnon (1940) nutrient solution, S₃: Full strength Rahman and Inden (2012) nutrient solution and S₄: ¾ strength Rahman and Inden (2012) nutrient solution. V₁: California Wonder, V₂: Wonder Bell, V₃: Capsicum F₁, V₄: Capsicum F₁.

Table 2. Interaction effect of nutrient solution concentrations and variety of capsicum on plant height at different days after transplanting.

Treatment	Plant height at different days after transplanting (cm)						
	0 DAT	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	180 DAT
S ₁ V ₁	13.18	28.10 f	39.22 j	52.25 h	60.31 g	64.99 g	69.12 f
S ₁ V ₂	12.98	28.83 ef	45.34 i	57.62 g	66.33 fg	71.17 f	75.35 e
S ₁ V ₃	13.35	30.46 de	49.81 f-h	63.63 ef	75.05 b-e	79.46 d	83.48 d
S ₁ V ₄	12.80	29.74 d-f	48.75 gh	61.14 fg	67.42 e-g	73.13 ef	76.88 e
S ₂ V ₁	13.56	30.64 de	44.72 i	60.29 fg	71.88 d-f	78.59 de	83.01 d
S ₂ V ₂	13.09	31.05 cd	50.39 e-g	63.71 ef	72.80 d-f	79.43 d	83.83 d
S ₂ V ₃	12.75	32.65 bc	53.29 c-e	65.83 de	73.47 c-f	78.80 de	83.39 d
S ₂ V ₄	12.95	32.83 bc	52.78 c-f	67.15 de	78.79 a-d	85.64 bc	89.81 bc
S ₃ V ₁	13.09	30.65 de	49.38 gh	60.13 fg	67.23 e-g	72.92 ef	77.52 e
S ₃ V ₂	12.73	33.23 b	51.26 d-g	67.78 c-e	75.07 b-e	80.89 cd	84.65 cd
S ₃ V ₃	13.45	35.91 a	55.82 a-c	72.38 a-c	82.77 ab	89.68 ab	93.36 ab
S ₃ V ₄	13.28	36.04 a	56.61 ab	74.44 ab	86.09 a	91.71 ab	95.74 a
S ₄ V ₁	12.29	30.81 d	47.04 hi	58.97 fg	62.29 g	67.47 fg	72.00 ef
S ₄ V ₂	13.38	34.42 ab	53.87 b-d	69.94 b-d	81.24 a-c	87.87 ab	92.22 ab
S ₄ V ₃	13.12	35.37 a	55.51 a-c	72.28 a-c	82.93 ab	88.89 ab	92.78 ab
S ₄ V ₄	13.43	36.26 a	57.25 a	75.26 a	86.87 a	93.27 a	97.20 a
Level of significance (P)							
S×V	>0.051	<0.0342	<0.0215	<0.0452	<0.0047	<0.001	<0.001

^aMeans with different letter (s) is significantly different by Tukey's test at $P \leq 0.05$. P represents the level of significance of two-way ANOVA. DAT – Days after transplanting. S₁: Full strength Hoagland and Arnon (1940) nutrient solution, S₂: $\frac{3}{4}$ strength Hoagland and Arnon (1940) nutrient solution, S₃: Full strength Rahman and Inden (2012) nutrient solution and S₄: $\frac{3}{4}$ strength Rahman and Inden (2012) nutrient solution. V₁: California Wonder, V₂: Wonder Bell, V₃: Capsicum F₁, V₄: Capsicum F₁.

Number of Fruit per Plant

Number of fruits per plant of capsicum were significantly affected by different doses of nutrient solution concentration (Figure 1). The highest fruit number was found in S₄ (7.67) which was statistically similar to that of S₃ (7.47) treatment. On the other hand, S₁ (6.33) showed lowest fruit number. Samawat *et al.* (2001) reported in 100% Vermicompost treatment, fruit weight and fruit number were three, five and nine times more than the control treatment. Patil *et al.* (2004) observed that significantly highest numbers of fruits (42.07 per plant) were recorded in the plants supplemented with 3 % of liquid organic fertilizers in tomato.

