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INFLUENCE OF THREE HYDROPONIC NUTRIENT SOLUTIONS ON THE YIELD AND QUALITY OF LEAFY VEGETABLES GROWN IN HYDROPONICS CULTURE

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Abstract

A study was conducted to evaluate three hydroponic nutrient solutions to grow six types of leafy vegetables in a deep water culture hydroponics system at the glasshouse of Olericulture Division of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI) during the period from 26 November 2020 to 31 January 2021.For this purpose plants of eleven varieties of six types of leafy vegetables (three varieties of lettuce viz. BARI Lettuce-1, Green Wave and New Red Fire; two varieties of spinach viz. BARI Palongshak-1 and BARI Palongshak-2; one variety of Pak Choi named BARI Batishak-1; three varieties of mizuna, namely Late White Stem, Mustard Green and Salad Kyomizuna; one variety (unknown) of Rocket Salad and one variety (unknown) of Chard) were grown in 300-litre culture boxes through deep water culture hydroponics using Modified Cooper's Solution-1 (1.5 dS/m) (MCS-1) (full strength), Modified Cooper's Solution-2 (1.5 dS/m) (MCS-2) (full strength) and Enshi-Shoho nutrient solution (ENS) (1/2 strength) on a completely randomized design (CRD). Results showed that growth of the selected leafy vegetables were varied significantly in three types of hydroponic nutrient solution. In general, it was evident that the overall growth performances of tested vegetables were found greater in MCS-1 than in MCS-2 and ENS. This result was followed by MCS-2 and lower growth of the tested vegetables was obtained from ENS Quality characteristics such as total soluble solids, shoot sap pH and tritratable acidity were found higher in MCS-1 followed by MCS-2. Results also revealed that lower amount of chlorophyll pigments and carotenoid content was recorded in plants grown in MCS-2 than other two nutrient solutions. Therefore, Modified Coopers solution-1 can be used for growing leafy vegetables following deep water culture hydroponics in the winter season of Bangladesh.

Introduction

Hydroponic is a profitable, sustainable, agricultural method and environmentally friendly technology for growing plants without soil. It is the fastest growing agricultural sector, rapidly gaining momentum and popularity, and could dominate food production in future. Hydroponic cultivation is revolutionizing agricultural crop production techniques all over the world owing to its minimal environmental footprint, enhanced pest control, and provide high crop yield (Al-Meselmani, 2022). Vegetables refer to mostly herbaceous annual plants of which some portion

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is eaten, either cooked or raw, during the principal part of the meal to complement starchy food and other food items (Anon., 2019). In other word, a plant raised for some edible part of it, such as the leaves, roots, fruit or flowers, but excluding any plant considered to be a fruit, grain, or spice in the culinary sense. They are classified into root vegetables (potatoes, sweet potatoes, cassava and yams), stem vegetables (stem amaranth, stolons of aroid etc.), leafy vegetables (arugula, pak choi, collards, kale, lettuce, spinach, swiss chard, mustard greens, watercress etc.), flower vegetables (broccoli, cauliflower etc.) and fruity vegetables (tomato, brinjal, bottle gourd, okra etc.) based on the parts of a plant used as vegetables.

Leafy green vegetables are packed with important and powerful nutrients that are critical for good health. Vegetable intake recommendation by FAO/WHO (2003) of ≥400 g/day (5 servings of 80 g) is for fruit and vegetables. As most countries follow the FAO/WHO guidelines and the majority suggest that at least three servings (240 g/day) should come from vegetables. According to Rashid (1996) daily vegetable demand of an adult should be 300 g (tuber and root crops, spices and other vegetables), of which at least 100 g to be leafy vegetables. As most of the leafy vegetables are consumed directly as fresh vegetable (salad), their leaves should be quality produce and free from any contamination (insects and other agrochemicals). Quality leafy vegetables can be produced through hydroponic culture. In Bangladesh, our daily dietary composition include potato based mixed curry with rice. It greatly lacks roots and fresh vegetables in the form of pickles and salad. As a result, our people are suffering from non-communicable disease due to intake of low-quality vegetables with heavy metals, environmental toxicants and pesticidal residues. Inclusion of safe and high-quality leafy vegetables in the dietary composition will provide health benefits and help prevent several food borne diseases.

Nutrient solution and its management are the cornerstone of a successful hydroponic system and are the most important determinant of crop production and quality, which is largely dependent on the extent to which plant nutrients are acquired from the nutrient solution. A hydroponic nutrient solution is basically the liquid that contains essential nutrients to influence this plant's root and stimulate growth. Yield and quality of vegetables greatly depends on the hydroponic nutrient composition, hydroponics production system, cultivation season, and handling procedures after harvest (Ding *et al.,* 2018; Kwack *et al.,* 2015; Kang and Kim, 2007). Thus, recommendation of specific vegetables for specific nutrient solution recipes is necessary. The study was, therefore, conducted to evaluate three hydroponics nutrient solutions for growing six types of leafy vegetables through deep water culture hydroponics.

Materials and Methods

The experiment was conducted in the glasshouse having Hydroponics and Controlled Environment Agriculture research facility at Olericulture Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institution (BARI), Gazipur-1701, Bangladesh during the period from 26 November 2020 to January 2021. The study area was situated in 23.9917° N longitude and 90.4137° E latitude at an altitude of 9 meter above the sea level. Temperature inside the glasshouse was between 19°C and 26°C and was greater by 1.5-2.0°C compared to outside, while the inside average relative humidity was remained around 75%. The experimental treatments consisted of two factors where the first factor was comprised of three hydroponic nutrient solutions, namely Modified Cooper's solution-1 (full strength, 1.5 dS/m) (MCS-1), Modified Cooper's solution-2 (full strength, 1.5 dS/m) (MCS-2) and Enshi-Shoho nutrient solution (1/2 strength) (ENS), and the second factor was comprised of eleven varieties of six leafy vegetables (three varieties of lettuce viz. BARI Lettuce-1, Green Wave and New Red Fire; two varieties of spinach viz. BARI Palongshak-1 and BARI Palongshak-2; one variety of Pak Choi named BARI Batishak-1; three varieties of mizuna, namely Late White Stem, Mustard Green and Salad Kyomizuna; one variety (unknown) of Rocket Salad and one variety (unknown) of Chard. The experiment was conducted in a completely randomized design (CRD) with three replications. The seeds of lettuce var. BARI Lettuce-1, spinach var. BARI Palongshak-1 & 2 and Pak choi var. BARI Batishak- were collected from Olericulture Division, HRC, BARI and the seeds of the remaining varieties of mizuna, lettuce, rocket salad (variety unknown) and chard (variety unknown) were collected from Takii Seeds and Tohuku Seeds, Japan (Table 1).

