

Project ID- 521

Competitive Research Grant

Sub-Project Completion Report

on

**Vertical farming: The future solutions for organic
vegetables production in urban area**

Project Duration

May 2017 to September 2018

Department of Entomology

Sylhet Agricultural University, Sylhet-3100

Submitted to



**Project Implementation Unit-BARC, NATP 2
Bangladesh Agricultural Research Council**

Farmgate, Dhaka-1215



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Acronyms

FAO Food and Agriculture Organization

FAOSTAT et al. cm	Food and Agriculture Organization Corporate Statistical Database et alii (and others) Centimeter
Soil + Vermi Soil + Coco Vermi + Coco	Soil + Vermicompost Soil + Coconut coir Vermicompost + Coconutcoir
RCBD	Randomized Complete Block Design
BARI	Bangladesh Agricultural Research Institute
HCL	Hydrochloric acid
°C	Degree Celsius
g	Gram
mL	Milliliter
HClO ₄	Perchloric acid
HNO ₃	Nitric acid
USA	United States of America
%	Percentage
SRDI	Soil Resources Development Institute
N	Nitrogen
Ca	Calcium
Mg	Magnesium
K	Potassium
P	Phosphorus
S	Sulphur
Fe	Iron
Mn	Manganese
Zn	Zinc
B	Boron
Na	Sodium

No.	Number
mm	Millimeter
Plant ⁻¹	Per plant
CV	Coefficient of variance
LS	Level of significance
FW	Fresh weight
mg	Milligram
kg	Kilogram
gm	Gram
Wt.	Weight
UN	United Nations
TK	Taka
&	And
etc.	et cetera
i.e.	id est (that is)
e.g.,	For example
BOAN	Bangladesh Organic Agriculture Network
±	Plus and Minus
/	Per

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Executive Summary

Bangladesh is densely populated country in the world where urbanization rate is 3.55%. Due to rapid urbanization huge arable land are decreasing day by day. To fulfill the local demand especially for the urban people a great amount of pesticides are using. With a view to increase the availability of organic and pesticide free vegetables and to ensure the nutritional security in urban areas we did an experiment entitled “Vertical farming: The future solutions for organic vegetables production in urban area. In this experiment we have used the vertical space of the rooftop of the Agriculture Faculty building of Sylhet Agricultural University. Several steel and iron made vertical frames with three layers on each were used to grow five winter vegetables viz. lettuce, pak-choi, red amaranth, french bean and spinach and five summer vegetables viz. indian mint, red amaranth, thankuni (asiatic pennywort), water spinach and indian spinach. All the vegetables were grown in four culture media viz. these are soil, Soil + Vermicompost (Soil + vermi), Soil + Coconut coir (Soil + coco), Vermicompost + Coconut coir (Vermi + coco). Here soil was used as control. In winter season lettuce, red amaranth, pak-choi and spinach showed better growth in soil + vermicompost and french bean growth significantly increase in soil + coconut coir culture media. Among these vegetables, red amaranth was found as Ca, Mg and P rich, pak-choi as K and S rich, lettuce as Fe, Mn and Zn rich, spinach as Na and B rich vegetables. In summer cultivation, out of five vegetables red amaranth could not continue its growth due to heavy rain. Indian mint and Indian spinach growth was significantly increased in soil + vermicompost and vermicompost + coconut coir culture media. However, water spinach, thankuni (asiatic pennywort) growth was significantly increased only in soil + vermicompost culture media. Among the four vegetables in summer cultivation, water spinach was found as Mg rich, indian spinach as P rich and thankuni (asiatic pennywort) as Ca, K and S rich vegetable. Out of four culture media, organic media especially soil + vermicompost and vermicompost+ coconut coir showed better performance in terms of growth and nutrient contents of the vegetable. Considering all the growth and nutritional data it can be concluded that highly nutritious vegetables can be grown in vertical frame using the soil + vermicompost culture media.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. Title of the CRG sub-project: **Vertical farming: The future solutions for organic vegetables production in urban area**
2. Implementing organization: Sylhet Agricultural University, Sylhet-3100, Bangladesh