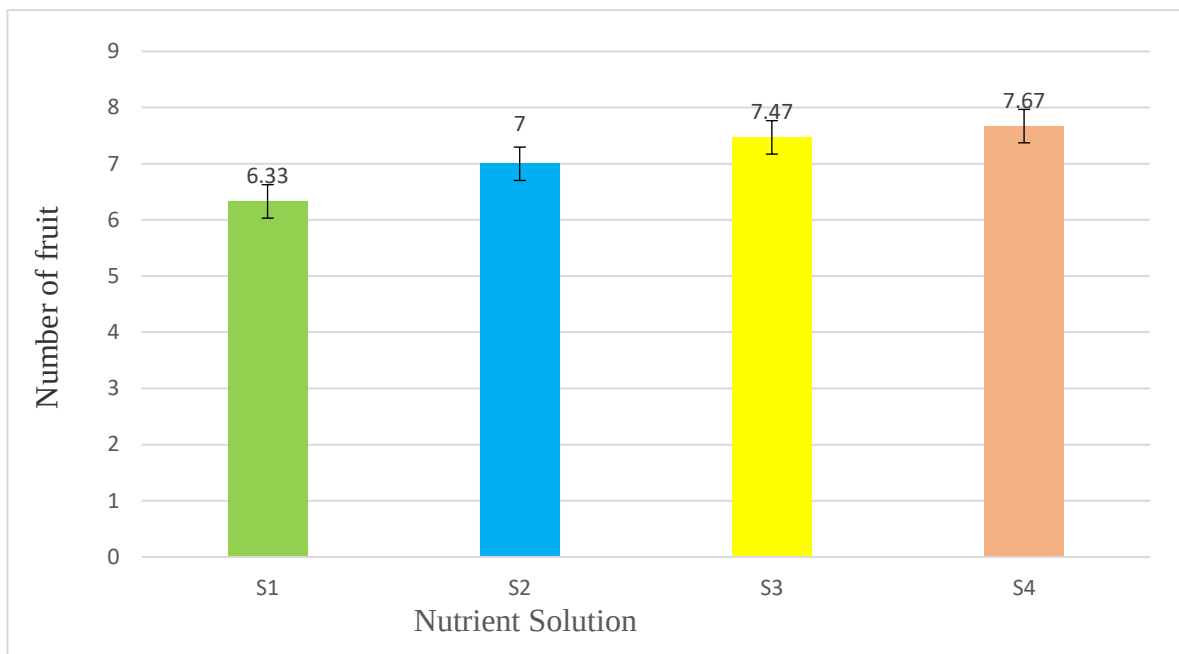


Figure 1. Effect of different doses of nutrient solution on number of fruits per plant of capsicum. S₁: Full strength Hoagland and Arnon (1940) nutrient solution, S₂: $\frac{3}{4}$ strength Hoagland and Arnon (1940) nutrient solution, S₂: Full strength Rahman and Inden (2012) nutrient solution and S₃: $\frac{3}{4}$ strength Rahman and Inden (2012) nutrient solution.

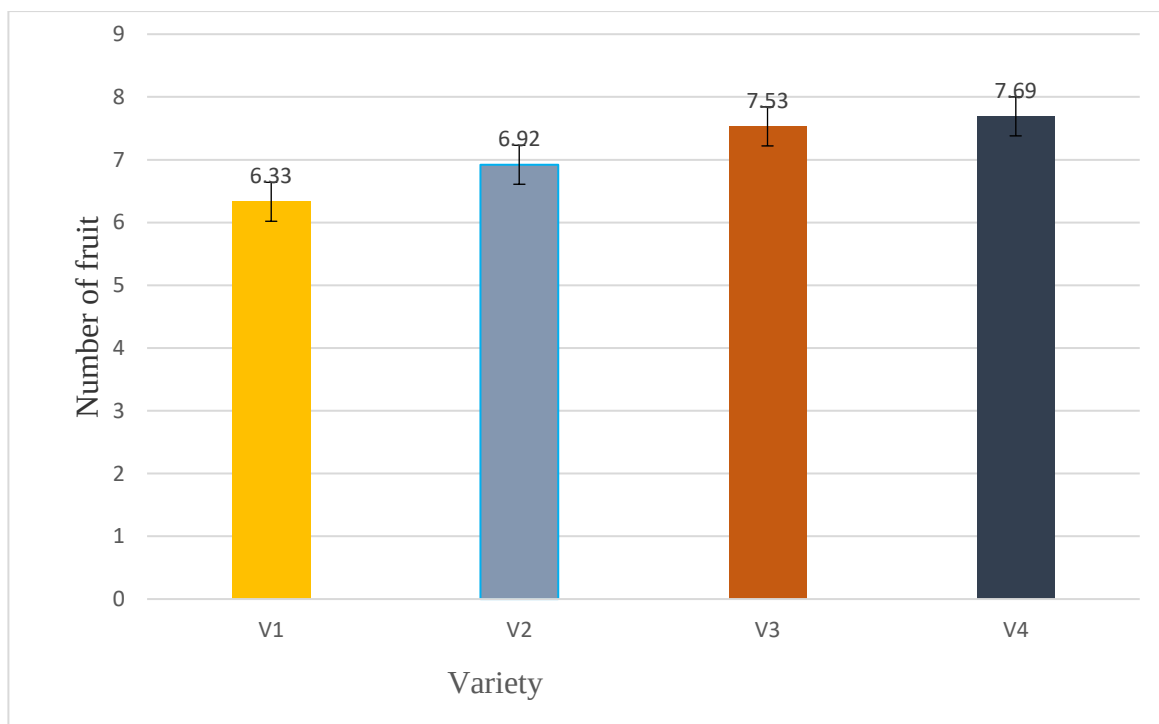


Figure.2. Effect of different variety of cow dung leachate on number of fruits per plant of capsicum. V₁: California Wonder, V₂: Wonder Bell, V₃: Capsicum F₁, V₄: Capsicum F₁.

Number of fruits per plant of capsicum were significantly affected by different variety (Figure 2). The highest fruit number was found in V₄ (7.69) which was statistically similar to that of V₃ (7.53). On the other hand, V₁ (6.33) showed lowest fruit number.

Significant influence was noted on number of fruits influenced by combined effect of different doses of nutrient solution concentration and variety (Table 3). The highest fruit number was recorded from the treatment combination S₄V₄ and the lowest were found in S₁V₁.

Individual Fruit Weight

Individual fruit weight of capsicum was significantly affected by different doses of nutrient solution concentration (Figure 3). The highest fruit weight was found in S₄ (105.25 g) which was statistically similar to that of S₃ (104.32 g) treatment. On the other hand, S₁ (94.01 g) showed lowest fruit weight. Attarde *et al.* (2012) found that fruit weight of okra increases due to the amplification of nutrient content through the application of vermicompost. Salas and Ramirez (2001) observed maximum fresh fruit weight in capsicum treated with organic manure like chicken manures, compost and vermicompost treatment than inorganic fertilizers.

Individual fruit weight of capsicum was significantly affected by different variety (Figure 4). The highest fruit weight was found in V₄ (105.30 g) which was statistically similar to that of V₃. On the other hand, V₁ (94.28 g) showed lowest fruit weight.

Significant influence was noted on Individual fruit weight influenced by combined effect of different doses of nutrient solution concentration and variety (Table 3). The highest individual fruit weight was recorded from the treatment combination S₄V₄ and the lowest were found in S₁V₁.