The seeds of eleven varieties of six leafy vegetables were sown in plastic cell trays (36 cells) filled with cleaned coco-coir on 26 November 2020. Previously coco-coir's were washed thoroughly and treated with potassium permanganate ($KMnO_4$) @ 20 g per 100 L tap water for general disinfection from fungal infection. After 24 hours the treated coco-coir were washed three times with tap water and sun dried before use. Only tap water was used to moisten the coco-coir until seedling emergence. Seedlings were nourished with standard MCS-1 (full strength, 1.5 dS/m EC) (Table 2) until transplanting. Rectangular culture boxes (frames only) (90 cm × 396 cm) were prepared with 15 cm wooden liner placed in the floor of glasshouse. Then two layers of green color plastic polythene (0.10 mm thickness) sheets were placed over the wooden boxes to hold water with nutrient solution. Each culture box can hold 300 L water.

There were three types of hydroponic nutrient solutions used in this study viz., MCS-1 (Asaduzzaman *et al.*, 2021), MCS-2 (composition unpublished) and ENS (Hori, 1966) (Table 2). In each culture box, 300 L working nutrient solution was prepared taking each of three types of hydroponic nutrient solutions.

Table 1. List of varieties of six types of leafy vegetables with specialty characters, English name, botanical name and family grown in deep water culture hydroponics in glasshouse of HRC, BARI, Gazipur

SL #	Variety	Specialty character	English name	Botanical name	Family	Organization/ Company
1.	BARI Lettuce -1	Green leaf lettuce, loosely fit with larger leaf	Lettuce	*Lactca sativa* L.	Asteraceae	HRC, BARI, Bangladesh
2.	Green Wave	Green color lettuce				
3.	New Red Fire	Red color lettuce				
4.	BARI Palongshak-1	Green color leaf having good palatability	Spinach	*Spinacea oleracea* L.	Chenopodiaceae	HRC, BARI, Bangladesh
5.	BARI Palongshak-2	Broad leaved, having heat tolerance				
6.	Unknown	Multiple colour having antioxidants	Chard	*Beta vulgaris* subsp. *vulgaris*	Chenopodiaceae	Bright light[z]
7.	BARI Batishak-1	Green fleshly leaf with bioactive compounds	Pak Choi	*Brassica rapa* subsp. *chinensis* L.	Brassicaceae	HRC, BARI, Bangladesh
8.	Late White Stem	Green, huge branching	Mizuna	*Brassica rapa* subsp. *npposininca*	Brassicaceae	Takii Seeds, Japan
9.	Mustard Green	Purple, single stem habit, rich in anthocyanin				
10.	Salad KyoMizuna	Green, single stem habit				
11.	Unknown	Rich in antioxidants	Salad Rocket	*Eruca vesicaria* subsp. *sativa*	Brassicaceae	Bright light[z]

[z] Country not known.

Table 2. Mineral nutrient elements composition in hydroponic nutrient solutions used in the study

Nutrient element	Cooper's solution (full strength, mg/L) (Shah *et al*., 2011)	Enshi-shoho solution (full strength, mg/L) (Hori, 1966)
Nitrogen (N)	236	245.8
Phosphorous (P)	60	41.8
Potassium (K)	300	312.5
Calcium (Ca)	185	161.3
Magnesium (Mg)	50	49.3
Sulfur	68	65.4
Iron (Fe) (EDTA)	12	3.8
Sodium (Na)	-	1.6
Copper (Cu)	0.1	0.012
Zinc (Zn)	0.1	0.05
Manganese (Mn)	2.0	0.46
Boron (B)	0.3	0.52
Molybdenum (Mo)	0.2	0.008

In each culture box one urethane styrofoam sheet (85 cm × 390 cm) was placed having 66 holes (11 rows, each containing 6 holes) where 11 varieties of six vegetables were transplanted in each row (6 plants of each variety) maintaining 36 cm distance between rows and 15 cm between plants. Silver color plastic mulch films were used to cover the styrofoam sheet which prevents algae from growing in the nutrient solution. Healthy seedlings of each variety having the optimum characters (3-5 leaf stage depending on the test vegetables) were transplanted in the culture boxes with urethane foam blocks for holding the plants tight and upright. Nutrient solutions were aerated frequently by circulating the water around using an automatic timer (10/30 min.; operation/stop). Culture solutions were not changed throughout the growing period for all the vegetables grown. All the leafy vegetables were allowed to grow for 4-6 weeks to grow and harvested at the particular date when they reached marketable stage.

At harvest three sets of plants from each vegetable grown in each type of nutrient solution were sampled for dry weight measurement. Three shoot samples for each vegetable from each treatment were stored in freezer (– 30°C) for subsequent analyses of quality characteristics such as total soluble solids (%), pH, titratable acidity (%), reducing sugar (%), total sugar (%), and also photosynthetic pigments content such as Chlorophyll a (Chl a) (mg g^{-1} FW), Chlorophyll b (Chl b) (mg g^{-1} FW), Total Chlorophyll (Chl t) (mg g^{-1} FW), and Carotenoids content (Car) (mg g^{-1} FW). Data on growth parameters, namely plant height (cm), number of leaves/plant, maximum leaf length (cm), maximum leaf width (cm), longest root length (cm), shoot fresh weight/plant (g), shoot dry matter/plant (g) and root dry weight (g) per plant for all vegetables were also recorded at harvest.

Total soluble solids of leaf extract of 11 leafy vegetable varieties were determined by hand refractometer (RF10, San Diego, USA) and pH was determined by portable pH meter (HANNA, HI98107, Romania). Titratable acidity (%), reducing sugar (%) and total sugar (%) were determined according to method and formula given by AOAC (1994). To determine photosynthetic pigment content, three plant individuals of each variety of six leafy vegetables were randomly selected. Total chlorophyll and carotenoids were extracted by 80% acetone from the leaves of 11 vegetable varieties (fully expanded, exposed) at a similar position for each treatment group. The absorbance of the extracts was measured with a UV-1200 spectrophotometer (SP-75, Shanghai spectrum instruments co., LTD, China) at 663 nm (A663), 645 nm (A645), and 470 nm (A470), respectively Arnon (1949) and Lichtenthaler (1987). Chlorophyll a (Chl a), Chlorophyll b (Chl b), and total carotenoids were calculated using the following equations:

$$\text{Chlorophyll a (mg/g)} = [12.7\ (A663) – 2.69\ (A645)] \times V/\ (1000 \times W)$$

$$\text{Chlorophyll b (mg/g)} = [22.9\ (A645) – 4.68\ (A663) \times V]/\ (1000 \times W)$$

$$\text{Total chlorophyll (mg/g)} = [20.2\ (A645) – 8.02\ (A663)] \times V/\ (1000 \times W)$$

$$\text{Total carotenoids (mg/g)} = (1000 \times A470 - 1.82 \times \text{Chl a} – 85.02 \times \text{Chl b})/198$$

Where, A= Absorbance at specific wavelengths; V= Final volume of chlorophyll extract in 80% acetone;

W= Weight of the fresh tissues extracted

All the data on growth and quality characteristics were analyzed using Statistrix 10.0 software. Means separation was done by Tukey’s HSD test at 5% level of probability. The photosynthetic pigment characters were calculated from three samples of each treatment.