3. Name and full address with phone, cell and E-mail of PI and Co-PI:

Principal Investigator: Dr. Md. Fuad Mondal

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4. Sub-project budget (Tk):
Total: Tk. 24,98,315 (Twenty four lakh ninety eight thousand three hundred Fifteen taka only)
4.1 Revised (if any): 23,59,513 (Twenty three lakh fifty nine thousand five hundred thirteen taka only)
5. Duration of the sub-project:
Start date (based on LoA signed): 14 May 2017
End date: 30 September 2018

6. Justification of undertaking the sub-project:

According to the United Nations (2013) until 2050, the number of people living in urban areas is expected to rise to more than 6 billion, 90% of them in developing countries. This unprecedented explosion and growth of mega-cities worldwide may prove unsustainable and ecologically disastrous. Moreover food and nutrition would be grater challenges of the huge

populations. United Nations World Food Programme mentioned that, nearly 1 billion people worldwide are undernourished (FAO, 2012). Bangladesh is a densely populated country in the world. To achieve the sustainable nutrition security it has changed from a single focus on rice to diversify with high value crops (FAO, 2011). Different types of vegetables play a key role in this effort. Bangladesh produces 156 types of vegetables with 1.42 crore tones per year (Palma, 2016). In fact, year round and organic and pesticide free vegetable production is still facing challenges (Schreinemachers et. al., 2016). Moreover, increasing urbanization (3.55%)

in Bangladesh (The world Factbook, 2015) will consume huge arable land which may compel us to import vegetables in near future from other countries. The global projections show that up to 2040 agricultural land can only be increased by another 2%. (FAOSTAT, 2012). The only way to overcome this situation is to maximize the land use efficiency. However, now a day's urbanization is hampering the maximization of the land use efficiency. In such circumstances, we have to modify our farming system from horizontal to vertical. Many developed countries in the world like Japan, Singapore have already started vertical farming for vegetables production (Mondal et. al., 2016, Singh, 2016). In this context, comprehensive research is necessary to make a vertical vegetable farming model in the urban areas for the food safety and nutritional security. Therefore, we conduct two experiment in vertical frame to evaluate the 10 vegetables in winter and summer season using different culture media.

7. Sub-project goal: Year round supply of organic vegetable in urban areas
8. Sub-project objective (s):
 - a. Increase the availability of organic and chemical pesticide free vegetables all the year round
 - b. To ensure the nutrition security by consuming the fresh organic vegetables
 - c. Using the vertical space for vegetable production in urban areas
 - d. Find out the suitable vegetables and soil media for the vertical agriculture
 - e. To increase the land use efficiency
 - f. To improve the organic farming industry
9. Implementing location (s): Sylhet Agricultural University, Sylhet-3100, Bangladesh
10. Methodology in brief:

The following activities were performed to achieve the goal(s) and objectives of the Sub-Project-

Study site

The experimental site was selected and prepared for establishing the vertical frame in the rooftop of the Agriculture faculty building at the Sylhet Agricultural University, Sylhet, Bangladesh

Making a vertical Frame

Rectangular vertical steel frame (6.4 feet × 5 feet × 1.8 feet) with its four stands was made. This frame was made with three vertical layers and four parts in its one layer. These were set up on the roof top of the Agriculture Faculty building of Sylhet Agricultural University, Sylhet,

Bangladesh. Portable perforated hard plastic trays with 8 cm culture media/substrate layers were used for the cultivation of vegetables. Another steel tray was used beneath the portable hard plastic tray for drainage the water.

Culture media/substrates

Four types of culture media/substrate were used to find out the suitable substrate for production of vegetables in summer and winter season. These are soil (Control), Soil + Vermicompost (Soil + vermi), Soil + Coconut coir (Soil + coco), Vermicompost + Coconut coir (Vermi + coco).