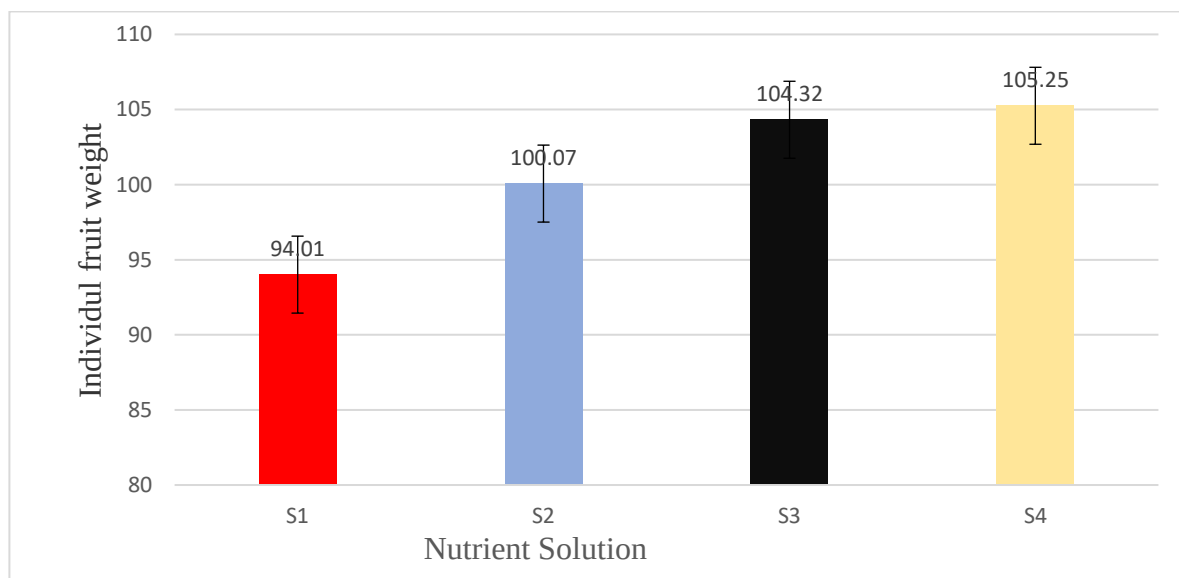


Figure. 3. Effect of different doses of nutrient solution on individual fruit weight of capsicum. S₁: Full strength Hoagland and Arnon (1940) nutrient solution, S₂: $\frac{3}{4}$ strength Hoagland and Arnon (1940) nutrient solution, S₃: Full strength Rahman and Inden (2012) nutrient solution and S₄: $\frac{3}{4}$ strength Rahman and Inden (2012) nutrient solution.

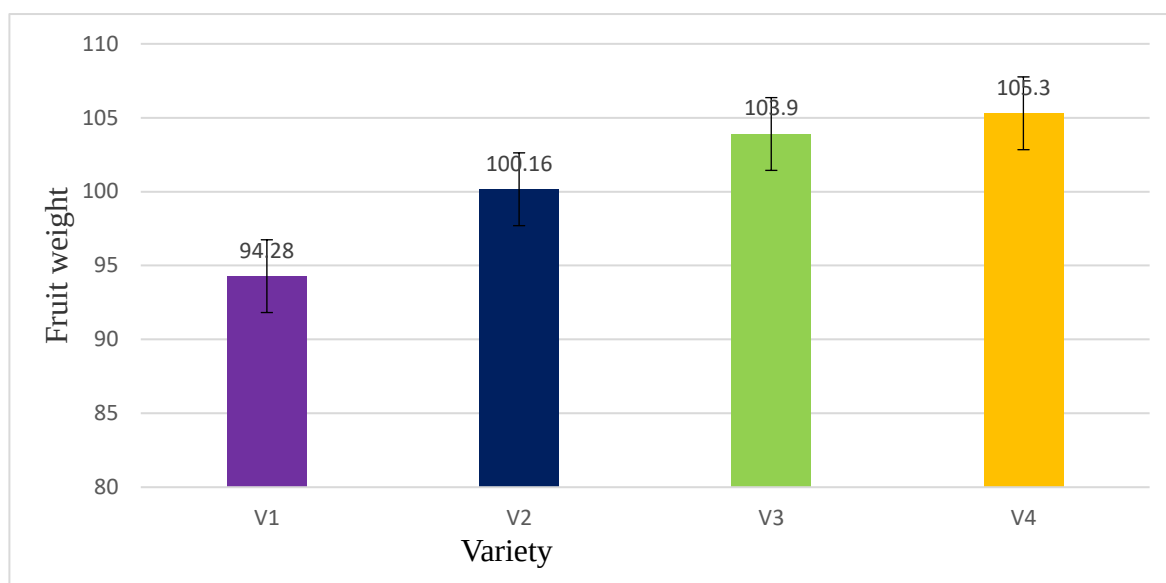


Figure 4. Effect of variety of variety of capsicum on individual fruit weight of capsicum. V₁: California Wonder, V₂: Wonder Bell, V₃: Capsicum F₁, V₄: Capsicum F₁.

Fruit Dry Weight per 100 g

Fruit dry weight of capsicum were significantly affected by different doses of nutrient solution concentration (Figure 5). The highest fruit dry weight was found in S₄ (9.77 g) which was statistically similar to that of S₃ (9.63 g) treatment. On the other hand, S₁ (7.67 g) showed lowest fruit dry weight. Aslani and Souri (2018) found that Plants produced significantly higher pod dry weight, although application of all the organic chelates significantly increased pod dry weight.