Results and discussion

Main effect of hydroponic nutrient solutions and leafy vegetable varieties on growth characters

Plant height, maximum leaf length, longest root length, shoot FW/plant, shoot DW/plant, and root DW/plant except number of leaves/plant and maximum leaf width were significantly influenced by three hydroponic nutrient solutions (Table 3). Plant height (38.8 cm), leaf length (35.2 cm), shoot FW/plant (88.3 g), and shoot and root DW/plant (4.20 g and 1.8 g, respectively) were found highest from MCS-1. No significant differences were found between MCS-2 and ENS in respect of these five growth characters except root DW/plant which was recorded higher from ENS (1.38 g). Maximum longest root length (36.8 cm) was obtained from ENS.

All the growth characters were significantly influenced by different leafy vegetables varieties irrespective of nutrient solution (Table 3). Mizuna var. Late White Stem recorded maximum plant height (48.2 cm), highest maximum leaf length (46.5 cm), maximum longest root length (43.9 cm) and maximum shoot DW (5.56 g/plant), whereas Mizuna var. Salad Kyomizuna produced maximum number of leaves/plant (108.0). No significant differences were found among three varieties of Mizuna in respect of plant height, maximum leaf length, and longest root length, shoot FW/plant and, shoot and root DW/plant. Among the eleven varieties of 6 leafy vegetables, lettuce var. BARI Lettuce -1 and New Red Fire produced highest maximum leaf width (18.7 cm) and shoot FW/plant (131.5 g), whereas lettuce var. Green Wave gave maximum root DW/plant (1.61 g). There were no significant differences found among three varieties of lettuce, namely BARI Lettuce-1, Green Wave and New Red Fire with regards to number of leaves/plant, maximum leaf length, maximum leaf width, longest root length, and shoot and root DW/plant. Two varieties of spinach viz., BARI Palongshak -1 and BARI Palongshak-2 showed identical results in respect of all growth characters. In three cultivars of lettuce. Pak Choi var. BARI Batishak-1 performed better in respect of shoot dry weight (3.78 g/plant) and root dry weight (1.22 g/plant), whereas Chard showed better performance with regard to root dry weight (1.17 g/plant). Moraes *et al*. (2020) found average leaf number (9.27/plant), fresh mass of areal part (31.53 g/plant) and fresh mass of root (6.0 g), leaf length (14.42 cm) and root length (23.14 cm) in Nutrient Film Technique (NFT) hydroponic system harvested at 40 days after planting. Lee *et al.* (2022) obtained plant height (25.70-36.80 cm), number of leaves/plant (24.73-40.58), fresh weight of shoot (76.75 - 284.28 g) from different amount of nutrient solutions and two varieties of lettuce at 34 days after sowing. Sundar and Chen (2020) got leaf number (7.0-10.9), shoot fresh weight (55.3-71.4 g), root fresh weight (4.87-8.24 g), shoot DW (3.40-5.99) and root dry weight (0.47-1.60 g) in aquaponic system through using Floating Raft, Closed Capillary Water Distribution and NFT hydroponics system in Pak Choi vegetables. Wiangsamut and Koolpluksee (2020) reported that they obtained plant height (26.8 cm), number of leaves/plant (16.7), fresh weight of plant (118.8 g) in NFT system at 49 days after sowing (37 days after planting) in Pak Choi. In two cultivars of lettuce, Sapkota *et al*. (2019) obtained average fresh weight/plant (49.53-104.25 g), number of leaves/plant (10.5-20.5) and root length (11.93-26.14 cm) when harvested at 30 days after the initiation of treatment consisting differential nutrient concentration of N, K and Ca.

Interaction effect of hydroponic nutrient solutions and leafy vegetable varieties on growth characters

Plants of Mizuna var. Late White Stem grown in MCS-1 gave maximum plant height (51.3 cm) which was statistically similar to those of Mizuna var. Mustard Green (46.8 cm), Mizuna var. Salad Kyomizuna (49.3 cm), spinach var. BARI Palongshak-1 (41.5 cm), lettuce var. Green Wave (41.0 cm) grown in same type of nutrient solution, all the three varieties of Mizuna grown in MCS-2 and ENS, and plants of spinach var. BARI Palongshak-2 grown only in ENS (Table 4). The leafy vegetable Rocket Salad under MCS-1 showed the poor result in respect of plant height. Plants of Mizuna var. Salad Kyomizuna grown in ENS recorded maximum number of leaves/plant (114.3) which was identical with those of Mizuna of the same variety grown in MCS-1 (109) and MCS-2 (100.7). The remaining treatment combinations produced the similar number of leaves/plants. Maximum leaf length was found highest from the plants of Mizuna var. Late White Stem grown in MCS-1 (50.3 cm) closely followed by those of the same vegetable crop var. Mustard Green (45.2 cm) and Salad Kyomizuna (48.0), and spinach var. BARI Palongshak-1 (39.0 cm) grown in the same nutrient solution, plants of Mizuna of all three varieties and spinach var. BARI Palongshak-2 grown in both MCS-2 and ENS. Plants of Rocket Salad grown in three nutrient solutions gave the poor result in respect of number of leaves/plants. Lettuce var. New Red Fire grown under MCS-1 gave the maximum leaf width (20.7 cm) which was statistically similar to all the remaining combinations except Mizuna var. Salad Kyomizuna, Rocket Salad and Chard each in combination with MCS-1 and MCS-2, and spinach var. BARI Palongshak-1, Mizuna var. Salad Kyomizuna and Rocket salad grown under ENS (Table 4). Plants of Rocket Salad grown in three nutrient solutions gave the inferior result in respect of maximum leaf width. Mizuna var. Late White Stem grown in the ENS produced maximum longest root length (61.3 cm) which was identical with Mizuna var. Mustard Green (58.0 cm) and Salad Kyomizuna (35.0 cm) each in combination with the same nutrient solution, and spinach var. BARI Palongshak-1 (41.0 cm) and Mizuna var. Late White Stem (41.7 cm) each grown under MCS-1 (Table 4). The Rocket Salad coupled with MCS-2 showed the poor result in respect of longest root length. Lettuce var. BARI Lettuce-1 grown under MCS-1 produced maximum shoot FW/plant (160.2 g), which was identical with Pak Choi var. BARI Batishak-1 (119.5 g), Mizuna var. Late White Stem (101.5 g) and Salad Kyomizuna (101.0 g), and lettuce var. Green Wave (107.3 g) and New Red Fire (114.3 g) each grown under MCS-1 and all the varieties of lettuce in combination with MCS-2). Mizuna var. Late White Stem in combination with MCS-1 produced the maximum shoot DW/plant (6.67 g) which was statistically similar to all the remaining combinations except Rocket Salad coupled with the same solution, spinach var. BARI Palongshak-1, Rocket Salad and Chard each coupled with MCS-2, and Pak Choi var. BARI Batishak-1, lettuce var. Green Wave and Rocket Salad each in combination with ENS (Table 4).