Vegetables types for the vertical frame cultivation

Short duration and low height and highly nutritious valuable vegetables were selected for this type of structure. Taking into consideration of the above points, the following crops were grown in the media inside the vertical frame in summer (April to August) and winter seasons (October to March).

Winter vegetables: lettuce (*Lactuca sativa*), Pak choi (*Brassica rapa*), Red amaranth, (*Amaranthus gangeticus*), French bean (*Phaseolus vulgaris*), Spinach (*Spinacia oleracea*),

Experimental Design: RCBD with three replications

Summer vegetables: Indian spinach (*Basella alba*), Mint (*Mentha Aquatica*), Red amaranth (*Amaranthus gangeticus*), Thankuni (*Centella asiatica*), water spinach (*Ipomoea aquatica*),

Experimental Design: RCBD with three replications

Irrigation and intercultural operations

Water was supplied through the gardening water cane. For collecting drained water steel bottom tray beneath the hard perforated plastic trays were used. Other intercultural operations weeding, thinning, were done on a regular basis. Steel ladder was used during the intercultural operations.

Pest management

In winter season red amaranth was frequently eaten by the birds. So, mosquito nets were used to prevent the birds.

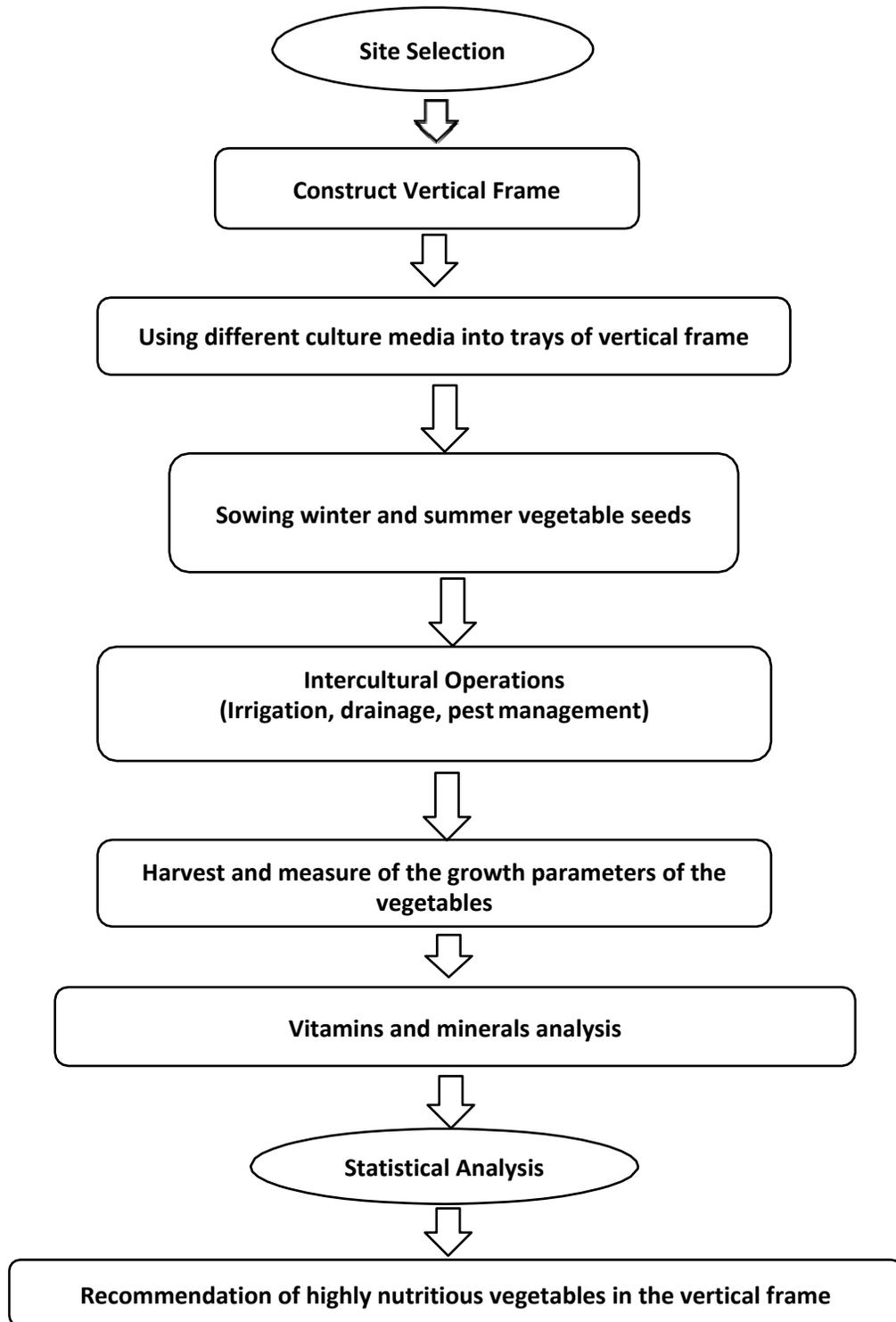


Figure: 1. Flow diagram of methodology

After harvest, shoot length, no of leaf, leaf area, and shoot fresh weight, no. of pod cluster, fruit length, fruit breadth of the respective vegetables was measured. After measuring, half of the sample was kept in the freeze at -80° temperatures for further analysis and another half of the sample was oven dried.

Chemical analysis of plant sample

Chemical analyses of plant samples were accomplished in the laboratory of the Department of Soil Science, Bangladesh Agricultural Research Institute (BARI), Gazipur-1701.

Preparation of plant samples

The plant samples were cleaned thoroughly with tap water and rinsed with 0.1 M HCL solution, followed by several rinses with distilled water for chemical analyses. The samples were dried in oven at 80°C for about 72 hours. The dried plant samples were ground with a mechanical grinder and stored in polythene zipper bags separately.

Preparation of plant extract for determination of macro and micro nutrients