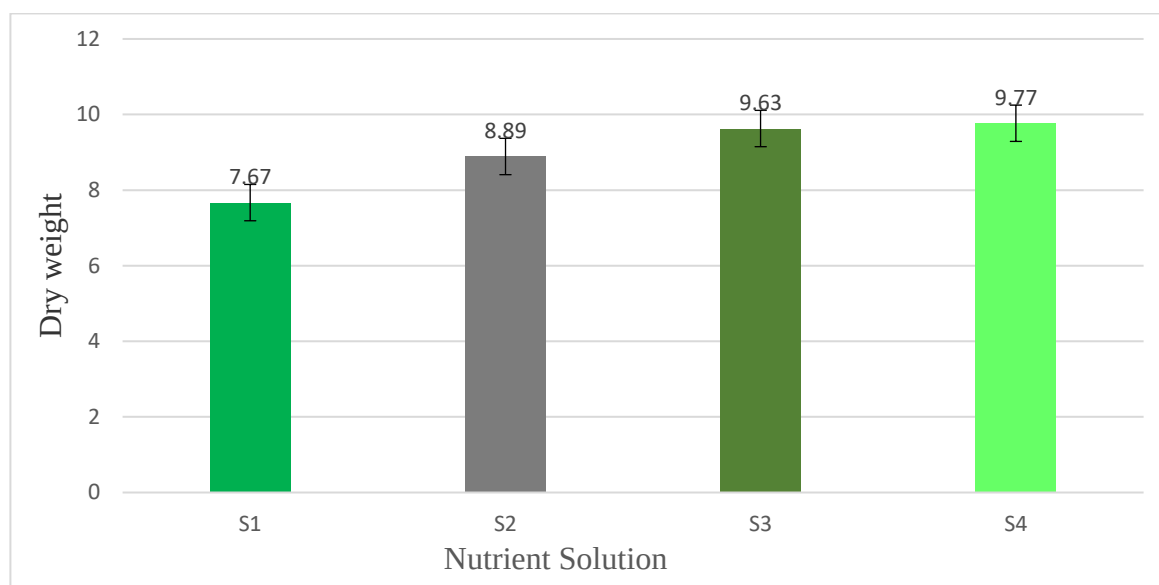


Figure.5. Effect of different doses of nutrient solution on fruit dry weight per 100 g. S₁: Full strength Hoagland and Arnon (1940) nutrient solution, S₂: ¾ strength Hoagland and Arnon (1940) nutrient solution, S₂: Full strength Rahman and Inden (2012) nutrient solution and S₃: ¾ strength Rahman and Inden (2012) nutrient solution.

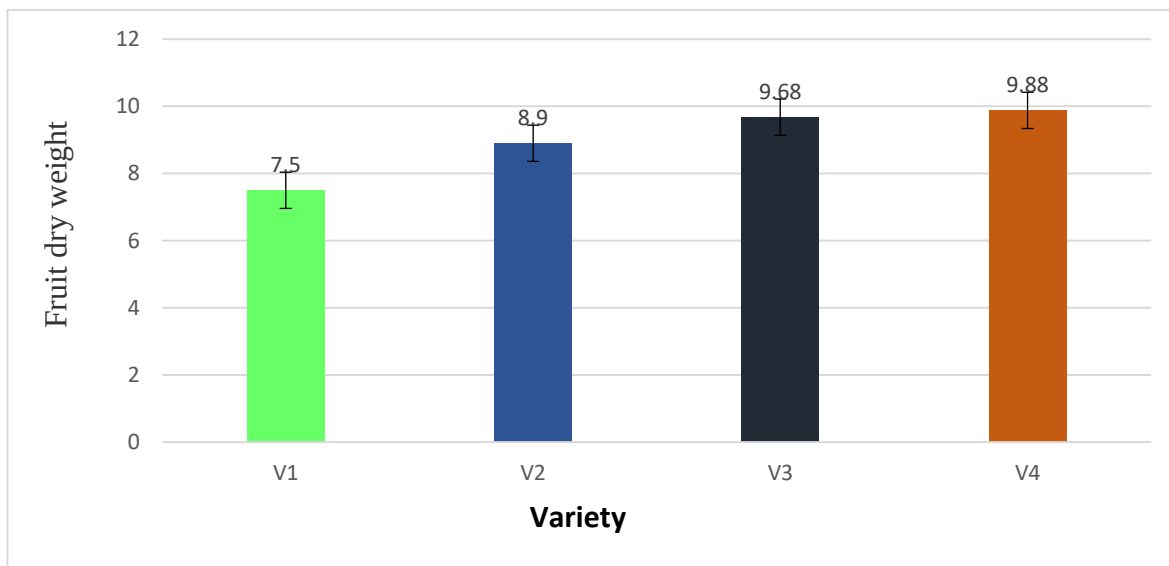


Figure 6. Effect of variety of capsicum on fruit dry weight per 100 g. V₁: California Wonder, V₂: Wonder Bell, V₃: Capsicum F₁, V₄: Capsicum F₁.

Fruit dry weight of capsicum were significantly affected by different variety (Figure 6). The highest fruit dry weight was found in V₄ (9.88 g) which was statistically similar to that of V₃. On the other hand, V₁ (7.50 g) showed lowest fruit dry weight. Significant influence was noted on fruit dry weight influenced by combined effect of different doses of nutrient solution concentration and variety (Table 3). The highest individual fruit weight was recorded from the treatment combination S₄V₄ and the lowest were found in S₁V₁.

Table 3. Interaction effect of nutrient solution and variety on fruits/plant, individual fruit weight and fruit dry weight of capsicum.