All the combinations of leafy vegetables and three nutrients solutions except lettuce var. BARI Lettuce -1, Mizuna var. Mustard Green, Rocket Salad each coupled with MCS-2 and Rocket Salad grown under ENS gave identical results in respect of root DW/plant. Lettuce var. BARI Lettuce -1, Mizuna var. Mustard Green, Rocket Salad each grown under MCS-2 and Rocket Salad grown in ENS recorded the poorest result in respect of root DW/plant (Table 4). In spinach, Agarwal *et al*. (2021) obtained maximum leaf length (44.64 cm), leaf width (8.19

cm), number of leaves/plant (16.57), fresh weight of leaves/plant (77.07 g), dry weight of leaves/plant (6.54 g), fresh weight of roots/plant (11.09 g) and dry weight of roots/plant (1.38 g), root length (15.40 cm) from hydroponics using nutrient solution (all in ppm: N 150, P 40, K 200, Fe 5, Ca 50, Mg 60, Zn 3, Mn 3, Cu (<1), B (<4), Mo (<1), Na (<1) and S 50). Oztekin *et al.* (2018) obtained maximum plant height (13.8 cm), shoot fresh weight (4.96 g), shoot dry weight (0.52 g), root fresh weight (0.60 g), root dry weight (0.046 g) from hydroponic solution (ppm: N 150, P 50, K 150, Fe 5, Ca 150, Mg 50, Zn 0.05, Mn 0.05, Cu 0.03, B 0.50, Mo 0.02) in spinach in Turkey. Shah and Shah (2009) reported in lettuce that number of leaves/plant (13.67), leaf length (17.53 cm), root length (227.3 cm) and leaf yields/plant (53.89 g) were recorded from full strength Cooper's Solution.

Main effect of hydroponic nutrient solutions and leafy vegetable varieties on quality characters

Total soluble solid (%), pH, titratable acidity (%), reducing sugar (%) and total sugar (%) were significantly influenced by different nutrient solutions (Table 5). MCS-1 gave maximum pH (6.65) and titratable acidity (1.36%) while MCS-2 recorded maximum total Soluble Solid (5.9%) which was statistically similar to that of MCS-1 (5.8%). Reducing sugar (18.0%) and total sugar (13.2%) were recorded maximum from ENS. Total soluble solid was influenced little by 11 leafy vegetable varieties (Table 5). Maximum total soluble solid was obtained from Mizuna var. Mustard Green (6.3%) which was closely followed by Mizuna var. Late White Stem (6.2%), spinach var. BARI Palongshak-2 (6.0) and BARI Palongshak-1 (5.7%), Pak Choi var. BARI Batishak-1, Mizuna var. Salad Kyomizuna (5.6%), Rocket Salad (5.6%) and lettuce var. BARI Lettuce-1 (5.2%) and lettuce var. New Red Fire gave the lowest total soluble solid (4.6%). Lettuce var. Green Wave gave maximum pH (6.73) followed by spinach var. BARI Palongshak-2 (6.63) and then followed by Pak Choi var. BARI Batishak-1 (6.59) and spinach var. BARI Palongshak-1 (6.57) and its lowest value was obtained from lettuce var. New Red Fire (6.07). Maximum titratable acidity was recorded from Mizuna var. Mustard Green (1.89%) followed by Pak Choi var. BARI Bartishak-1 (1.72%) and minimum titratable acidity was obtained from lettuce var. BARI Letuuce-1 (0.74). Lettuce var. New Red Fire gave maximum reducing sugar (17.5%) which was significantly higher than other vegetable varieties. The second maximum reducing sugar was recorded from lettuce var. Green Wave (14.1%) and its minimum value was obtained from spinach var. BARI Palongshak-2 (6.8%). Maximum total sugar was obtained from lettuce var. BARI Lettuce-1 (15.6%) which was followed by spinach var. BARI Palongshak-1 (15.4%) and then followed by Rocket Salad (12.8%). The lowest total sugar was recorded from Mizuna var. Mustard Green (11.3%). Research results indicated that crop species responded differently in different hydroponics nutrient formulations, as it was found that "Korea Wonshi" nutrient solution can enhance growth and quality of romaine lettuce while "Yamazaki" nutrient solution enhances the growth of lettuce, red color of beet and red radish (Kwack *et al.*, 2015).

Table 3. Main effect of hydroponic nutrient solution and leafy vegetables varieties on the growth parameters of leafy vegetables grown in deep water culture hydroponics