The samples were digested by following procedure outlined by Tandon (1995). For analyses of macro and micro nutrients 1g of ground plant sample was taken in a 250 mL conical flask and then 10 ml of di-acid mixture (0.5M HClO₄ and conc. HNO₃) was added. The content was stirred to moisten the plant sample and then placed on an electric hot plate (sand bath) and heated at 180-200°C until white fumes were evolved. The content was cooled, diluted with deionized water, filtered through filter paper (Whatman No. 42). The volume was made up to 100 mL.

Determination of macro and micro nutrients within the vegetables

Determination of different macro and micro nutrients viz. Ca, Mg, K, P, S, Fe, Mn, Zn, B, Na in aliquot were determined using atomic absorption spectrophotometer (iCE 3300, Thermo Fisher Scientific, USA) using the reagent blank.

Measurement of soluble solid and Vitamin C

After harvest, the sample will be composited and frozen at -30°C for subsequent analysis of ascorbic acid content. The Vitamin C content was determined by Indophenol Method (Nielsen, 2017).

Culture media analysis: Initial and after harvest of winter and summer vegetables the culture media were analyzed to check the pH, Total-N (%), Macro nutrients (Ca, Mg, K, P, Cu, S) and micro nutrients (Fe, Mn, Zn). All the analysis was done at Soil Research and Development Institute (SRDI), Sylhet.

Statistical analysis

Growth, mineral content and vitamin data was calculated by using computer package program R software (Version 3.4.3).



Picture 1. Culture media used in the vertical frame



Picture 2. Vertical frame with vegetable seedlings



Picture 3. Vegetables grown in vertical frames in the roof top of Faculty of Agriculture, Sylhet Agricultural University



Picture. 4. MS student Taslima Aktar working the vertical frames

11. Results and discussion

Results of winter vegetable cultivation in vertical frames:

Four types of culture media were used to find out the suitable substrate for production of lettuce, red amaranth, pak-choi, spinach and french bean following the RCBD design in vertical frames. Data of shoot length, no of leaf, leaf area, and shoot fresh weight, no. of pod cluster, fruit length, fruit breadth, vitamin C, macro and micro minerals of the respective vegetables were measured. Initial and post-harvest soil was also analyzed.