Treatment	Number of fruits per plant	Individual fruit weight (g)	Fruit dry weight per 100 g (g)
S ₁ V ₁	6.11 d	91.16 f	6.61 h
S ₁ V ₂	6.22 d	92.68 ef	7.46 f-h
S ₁ V ₃	6.78 cd	96.13 d-f	8.69 c-e
S ₁ V ₄	6.22 d	96.07 d-f	7.91 e-g
S ₂ V ₁	6.44 d	98.59 d-f	8.35 d-f
S ₂ V ₂	6.89 cd	99.08 c-f	8.73 c-e
S ₂ V ₃	7.00 cd	100.51 c-e	8.94 cd
S ₂ V ₄	7.67 a-c	102.11 b-d	9.54 bc
S ₃ V ₁	6.33 d	94.85 d-f	7.83 e-g
S ₃ V ₂	7.00 cd	101.86 b-d	9.18 cd
S ₃ V ₃	8.22 ab	109.65 ab	10.59 a
S ₃ V ₄	8.33 ab	110.90 a	10.92 a
S ₄ V ₁	6.44 d	92.54 ef	7.20 gh
S ₄ V ₂	7.56 bc	107.02 a-c	10.22 ab
S ₄ V ₃	8.11 ab	109.30 ab	10.51 a
S ₄ V ₄	8.56 a	112.12 a	11.15 a
Level of significance (P)			

S×V	<0.0346	<0.0474	<0.001
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Means with different letter (s) is significantly different by Tukey's test at $P \leq 0.05$. P represents the level of significance of two-way ANOVA. DAT – Days after transplanting. S₁: Full strength Hoagland and Arnon (1940) nutrient solution, S₂: $\frac{3}{4}$ strength Hoagland and Arnon (1940) nutrient solution, S₃: Full strength Rahman and Inden (2012) nutrient solution and S₄: $\frac{3}{4}$ strength Rahman and Inden (2012) nutrient solution. V₁: California Wonder, V₂: Wonder Bell, V₃: Capsicum F₁, V₄: Capsicum F₁.

Yield per Plant

Marketable yield was affected by nutrient solution and variety (Figure 7). The highest yield (812.75 g/plant) was found in S₄ treatment while, the lowest yield (597.39 g/plant) was found in S₁ treatment. This might be due to higher number of fruit by application of S₄. Doss *et al.* (1981) reported that average yields from the lower nitrogen rate were greater than the higher nitrogen rate in the two driest years and were similar or higher from the higher nitrogen rate in year of more average rain. The effects of vermicompost on flowering and fruiting of strawberry might be attributed to the higher doses of vermicompost have resulted in to better growth of plants and consequently they took lesser days to flower and produced higher fruit yield than those receiving inorganic fertilizers only (Atiyeh *et al.*, 2001; Arancon *et al.*, 2004).

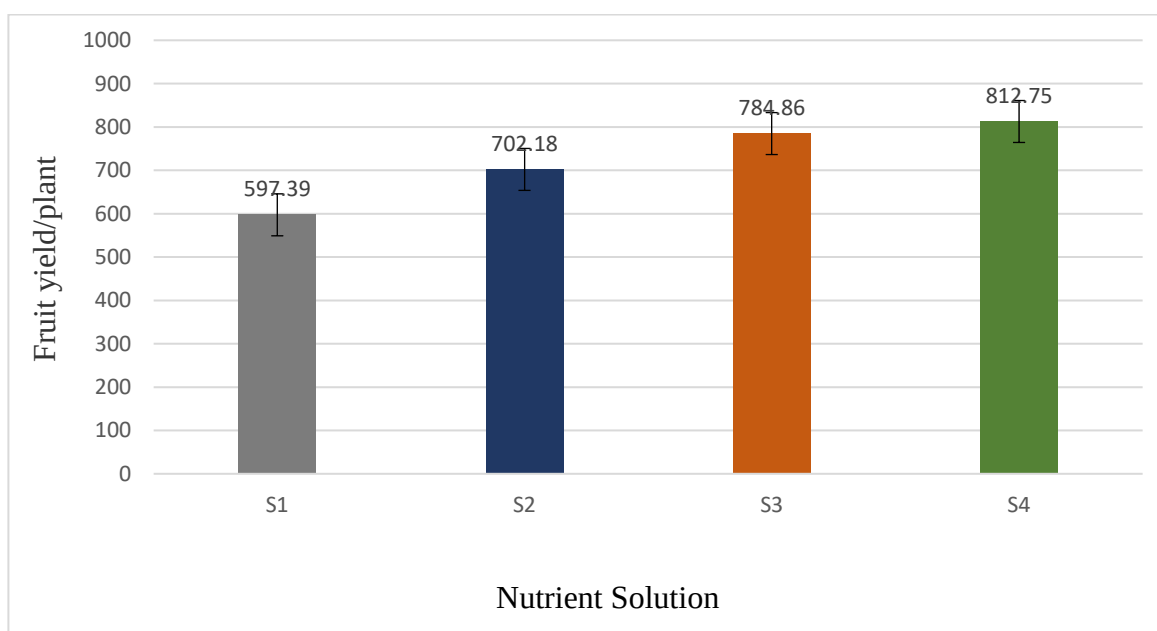


Figure 7. Effect of different doses of nutrient solution on fruit yield/plant of capsicum. S₁: Full strength Hoagland and Arnon (1940) nutrient solution, S₂: $\frac{3}{4}$ strength Hoagland and Arnon (1940) nutrient solution, S₃: Full strength Rahman and Inden (2012) nutrient solution and S₄: $\frac{3}{4}$ strength Rahman and Inden (2012) nutrient solution.