Experimental treatments	Plant height (cm)	Number of leaves/ plant	Maximum leaf length (cm)	Maximum leaf width (cm)	Longest root length (cm)	Shoot FW/plant (g)	Shoot DW/plant (g)	Root DW/plant (g)
Nutrient solution								
Modified Cooper's solution-1	38.8 a[z]	23.0 a	35.2 a	13.4 a	31.3 b	88.3 a	4.20 a	1.80 a
Modified Cooper's solution-2	36.1 b	21.7 a	32.4 b	12.5 a	27.9 b	68.2 b	3.32 b	0.74 c
Enshi-shoo solution	35.5 b	21.3 a	33.6 ab	12.1 a	36.8 a	61.2 b	3.24 b	1.38 b
Level of Significance	**	ns	*	ns	**	**	**	**
Vegetables with variety								
Lettuce var. BARI Lettuce-1	33.5 cd	14.9 bc	27.8 ef	18.7 a	24.6 c	131.5 a	4.94 ab	1.50 ab
Lettuce var. Green Wave Lettuce	35.9 b-d	11.4 bc	25.7 f	16.4 a-c	31.2 a-c	90.3 bc	3.00 b-d	1.61 a
Lettuce. Var. New Red Fire Lettuce	27.3 e	15.4 bc	25.7 f	18.7 ab	30.4 bc	96.1 b	3.17 bc	1.39 ab
Spinach var. BARI Palongshak-1	38.3 bc	9.9 bc	36.0 cd	12.5 c-f	31.0 a-c	54.7 de	3.39 bc	1.17 ab
Spinach var. BARI Palogshak-2	38.9 b	11.1 bc	38.7 bc	11.2 def	31.7 a-c	60.6 c-e	4.33 a-c	1.39 ab
Pak Choi var. BARI Batishak-1	32.8 d	12.0 bc	28.6 ef	11.0 def	29.0 bc	82.9 b-d	3.78 a-c	1.22 ab
Mizuna var. Late White Stem	48.2 a	23.6 b	46.5 a	13.6 b-e	43.9 a	82.2 b-d	5.56 a	1.33 ab
Mizuna var. Mustard Green	45.1 a	16.9 bc	43.2 ab	14.8 a-d	41.0 ab	61.8 b-e	3.78 a-c	1.33 ab
Mizuna var. Salad Kyomizuna	44.9 a	108.0 a	43.8 ab	7.9 fg	34.1 a-c	83.7 b-d	3.89 a-c	1.39 ab
Rocket Salad var. unknown	25.6 e	11.3 bc	23.7 f	5.7 g	25.6 c	14.2 f	1.11 d	0.89 b
Chard var. unknown	33.9 b-d	7.6 c	31.7 de	8.9 e-g	29.9 bc	40.6 ef	2.50 cd	1.17 ab
Level of Significance	**	**	**	**	**	**	**	**

[z]values within a column followed by different letters are significantly different according to the Tukey's HSD test at $P \leq 0.05$.
ns, *, **indicates not significant or significant at $p \leq 0.05$, $p \leq 0.01$, respectively.

Table 4. Interaction effect of hydroponic nutrient solution and leafy vegetables varieties on the growth parameters of leafy vegetables grown in deep water culture hydroponics

Nutrient solution × Leafy vegetables with variety		Plant height (cm)	Number of leaves /plant	Maximum leaf length (cm)	Maximum leaf width (cm)	Longest root length (cm)	Shoot FW /plant(g)	Shoot DW /plant (g)	Root DW /plant (g)
Modified Cooper's solution-1	Lettuce var. BARI Lettuce-1	35.2 e-l[z]	16.7 b	27.5 g-k	20.0 ab	26.0 cd	160.2 a	6.00 ab	2.17 a
	Lettuce var. Green Wave	41.0 a-g	12.0 b	27.3 g-k	18.5 a-c	31.2 b-d	107.3 a-e	3.50 a-d	2.00 ab
	Lettuce var. New Red Fire	29.5 i-m	17.7 b	27.7 f-k	20.7 a	34.0 b-d	114.3 a-d	3.17 a-d	1.67 a-c
	Spinach var. BARI Palongshak-1	41.5 a-g	10.7 b	39.0 a-g	11.3 a-g	41.0 a-d	70.5 c-h	5.00 a-d	1.50 a-c
	Spinach var. BARI Palongshak-2	38.0 c-j	10.3 b	36.5 b-i	10.8 a-g	24.3 cd	68.8 c-h	4.67 a-d	1.33 a-c
	Pak Choi var. BARI Batishak-1	33.7 f-l	11.3 b	28.5 e-k	12.3 a-g	31.7 b-d	119.5 a-c	4.67 a-d	1.67 a-c
	Mizuna var. Late White Stem	51.3 a	30.0 b	50.3 a	15.3 a-f	41.7 a-d	101.5 a-e	6.67 a	2.17 a
	Mizuna var. Mustard Green	46.8 a-d	17.7 b	45.2 a-c	15.3 a-f	31.3 b-d	66.0 c-g	4.17 a-d	1.83 a-c
	Mizuna var. Salad Kyomizuna	49.3 ab	109.0 a	48.0 ab	9.2 c-g	34.3 b-d	101.0 a-e	4.33 a-d	2.00 ab
	Rocket Salad vr. unknown	26.8 k-m	10.3 b	25.6 i-k	5.7 fg	25.5 cd	15.5 gh	1.17 d	1.67 a-c
	Chard var. unknown	33.2 f-m	7.7 b	31.5 d-j	8.5 c-g	23.7 cd	46.5 d-g	2.83 a-d	1.83 a-c
Modified Cooper's solution-2	Lettuce var. BARI Lettuce-1	38.3 c-j	15.3 b	31.3 d-j	20.0 ab	19.7 cd	145.5 ab	5.00 a-d	0.50 c
	Lettuce var. Green Wave	37.7 c-k	12.7 b	24.7 i-k	15.5 a-f	23.0 cd	109.8 a-e	3.67 a-d	1.00 a-c
	Lettuce var. New Red Fire	27.7 j-m	15.3 b	25.7 i-k	17.0 a-e	26.0 cd	98.0 a-e	2.83 a-d	0.67 bc
	Spinach var. BARI Palongshak-1	34.2 e-l	10.7 b	31.3 d-j	17.0 a-e	29.0 cd	41.5 e-h	2.00 b-d	0.83 a-c
	Spinach var. BARI Palongshak-2	37.3 d-k	11.0 b	40.0 a-e	9.5 b-g	43.3 a-c	41.8 e-h	2.67 a-d	0.83 a-c
	Pak Choi var. BARI Batishak-1	31.3 g-m	13.3 b	25.5 i-k	10.2 a-g	27.7 cd	65.8 c-h	4.33 a-d	1.17 a-c