Lettuce (*Lactuca sativa*)

Results showed that maximum shoot length (18.28 cm), no. of leaf plant⁻¹ (9.1) and leaf area (130.7 mm²) of lettuce were found in soil + vermicompost culture media; whereas minimum shoot length (11.7 cm), no. of leaf plant⁻¹ (6.3) and leaf area (66.19 mm²) were found in soil (**Table 1**). Maximum shoot fresh and dry weight of lettuce were also evidenced in soil + vermicompost culture media and minimum results of shoot fresh and dry weight were recorded in soil (**Figure 2**). Might be, lettuce increased its shoot fresh and dry weight grown in soil + vermicompost though the improvement of shoot length, no. of leaf plant⁻¹ and leaf area.

Table 1: Effects of culture media on shoot length, No. of leaf plant⁻¹ and leaf area of Lettuce at harvest in winter season

Culture media	Shoot length (cm)	No. of leaf plant ⁻¹	Leaf area (mm ²)
Soil	11.77±1.35d	6.33±1.10c	66.19±5.17c
Soil + Coco	13.69±0.72c	6.73±0.50bc	71.98±5.10c
Soil + Vermi ^Y	18.28±1.21a	9.10±0.61a	130.77±4.34a
Vermi + Coco	15.46±1.24b	8.33±0.95ab	90.01±2.77b
CV	6.64	11.96	5.45
LS	**	**	**

CV=coefficient of variance, LS=level of significance; **Significant at 5% level; ^Y=Soil + Vermicompost (Soil + vermi), Soil + Coconut coir (Soil + coco), Vermicompost + Coconut coir (Vermi + coco)

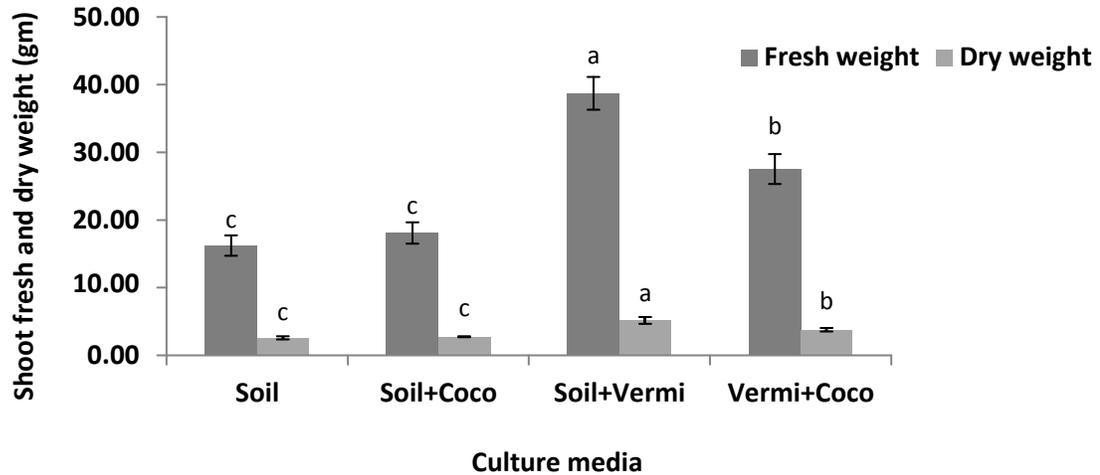


Figure 2: Effects of culture media on shoot fresh and dry weight of Lettuce at harvest



Picture 5. Effects of culture media on growth of Lettuce at harvest in winter season

Macro and micro nutrient contents of lettuce were analyzed. Maximum macro nutrients content (Ca-2.36 g, Mg-1.40 g, K-3.94 g, and S-0.033 g/100g dry basis) were recorded when lettuce were grown in soil + vermicompost culture media (**Table 2**). However, P content was significantly increased both in soil + vermicompost (0.485g/100g dry basis) and Soil + coconut coir (0.477g/100g dry basis). Fe content was significantly increased in soil + Vermicompost (0.1346 g/100g dry basis) rather than others treatments (**Table 3**). When Vitamin c content of fresh lettuce were analyzed, it was found that Vitamin C content was significantly reduced in vermicompost + coconut coir culture media (**Table 3**).