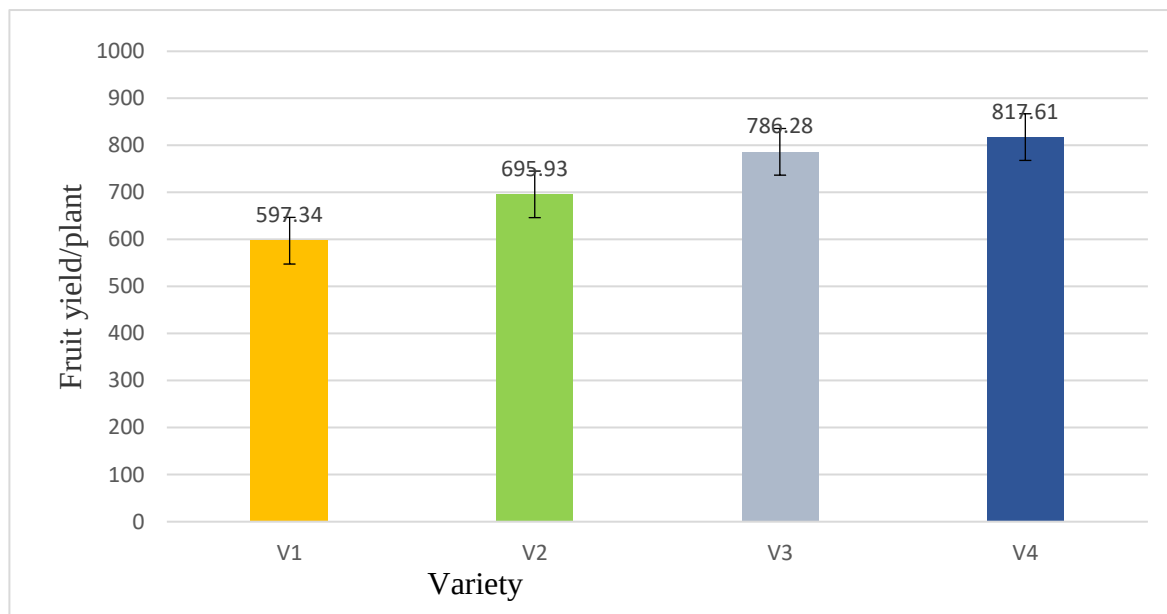


Figure 8. Effect of variety of cow dung leachate on fruit yield/plant of capsicum. V₁: California Wonder, V₂: Wonder Bell, V₃: Capsicum F₁, V₄: Capsicum F₁.

The yield contributing characters of the capsicum has significance due to different variety (Figure 8). Marketable yield of capsicum was significantly affected by different variety. The highest yield (817.61 g/plant) was found in S₄ treatment while, the lowest yield (597.34 g/plant) was found in S₁ treatment.

Dry Weight of Capsicum Plant

Leaf Dry Weight:

Leaf dry weight of capsicum at 180 DAT varied significantly by different doses of nutrient solution concentration (Table 4). Result revealed that topmost result (11.37 g) was recorded from S₄ treatment whereas S₁ treatment was scored as the lowest (9.34 g) after final harvest.

Leaf dry weight of capsicum were significantly affected by different variety (Table 4). The highest root fresh weight was found in V₄ (11.63 g) which was statistically similar to that of V₃. V₁ treatment was scored as the lowest (9.00 g) after final harvest. Foliar application of vermicompost leachate produce significantly higher leaf area and dry weight of plants than control (Singh et al. 2010). Significant influence was noted on root fresh weight influenced by combined effect of different doses of nutrient solution concentration and variety (Table 5). The highest root fresh weight was recorded from the treatment combination S₄V₄ the lowest were found in S₁V₁.

Stem Dry Weight:

Stem dry weight of capsicum at 180 DAT varied significantly by different treatment of nutrient solution concentration (Table 4). Result revealed that topmost result (12.21 g) was recorded from S₄ treatment whereas S₁ treatment was scored as the lowest (9.65 g) after final harvest.

Stem dry weight of capsicum were significantly affected by different variety (Table 4). The highest root fresh weight was found in V₄ (12.37 g) which was statistically similar to that of V₃. V₁ treatment was scored as the lowest (9.44 g) after final harvest.

Significant influence was noted on root fresh weight influenced by combined effect of different doses of nutrient solution concentration and variety (Table 5). The highest root fresh weight was recorded from the treatment combination S₄V₄ the lowest were found in S₁V₁.

Root Dry Weight:

Root dry weight of capsicum at 180 DAT varied significantly by different treatment of nutrient solution concentration (Table 4). Result revealed that topmost result (5.23 g) was recorded from S₄ treatment whereas S₁ treatment was scored as the lowest (4.43 g) after final harvest.

Root fresh weight of capsicum were significantly affected by different variety (Table 4). The highest root fresh weight was found in V₄ (5.23 g) which was statistically similar to that of V₃. V₀ treatment was scored as the lowest (4.43 g) after final harvest.

Significant influence was noted on root fresh weight influenced by combined effect of different doses of nutrient solution concentration and variety (Table 5). The highest root fresh weight was recorded from the treatment combination S₄V₄ the lowest were found in S₁V₁.

Table 4. Main effect of nutrient solution and variety on leaf dry weight, stem dry weight and root dry weight of capsicum per plant.

Treatment	Leaf dry weight per plant (g)	Stem dry weight per plant (g)	Root dry weight per plant (g)
Nutrient Solution (S)			
S ₁	9.34 c	9.65 c	4.43 c
S ₂	10.55 b	11.11 b	4.87 b
S ₃	11.23 a	12.05 a	5.16 a
S ₄	11.37 a	12.21 a	5.23 a
Variety (V)			
V ₁	9.00 c	9.44 c	4.45 c
V ₂	10.48 b	11.14 b	4.86 b
V ₃	11.37 a	12.09 a	5.14 a
V ₄	11.63 a	12.37 a	5.24 a
Level of significance (P)			
S	<0.001	<0.001	<0.001
V	<0.001	<0.001	<0.001

^aMeans with different letter (s) is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of two-way ANOVA. DAT – Days after transplanting. S₁: Full strength Hoagland and Arnon (1940) nutrient solution, S₂: $\frac{3}{4}$ strength Hoagland and Arnon (1940) nutrient solution, S₃: Full strength Rahman and Inden (2012) nutrient solution and S₄: $\frac{3}{4}$ strength Rahman and Inden (2012) nutrient solution. V₁: California Wonder, V₂: Wonder Bell, V₃: Capsicum F₁, V₄: Capsicum F₁.