Nutrient solution × Leafy vegetables with variety		Plant height (cm)	Number of leaves /plant	Maximum leaf length (cm)	Maximum leaf width (cm)	Longest root length (cm)	Shoot FW /plant(g)	Shoot DW /plant (g)	Root DW /plant (g)
	Mizuna var. Late White Stem	48.2 a-c	25.7 b	44.2 a-c	13.0 a-g	28.8 cd	80.5 b-g	5.67 a-c	0.83 a-c
	Mizuna var. Mustard Green	45.0 a-e	17.7 b	42.7 a-d	14.3 a-g	33.7 b-d	67.0 c-h	4.50 a-d	0.50 c
	Mizuna var. Salad Kyomizuna	45.0 a-e	100. 7 a	43.7 a-c	8.2 c-g	33.0 b-d	71.5 c-h	3.00 a-d	0.67 bc
	Rocket Salad vr. unknown	22.4 m	10.0 b	19.2 k	4.6 g	15.0 d	9.0 h	1.17 d	0.50 c
	Chard var. unknown	29.8 h-m	6.0 b	28.5 e-k	7.9 d-g	27.7 cd	20.2 f-h	1.67 cd	0.67 bc
Enshi-shoho solution	Lettuce var. BARI Lettuce-1	27.0 k-m	12.7 b	24.6 i-k	16.2 a-f	28.0 cd	88.8 b-f	3.83 a-d	1.83 a-c
	Lettuce var. Green Wave	29.2 i-m	9.7 b	25.0 i-k	15.2 a-g	39.3 a-d	53.8 c-g	1.83 cd	1.83 a-c
	Lettuce var. New Red Fire	24.6 lm	13.3 b	23.8 jk	18.3 a-d	31.2 b-d	76.0 b-h	3.50 a-d	1.83 a-c
	Spinach var. BARI Palongshak-1	39.3 b-i	8.3 b	37.7 b-h	9.2 c-g	23.0 cd	52.2 c-h	3.17 a-d	1.17 a-c
	Spinach var. BARI Palongshak-2	41.5 a-g	12.0 b	39.5 a-f	13.2 a-g	27.3 cd	71.0 c-h	5.67 a-c	2.00 ab
	Pak Choi var. BARI Batishak-1	33.3 f-l	11.3 b	31.7 d-j	10.5 a-g	27.7 cd	63.3 c-h	2.33 b-d	0.83 a-c
	Mizuna var. Late White Stem	45.0 a-e	15.0 b	45.0 a-c	12.3 a-g	61.3 a	64.5 c-h	4.33 a-d	1.00 a-c
	Mizuna var. Mustard Green	43.4 a-f	15.3 b	41.6 a-d	14.6 a-g	58.0 ab	52.3 c-h	2.67 a-d	1.67 a-c
	Mizuna var. Salad Kyomizuna	40.5 a-h	114. 3 a	39.7 a-e	6.5 e-g	35.0 a-d	78.5 b-h	4.33 a-d	1.50 a-c
	Rocket Salad var. unknown	27.6 j-m	13.7 b	26.3 h-k	6.8 e-g	36.2 a-d	18.0 f-h	1.00 d	0.50 c
	Chard var. unknown	38.7 b-i	9.0 b	35.0 c-j	10.4 a-g	38.3 a-d	55.0 c-h	3.00 a-d	1.00 a-c
Level of Significance		**	**	*	*	**	*	*	**

[z]values within a column followed by different letters are significantly different according to the Tukeys HSD test at $P \leq 0.05$.

*, **indicates significant at $p \leq 0.05$, $p \leq 0.01$ respectively.

FW = Fresh weight, DW = Dry weight

During cultivation of micro-greens (1 true leaf stage), Bulgaria *et al*. (2017) obtained, 0.74 mg/g FW reducing sugar and 2.21 mg/g FW total sugar in Swiss Chard, and 1.42 mg/g FW reducing sugar and 4.22 mg/g FW total sugar content in Rocket. Miceli *et al.* (2019) reported that they obtained TSS (2.8 ^{o}Brix), titratable acidity (28.5 mg/100 g FW) in lettuce while TSS (5.5 ^{o}Brix) and titratable acidity (45.3 mg/100 g) in Rocket. Ramos-Sotelo *et al.* (2021) obtained pH (6.10), titratable acidity (0.12% on FW), TSS (2.54%), moisture (90.4%) and carbohydrate (5.10%) content at 50 days after sowing in lettuce. Rossi *et al*. (2020) reported that they obtained pH (5.90), TSS (2.20%) and titratable acidity (1.90 g/100 ml leaf extracts from green Romanela lettuce in NFT hydroponics system. Ahmed *et al*. (2000) obtained reducing sugar (4.63-6.22 mg/g FW) and total sugar (6.53 -8.64 mg/g FW) in Rocket. Quality parameters in lettuce can also be influenced by the growing season or environmental factors, and nutrient compositions (Sublett *et al*., 2018).

Table 5. Main effect of hydroponic nutrient solutions and leafy vegetables varieties on the quality parameters of leafy vegetables grown in deep water culture hydroponics

Experimental treatments	Total soluble solids (%)	pH	Titratable acidity (%)	Reducing sugar (%)	Total sugar (%)
Nutrient solution					
Modified Cooper's solution-1	5.8 a^{z}	6.65 a	1.36 a	5.8 c	13.0 b
Modified Cooper's solution-2	5.9 a	6.58 b	1.15 b	6.6 b	12.2 c
Enshi-Shoho solution	5.2 b	6.06 c	0.52 c	18.0 a	13.2 a
Level of Significance	**	**	**	**	**
Cultivars					
Lettuce var/ BARI Lettuce-1	5.2 ab	6.47 d	0.74 f	7.3 h	15.6 a
Lettuce var. Green Wave	5.5 ab	6.73 a	0.41 g	14.1 b	11.4h
Lettuce var. New Red Fire	4.6 b	6.07 g	0.38 g	17.5 a	12.3 f
Spinach var. BARI Palongshak-1	5.7 ab	6.57 c	0.79 f	9.4 f	15.4 b
Spinach var. BARI Palogshak-2	6.0 a	6.63 b	0.88 e	6.8 i	12.1 g
Pak Choi var. BARI Batishak-1	5.7 ab	6.59 c	1.72 b	8.6 g	12.5 e
Mizuna var. Late White Stem	6.2 a	6.19 f	1.24 c	9.6 e	12.0 g
Mizuna var. Mustard Green	6.3 a	6.47 d	1.89 a	10.4 d	11.3 i
Mizuna var. Salad Kyomizuna	5.6 ab	6.17 f	1.18 d	10.5 c	12.6 d
Rocket Salad	5.6 ab	6.40 e	0.84 e	7.3 h	12.8 c
Chard	-	-	-	-	-
Level of Significance	**	**	**	**	**

^{z}values within a column followed by different letters are significantly different according to the Tukeys HSD test at $P \leq 0.05$.
**indicates significant at $p \leq 0.01$.