Table 2. Macro nutrient content (gm/100gm dry weight) of Lettuce cultivated in winter season

Culture media	Ca	Mg	K	P	S
Soil	2.26±0.10a	1.37±0.08a	3.77±0.06a	0.352±0.018b	0.027±0.004a
Soil + Coco	2.28±0.06a	1.37±0.04a	3.76±0.24a	0.383±0.010b	0.030±0.006a
Soil + Vermi	2.36±0.08a	1.40±0.06a	3.94±0.03a	0.485±0.024a	0.033±0.003a
Vermi + Coco	2.29±0.08a	1.38±0.05a	3.80±0.10a	0.477±0.018a	0.026±0.003a

Table 3. Micro nutrient content (gm/100gm dry weight) and Vitamin C (mg/100 g FW of leaves) of Lettuce cultivated in winter season

Culture media	Fe	Mn	Zn	B	Na	Vit. C
Soil	0.1093±0.0045b	0.0305±0.0026a	0.0161±0.0015a	0.0020±0.0003a	0.292±0.005a	43.22 a
Soil + Coco	0.1108±0.0013b	0.0317±0.0004a	0.0159±0.0011a	0.0018±0.0003a	0.311±0.026a	42.73a
Soil + Vermi	0.1346±0.0117a	0.0264±0.0034a	0.0182±0.0004a	0.0018±0.0002a	0.298±0.008a	44.53a
Vermi + Coco	0.1068±0.0035b	0.0295±0.0027a	0.0169±0.0015a	0.0018±0.0002a	0.294±0.004a	30.36b



Picture 6. Lettuce and Red amaranth grown on four culture media in vertical frame during winter season

Red amaranth (*Amaranthus gangeticus*)

It was evidenced that maximum shoot length (19.71 cm), no. of leaf plant⁻¹ (7.40) and leaf area (11.20 mm²) of red amaranth were measured in soil + vermicompost culture media; on the other hand minimum shoot length (6.17 cm), no. of leaf plant⁻¹ (4.33) and leaf area (1.54 mm²) were found in vermin + coco culture media (Table 4). Maximum shoot fresh and dry weight of red amaranth were also recorded in soil + vermicompost culture media and minimum values were recorded in vermin + coco culture media (Figure 3).

Table 4: Effects of culture media on shoot length, No. of leaf plant⁻¹ and leaf area of red amaranth at harvest in winter season

Culture media	Shoot length (cm)	No. of leaf plant ⁻¹	Leaf area (cm ²)
Soil	15.68±1.38b	6.80±0.80ab	7.67±1.82b
Soil + Coco	16.71±2.03ab	5.40±0.69bc	3.97±0.60c
Soil + Vermi ^Y	19.71±2.27a	7.40±1.06a	11.20±1.15a
Vermi + Coco	6.17±1.00c	4.33±0.64c	1.54±1.04d
CV	13.01	13.40	20.27
LS	**	**	**

CV=coefficient of variance, LS=level of significance; **Significant at 5% level; ^Y=Soil + Vermicompost (Soil + vermi), Soil + Coconut coir (Soil + coco), Vermicompost + Coconut coir (Vermi + coco)