Table 5. Interaction effect of nutrient solution and variety on leaf dry weight, stem dry weight and root dry weight of capsicum per plant

Treatment	Leaf dry weight per plant (g)	Stem dry weight per plant (g)	Root dry weight per plant (g)
S ₁ V ₁	8.22 g	8.18 h	4.20 f
S ₁ V ₂	9.11 fg	9.50 fg	4.31 ef
S ₁ V ₃	10.43 cd	10.95 c-e	4.61 c-f
S ₁ V ₄	9.58 d-f	9.99 e-g	4.59 c-f
S ₂ V ₁	10.06 d-f	10.54 d-f	4.73 c-e
S ₂ V ₂	10.29 c-e	10.86 c-e	4.80 c-e
S ₂ V ₃	10.49 cd	11.13 c-e	4.92 b-d
S ₂ V ₄	11.37 bc	11.93 bc	5.03 bc
S ₃ V ₁	9.26 e-g	9.95 e-g	4.49 d-f
S ₃ V ₂	10.64 cd	11.43 cd	4.99 b-d
S ₃ V ₃	12.34 ab	13.18 a	5.54 a
S ₃ V ₄	12.68 a	13.63 a	5.62 a
S ₄ V ₁	8.46 g	9.09 gh	4.37 ef
S ₄ V ₂	11.87 ab	12.76 ab	5.34 ab
S ₄ V ₃	12.23 ab	13.09 ab	5.51 a
S ₄ V ₄	12.90 a	13.91 a	5.70 a
Level of significance(P)			
S×V	<0.001	<0.0006	<0.0265

^aMeans with different letter (s) is significantly different by Tukey's test at $P \leq 0.05$. P represents the level of significance of two-way ANOVA. DAT – Days after transplanting. S₁: Full strength Hoagland and Arnon (1940) nutrient solution, S₂: ¾ strength Hoagland and Arnon (1940) nutrient solution, S₃: Full strength Rahman and Inden (2012) nutrient solution and S₄: ¾ strength Rahman and Inden (2012) nutrient solution. V₁: California Wonder, V₂: Wonder Bell, V₃: Capsicum F₁, V₄: Capsicum F₁.

Physiological Growth Traits

The physiological growth parameters of capsicum plants were significantly influenced by different cow dung leachate application (Table 6). Cow dung leachate increased leaf area. In case of leaf area (LA), the higher leaf area (LA) was found S₃ treatment (575.69 cm²) and the lower was found in S₀ (523.15 cm²). Leaf area is an important factor of light interception and consequently of transpiration, photosynthesis and plant productivity (Dufour, L. and Guérin, V. (2005). Foliar application of vermicompost leachate produce significantly higher leaf area and dry weight of plants than control (Singh et al. 2010). In case of Leaf Mass Ratio (LMR), the higher Leaf Mass Ratio (LMR) was found in S₄ and the lower was found in S₁. Higher LMR is one of the important criteria for producing higher metabolites. Prieto et al. (2007) reported that increased LMR gave the plants an increased ability to intercept light. In case of Leaf Area Ratio (LAR), the lower Leaf Area Ratio (LAR) was found in S₁ while the higher was found in S₄. Lower LAR is one of the important criteria for producing higher metabolites. Decreased LAR was found by Starck (1983) in tomato, which agreed with our findings. The physiological growth parameters of capsicum plants were significantly influenced by different variety (Table 6). In case of leaf area (LA), the higher leaf area (LA) was found in V₄ and the lower was found in V₁. In case of Leaf Mass Ratio (LMR), the higher Leaf Mass Ratio (LMR) was found in V₃ and the lower was found in V₁. In case of Leaf Area Ratio (LAR), the lower Leaf Area Ratio (LAR) was found in V₁ while the higher was found in V₄. Decreased LAR was found by Starck (1983) in tomato, which agreed with our findings.

Significant influence was noted on plant physiological traits by combined effect of different doses of nutrient solution concentration and variety (Table 7). In case of leaf area ratio (LAR), the lower LAR was found in S₄V₄ while the higher was found in S₄V₄. Lower LAR is one of the important criteria for producing higher metabolites. Starck (1983) in tomato crops found decreased LAR.

Table 6. Main effect of nutrient solution and variety on leaf area, leaf mass ratio, leaf area ratio of capsicum.

Treatment	Leaf area (cm ²)	LMR (g g ⁻¹)	LAR (cm ² g ⁻¹)
Nutrient solution (S)			
S ₁	523.15 b	0.399 a	22.47 a
S ₂	538.79 b	0.397 a	20.33 b
S ₃	563.08 a	0.395 b	19.93 b
S ₄	575.59 a	0.394 b	20.25 b
Variety (V)			
V ₁	513.77 c	0.393 b	22.60 a
V ₂	540.90 b	0.396 ab	20.55 b
V ₃	569.81 a	0.398 a	19.99 c
V ₄	576.13 a	0.398 a	19.84 c
Level of significance(P)			
S	<0.001	<0.0029	<0.001
V	<0.001	<0.0060	<0.001

^aMeans with different letter (s) is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of two-way ANOVA. DAT – Days after transplanting. S₁: Full strength Hoagland and Arnon (1940) nutrient solution, S₂: ¾ strength Hoagland and Arnon (1940) nutrient solution, S₃: Full strength Rahman and Inden (2012) nutrient solution and S₄: ¾ strength Rahman and Inden (2012) nutrient solution. V₁: California Wonder, V₂: Wonder Bell, V₃: Capsicum F₁, V₄: Capsicum F₁.