Interaction effect of hydroponic nutrient solutions and leafy vegetable varieties on quality characters

The quality characters, pH, titratable acidity, reducing sugar and total sugar were significantly affected by the interaction of nutrient solutions and leafy vegetables varieties but total soluble solid remained non-significant (Table 6). Plants of spinach var. BARI Palongshak-1 grown under MCS-1 gave maximum pH (7.17), which was followed by the spinach var. BARI Palongshak-2 grown in same nutrient solution (7.00) and Rocket salad grown under MCS-2 (6.97). The higher pH in BARI palongshak-1, BARI Palongshak-2 and Rocket salad under MCS-1 and MCS-2 indicates bitterness in taste. The vegetable lettuce var. New red Fire gave lower pH value under MCS-1 (5.60) and MCS-2 (5.90), and spinach var. BARI Palongshak-1 (5.80), Mizuna var. Late White Stem (5.50) and Rocket Salad (5.50) recorded lower pH values under ENS. Overall lower pH values in the tested 11 varieties of vegetables were observed in ENS compared to MCS-1 and MCS-2. MCS-1 in combination with Mizuna var. Mustard Green gave maximum titratable acidity (2.83%) followed by MCS-1 coupled with Pak Choi var. BARI Batishak-1 (2.43%), then followed by two varieties of Mizuna viz., Late White Stem and Mustard Green (2.30%) except Salad Kyomizuna (1.80%) coupled with MCS-1, and spinach var. BARI Batishak-1 in combination with MCS-2 (2.20%) and Mizuna var. Salad Kyomizuna under MCS-1 (1.80%) also gave fair amount of titratable acidity. Overall lower titratable acidy content in the tested leafy vegetables varieties were observed under ENS. Mizuna var. Late White Stem grown under ENS produced maximum reducing sugar (25.8%) which was followed by Mizuna var. Mustard green grown under the same nutrient solution (24.8%), then followed by Mizuna var. Late white stem' grown in ENS (22.8%). Spinach var. BARI Palongshak-1 grown in ENS (21.8%) and lettuce var. Green Wave and New Red Fire grown under MCS-2 (20.8%) recorded fair amount of reducing sugar. Lettuce var. BARI Lettuce-1 grown under MCS-1 and spinach var. BARI Palongshak-1 grown under ENS gave maximum total sugar content (17.5%) which was identical with Rocket Salad grown in ENS (15.5%). Spinach var. BARI Palongshak-1 produced moderate amount of total sugar (14.7%) when grown in MCS-1. Lettuce var. BARI Lettuce-1 grown under MCS-2 and ENS also gave moderate amount of total sugar (14.7). Agarwal *et al*. (2021) also got maximum total sugar content (0.42 g/100 g) from hydroponics using nutrient solution (all in ppm: N 150, P 40, K 200, Fe 5, Ca 50, Mg 60, Zn 3, Mn 3, Cu (<1), B (<4), Mo (<1), Na (<1) and S 50). It is also reported that quality of some leafy vegetables like vitamin-C content showed negative correlations with NO_3^- content in Pak choi, romaine lettuce and chungchima lettuce (Kang and Kim, 2007).

Table 6. Interaction effect of hydroponic nutrient solution and leafy vegetables varieties on the quality parameters of leafy vegetables grown in deep water culture hydroponics

Nutrient solution × Leafy vegetables with variety		Total soluble solids (%)	pH	Titratable acidity (%)	Reducing sugar (%)	Total sugar (%)
Modified Cooper's solution-1	Lettuce var. BARI Lettuce-1	5.1 a[z]	6.87 de	0.80 i	3.3 l	17.5 a
	Lettuce var. Green Wave	5.3 a	6.70 g	0.40 l	18.3 g	11.9 i
	Lettuce var. New Red Fire	4.6 a	5.60 q	0.30 m	14.8 j	13.0 f
	Spinach var. BARI Palongshak-1	6.4 a	7.17 a	1.20 f	2.8 n	14.7 c
	Spinach var. BARI Palogshak-2	6.7 a	7.00 b	1.03 g	2.8 n	12.2 h
	Pak Choi var. BARI Batishak-1	5.7 a	6.90 cd	2.43 b	3.6 k	13.3 e
	Mizuna var. Late White Stem	6.9 a	6.50 j	2.30 c	3.1 m	11.7 j
	Mizuna var. Mustard Green	6.1 a	6.50 j	2.30 c	2.8 n	13.3 e
	Mizuna var. Salad Kyomizuna	5.2 a	6.50 j	1.80 e	3.3 l	11.2 k
	Rocket Salad	6.2 a	6.73 fg	1.03 g	3.3 l	11.7 j
	Chard	-	-	-	-	-
Modified Cooper's solution-2	Lettuce var. BARI Lettuce-1	5.5 a	6.53 ij	0.90 h	2.9 n	14.7 c
	Lettuce var. Green Wave	5.6 a	6.80 ef	0.30 m	20.8 e	11.3 k
	Lettuce var. New Red Fire	4.7 a	5.90 o	0.30 m	20.8 e	10.8 l
	Spinach var. BARI Palongshak-1	5.1 a	6.73 fg	0.53 k	3.6 k	14.0 d
	Spinach var. BARI Palogshak-2	6.1 a	6.90 cd	1.20 f	2.8 n	10.8 l
	Pak Choi var. BARI Batishak-1	6.6 a	6.67 gh	2.20 d	3.3 l	12.2 h
	Mizuna var. Late White Stem	6.5 a	6.57 ij	0.80 i	2.9 n	11.2 k
	Mizuna var. Mustard Green	6.8 a	6.30 l	2.83 a	2.6 o	12.7 g
	Mizuna var. Salad Kyomizuna	6.0 a	6.40 k	1.20 f	3.3 l	13.3 e
	Rocket Salad	6.1 a	6.97 bc	1.20 f	2.8 n	11.2 k
	Chard	-	-	-	-	-

Enshi-shoo solution	Lettuce var. BARI Lettuce-1	5.0 a	6.00 n	0.53 k	15.8 i	14.7 c
	Lettuce var. Green Wave	5.6 a	6.70 g	0.53 k	3.1 m	11.2 k
	Lettuce var. New Red Fire	4.5 a	6.70 g	0.53 k	16.8 h	13.3 e
	Spinach var. BARI Palongshak-1	5.7 a	5.80 p	0.63 j	21.8 d	17.5 a
	Spinach var. BARI Palogshak-2	5.2 a	6.00 n	0.40 l	14.8 j	13.3 e
	Pak Choi var. BARI Batishak-1	4.7 a	6.20 m	0.53 k	18.8 f	12.2 h
	Mizuna var. Late White Stem	5.4 a	5.50 r	0.63 j	22.8 c	13.3 e
	Mizuna var. Mustard Green	6.1 a	6.60 hi	0.53 k	25.8 a	7.9 m
	Mizuna var. Salad Kyomizuna	5.7 a	5.60 q	0.53 k	24.8 b	13.3 e
	Rocket Salad	4.4 a	5.50 r	0.30 m	15.8 i	15.5 a
	Chard	-	-	-	-	-
Level of Significance		ns	**	**	**	**

[z]values within a column followed by different letters are significantly different according to the Tukeys HSD test at $P \leq 0.05$.
ns, **indicates not significant or significant at $p \leq 0.01$, respectively.