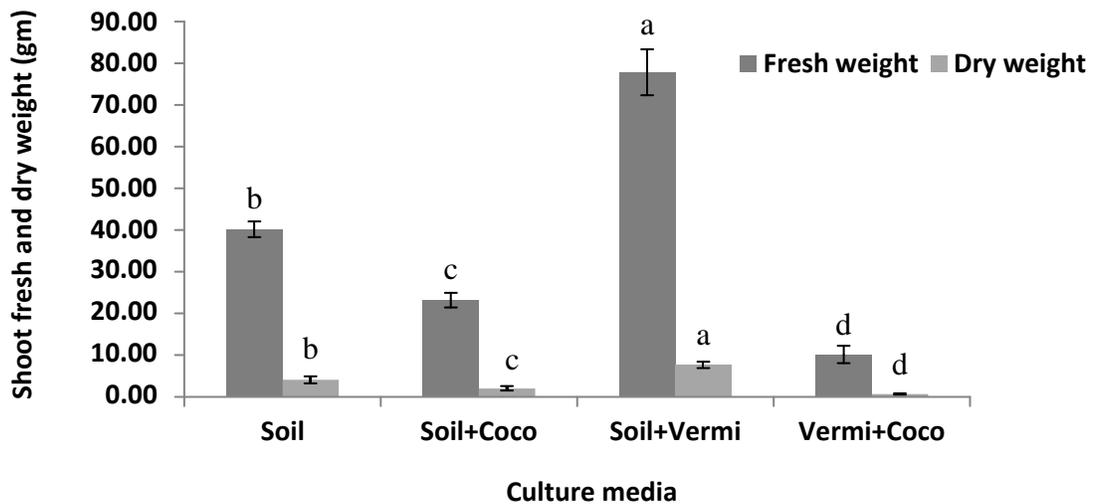


Figure 3: Effects of culture media on shoot fresh and dry weight of Red amaranth at harvest



Picture 7. Effects of culture media on growth of Red amaranth at harvest in winter season

Red amaranth is rich in macro and micro nutrients. When nutrient contents were analyzed in red amaranth, macro nutrients contents (Ca-2.53 g, Mg-1.44 g and K-3.85 g) were found highest in soil + vermicompost culture media; whereas P and S (0.881 g and 0.391 g) recorded in vermin + coco culture media (**Table 5**). On the other hand micro nutrients content (Fe-0.0531 g and Mn-0.0156 g) were maximum in vermin + coco and Zn-0.0170 g, B-0.0031 g, Na-0.227g found maximum in soil + Vermicompost culture media (**Table 6**). Red amaranth vitamin C content did not differ significantly by using the different culture media (**Table 6**).

Table 5. Macro nutrient content (gm/100gm dry weight) of Red amaranth cultivated in winter season

Culture media	Ca	Mg	K	P	S
Soil	2.26±0.10b	1.33±0.09a	3.64±0.07a	0.648±0.068c	0.278±0.044b
Soil + Coco	2.33±0.05b	1.35±0.11a	3.78±0.38a	0.762±0.006b	0.362±0.049ab
Soil + Vermi	2.53±0.05a	1.44±0.08a	3.85±0.14a	0.821±0.040ab	0.281±0.046b
Vermi + Coco	2.30±0.06b	1.36±0.10a	3.59±0.10a	0.881±0.099a	0.391±0.056a

Table 6. Micro nutrient content (gm/100gm dry weight) and Vitamin C (mg/100 g FW of leaves) of Red amaranth cultivated in winter season

Culture media	Fe	Mn	Zn	B	Na	Vit C
Soil	0.0500±0.0045a	0.0149±0.0003a	0.0163±0.0010a	0.0025±0.0001a	0.223±0.003a	68.21a
Soil + Coco	0.0527±0.0005a	0.0151±0.0001a	0.0152±0.0004a	0.0028±0.0001a	0.221±0.006a	51.47a
Soil + Vermi	0.0510±0.0013a	0.0151±0.0005a	0.0170±0.0006a	0.0031±0.0002a	0.227±0.002a	63.33a
Vermi + Coco	0.0531±0.0005a	0.0156±0.0004a	0.0159±0.0011a	0.0029±0.0002a	0.224±0.004a	68.33a

Pak-choi (*Brassica rapa*)

Pak-choi growth was significantly differed in different culture media. Highest shoot length (18.23 cm), no. of leaf plant⁻¹ (7.00) and leaf area (46.62 mm²) were observed in soil + vermicompost culture media; minimum shoot length (12.58 cm), no. of leaf plant⁻¹ (5.87) were found in soil and minimum leaf area (26.17 mm²) was recorded in soil + coco culture media (**Table 7**). Higher shoot fresh and dry weight of pak-choi were also measured in soil + vermicompost culture media and minimum results of shoot fresh and dry weight were recorded in soil (**Figure 4**). Might be increased in leaf size and number lead to higher fresh and dry weight of pak-choi that grown in soil + vermicompost.