Table 7. Interaction effect of nutrient solution and variety on leaf area, leaf mass ratio, leaf area ratio of capsicum

Treatment	Leaf area (cm ²)	LMR (g g ⁻¹)	LAR (cm ² g ⁻¹)
S ₁ V ₁	509.42 e	0.399 a-c	24.76 a
S ₁ V ₂	516.17 e	0.398 a-c	22.53 bc
S ₁ V ₃	545.74 c-e	0.401 a	21.01 de
S ₁ V ₄	521.25 de	0.397 a-c	21.59 c-e
S ₂ V ₁	519.67 de	0.397 a-c	20.52 ef
S ₂ V ₂	531.99 de	0.396 a-d	20.51 ef
S ₂ V ₃	542.98 c-e	0.395 b-d	20.48 ef
S ₂ V ₄	560.50 b-d	0.401 ab	19.83 fg
S ₃ V ₁	514.65 e	0.391 de	21.74 cd
S ₃ V ₂	535.43 de	0.393 cd	19.79 fg
S ₃ V ₃	595.74 ab	0.397 a-c	19.18 g
S ₃ V ₄	606.50 a	0.397 a-c	18.99 g
S ₄ V ₁	511.33 e	0.386 e	23.36 b
S ₄ V ₂	580.00 a-c	0.396 a-d	19.38 fg
S ₄ V ₃	594.75 ab	0.397 a-d	19.30 g
S ₄ V ₄	616.26 a	0.397 a-c	18.95 g

Level of significance			
S×V	<0.0241	<0.0214	<0.001

^zMeans with different letter (s) is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of two-way ANOVA. DAT – Days after transplanting. S₁: Full strength Hoagland and Arnon (1940) nutrient solution, S₂: ¾ strength Hoagland and Arnon (1940) nutrient solution, S₃: Full strength Rahman and Inden (2012) nutrient solution and S₄: ¾ strength Rahman and Inden (2012) nutrient solution. V₁: California Wonder, V₂: Wonder Bell, V₃: Capsicum F₁, V₄: Capsicum F₁.

CONCLUSION

It can be concluded that higher fruit yield and other vegetative growth parameters and physiological traits of capsicum were found in S₄ treatment which is similar to that of S₃. The best varietal of capsicum was V₄ which was similar to that of V₃. Therefore, it can be concluded that treatment combination of V₄S₄ or V₃S₃ can be used for production capsicum in hydroponic system in Bangladesh.

ACKNOWLEDGEMENTS

The authors extend their gratitude to the Social Science Research Council (SSRC), Planning Division, Ministry of Planning, Government of Bangladesh for their contribution towards this research under the project of the fiscal year 2018-2020.

References

- Savvas, D. (2003). Hydroponics: A modern technology supporting the application of integrated crop management in greenhouse. *J. Food Agric. Environ.* 1: 80-86. Schnitzler,
- Avidan, A. (2000). The use of substrates in Israel. World congress on 'Soilless Culture on Agriculture in the coming millennium.' Maale Hachamisha, Israel. p.17.
- De Kreij, C., Voogt, W. and Baas, R. (1999). Nutrient solutions and water qualities for soilless cul-tures. Brochure No. 196, Research Station Floriculture and Glasshouse Vegetables, The Netherlands:Naaldwijk (2)
- Narkhede, S. D., Attarde, S. B., and Ingle, S. T. (2011). Study on effect of chemical fertilizer and vermicompost on growth of chilli pepper plant (*Capsicum annum*). *Journal of Applied Sciences in Environmental Sanitation*, 6(3).
- Samawat, S., LAKZIAN, A., and Zamirpour, A. R. (2001). The effect of vermicompost on growth characteristics of tomato.
- Patil, M. B., Mohammed, R. G., & Ghadge, P. M. (2004). Effect of organic and inorganic fertilizers on growth, yield and quality of tomato. *J. Maharashtra Agric. Univ*, 29(2), 124-127.
- Attarde, S.B., S.D. Narkhede, R.P. Patil, S.T. Ingle. 2012. Effect of organic and inorganic fertilizers on growth and nutrient content of [*Abelmoschus esculentus* (L.) Moench], 4(10), 137-140.
- Salas, E, and Ramirez, C. A microbial bioassay to estimate nutrient availability in organic fertilizers; field calibration; Bioensayo microbiano para estimular los nutrimentos disponibles en los abonos organicos: calibracion en el campo. Costa Rica.
- Aslani, M., and Souri, M. K. (2018). Growth and quality of green bean (*Phaseolus vulgaris* L.) under foliar application of organic-chelate fertilizers. *Open Agriculture*, 3(1), 146-154.
- Doss, B. D., J. L. Turner and C.E. Evans. 1981. Influence of tillage nitrogen and rye cover on growth and yield of tomato. *J. Amer. Soc. Hort. Sci.*, 106(1): 95-97.

Atiyeh, R. M., Edwards, C. A., Subler, S., and Metzger, J. D. (2001). Pig manure vermicompost as a component of a horticultural bedding plant medium: effects on physicochemical properties and plant growth. *Bioresource technology*, 78(1), 11-20.

Arancon, N. Q., Edwards, C. A., Bierman, P., Welch, C., and Metzger, J. D. (2004). Influences of vermicomposts on field strawberries: 1. Effects on growth and yields. *Bioresource technology*, 93(2), 145-153.

Singh, R., Gupta, R. K., Patil, R. T., Sharma, R. R., Asrey, R., Kumar, A., and Jangra, K. K. (2010). Sequential foliar application of vermicompost leachates improves marketable fruit yield and quality of strawberry (*Fragaria× ananassa* Duch.). *Scientia Horticulturae*, 124(1), 34-39.

Dufour, L. and Guérin, V. (2005). Nutrient solution effects on the development and yield of anthurium and reanum Lind. In *Tropical Soilless Conditions. Sci. Hortic.* 105(2): 269- 282, ISSN 0304-4238.

Prieto, M., Peñalosa, J., Sarro, M.J., Zornoza, P. and Gárate, A. (2007). Seasonal effect on growth parameters and macronutrient uses of capsicum. *J. Plant Nutr.* 30: 1803-1820.

Starck, Z. (1983). Photosynthesis and endogenous regulation of the source-sink relation in tomato plants [beta-naphthoxyacetic acid, GA, dry matter]. *Photosynthetica* (Czechoslovakia).