Effect of hydroponic nutrient solutions and leafy vegetables varieties on the photosynthetic pigments of leafy vegetables

Photosynthetic pigment content in ten leafy vegetables (except Chard) grown in three nutrient solutions varied significantly when grown in deep water culture hydroponics (Table 7). Results revealed that comparatively lower chlorophyll pigments and carotenoid content obtained in plants grown in MCS-2 than other two nutrient solutions. In MCS-1, Mizuna var. Late White Stem and Mizuna var. Mustard Green showed significantly lower chlorophyll a and it was also evident in MCS-2 however, Mizuna var. Salad Kyomizuna had lower chlorophyll a in ENS. ENS has lower EC value compared to MCS-1 and -2, thus showed lower photosynthetic pigments which is consistent with the findings of Roosta and Hamidpour (2011), Ding *et. al*., (2018), and Wortman, (2015). In general, chlorophyll a, b and t were comparatively higher in BARI Lettuce-1, BARI Palongshak-1 and -2 in all the nutrient solution used. Carotenoid content also followed similar trend. Lee *et al.* (2022) obtained chlorophyll content (0.87-2.03 mg/g FW) from different amount of nutrient solutions and two varieties of lettuce at 34 days after sowing. In case of spinach, it was reported variation in Chl a (1.37 mg/g FW), Chl b (0.68 mg/g FW) and Chl t (2.05 mg/g FW) content when grown in hydroponics using nutrient solution (all in ppm: N 150, P 40, K 200, Fe 5, Ca 50, Mg 60, Zn 3, Mn 3, Cu (<1), B (<4), Mo (<1), Na (<1) and S 50) (Agarwal *et al*., 2021). While in Turkey, it was reported Chl t content (1.67 mg/g FW) from hydroponic solution (ppm: N 150, P 50, K 150, Fe 5, Ca 150, Mg 50, Zn 0.05, Mn 0.05, Cu 0.03, B 0.50, Mo 0.02) in spinach (Oztekin et al., 2018). Bulgaria *et al.* (2017) obtained 0.510 mg/g FW Chl a, 0.191 mg/g FW Chl b and 0.0.701 mg/g FW Chl t and 0.122 mg/g FW carotenoid in Swiss Chard, and 0.740 mg/g FW Chl a, 0.260 mg/g FW Chl b, 1.007 mg/g FW Chl t, and 0.171 mg/g FW Car in Rocket.

Table 7. Effect of hydroponic nutrient solutions on the photosynthetic pigments of leafy vegetables grown in deep water culture hydroponics.

Nutrient solution	Leafy vegetables	Chl a (mg g^{-1} FW)	Chl b (mg g^{-1} FW)	Chl t (mg g^{-1} FW)	Car (mg g^{-1} FW)
Modified Cooper's solution-1	Lettuce var. BARI Lettuce-1	39.7[z]	38.6	34.8	0.095
	Lettuce var. Green Wave				
	Lettuce var. New Red Fire				
	Spinach var. BARI Palongshak-1	32.7	24.1	21.9	0.045
	Spinach var. BARI Palogshak-2	38.5	29.6	26.8	0.068
	Pak Choi var. BARI Batishak-1	39.7	38.3	34.6	0.088
	Mizuna var. Late White Stem	4.0	2.9	2.7	0.020
	Mizuna var. Mustard Green	9.4	6.9	6.3	0.030
	Mizuna var. Salad Kyomizuna	36.2	27.4	24.9	0.070
	Rocket Salad	37.7	29.0	26.3	0.016
	Chard	-	-	-	-

Nutrient solution	Leafy vegetables	Chl a (mg g^{-1} FW)	Chl b (mg g^{-1} FW)	Chl t (mg g^{-1} FW)	Car (mg g^{-1} FW)
Modified Cooper's solution-2	Lettuce var. BARI Lettuce-1	17.5	13.1	11.9	0.061
	Lettuce var. Green Wave	15.7	11.8	10.7	0.064
	Lettuce var. New Red Fire	27.0	19.3	17.6	0.050
	Spinach var. BARI Palongshak-1	21.8	16.8	15.2	0.043
	Spinach var. BARI Palogshak-2	11.8	9.3	8.4	0.035
	Pak Choi var. BARI Batishak-1	13.9	10.2	9.2	0.037
	Mizuna var. Late White Stem	9.5	7.4	6.7	0.006
	Mizuna var. Mustard Green	12.0	8.8	8.0	0.015
	Mizuna var. Salad Kyomizuna	16.5	12.1	11.0	0.032
	Rocket Salad	37.5	29.8	27.0	0.107
	Chard	-	-	-	-
Enshi-shoho solution	Lettuce var. BARI Lettuce-1	32.1	23.5	21.3	0.071
	Lettuce var. Green Wave	36.6	28.7	26.0	0.075
	Lettuce var. New Red Fire	30.3	20.6	18.7	0.059
	Spinach var. BARI Palongshak-1	40.3	46.1	41.5	0.066
	Spinach var. BARI Palogshak-2	37.8	28.5	25.9	0.053
	Pak Choi var. BARI Batishak-1	11.3	8.2	7.5	0.044
	Mizuna var. Late White Stem	40.1	39.8	35.8	0.092
	Mizuna var. Mustard Green	39.6	36.4	32.9	0.094
	Mizuna var. Salad Kyomizuna	5.8	4.6	4.2	0.020
	Rocket Salad	22.5	16.3	14.8	0.018
	Chard	-	-	-	-

zValues were calculated from the Spectrophotometric absorbance for each sample.

Chl a = Chorophyll a, Chl b = Chlorophyll b, Chl t = Total Chlorophyll, Car = Carotenoid, FW = Fresh weight

Conclusions

Based on the above results and discussion it is observed that growth of eleven varieties of six leafy vegetables was varied significantly in three types of hydroponic nutrient solutions in deep water culture system. The growth performances of tested vegetables were found better in Modified Cooper's solution-1 (MCS-1) which was followed by Modified Cooper's solution-2 (MCS-2) and the lower performance was obtained from Enshi-shoho nutrient solution (ENS). In case of quality characteristics such as total soluble solids, pH, and titratable acidity were found higher in MCS-1 followed by MCS-2. Lower chlorophyll pigments (Chl a, Chl b and Chl t) and carotenoid content were recorded from plants grown in MCS-2 compared to other two hydroponic nutrient solutions. All three varieties of lettuce, two varieties of spinach, variety of Pak Choi and three varieties of Mizuna performed better when their plants were grown in MCS-1. Therefore, MCS-1 can be recommended for growing these leafy vegetables in hydroponics following deep water culture technique. In further studies, hydroponic systems, and growing season will be considered for evaluating performances of these selected leafy vegetables.

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