Picture 8. Effects of culture media on growth of Pak-choi at harvest in winter season

Table7: Effects of culture media on shoot length, No. of leaf plant⁻¹ and leaf area of Pak-choi at harvest in winter season

Culture media	Shoot length (cm)	No. of leaf plant ⁻¹	Leaf area (cm ²)
Soil	12.58±3.06b	5.87±0.42b	27.27±2.82b
Soil + Coco	14.45±0.53b	5.93±0.12b	26.17±1.65b
Soil + Vermi ^Y	18.23±2.58a	7.00±0.72a	46.62±2.67a
Vermi + Coco	13.79±1.41b	6.33±0.81ab	30.49±2.32b
CV	9.38	9.26	7.17
LS	**	**	**

CV=coefficient of variance, LS=level of significance; **Significant at 5% level; ^Y=Soil + Vermicompost (Soil + vermi), Soil + Coconut coir (Soil + coco), Vermicompost + Coconut coir (Vermi + coco)

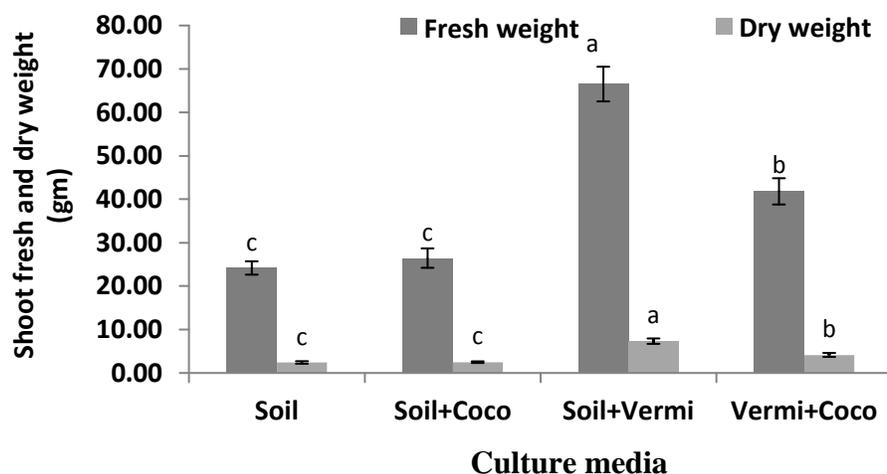


Figure 4: Effects of culture media on shoot fresh and dry weight of Pak-choi at harvest

Results indicate that pak-choi contain Ca, Mg, K, P, S, Fe, Zn, Mn, Br. Maximum macro nutrients content (Ca-2.20 g, Mg-1.25 g, K-4.74 g and P-0.558 g) were found when pak-choi grown in soil + vermicompost culture media; whereas S (0.729 g) was higher in soil + coco culture media (Table 8). Similar pattern was also observed in micro nutrient of pak-choi. Micro nutrients content (Fe-0.0391 g, Mn-0.0115 g Zn-0.0092 g, B-0.0021 g and Na-0.464g) found maximum in soil + vermicompost culture media (Table 9). Vitamin C content of pak-choi was also measured. Result found that Vitamin C content did not differ significantly grown among the culture media (Table 9).

Table 8. Macro nutrient content (gm/100gm dry weight) of Pak-choi in winter season

Culture media	Ca	Mg	K	P	S
Soil	1.99±0.18b	1.06±0.09b	4.22±0.17bc	0.455±0.058ab	0.657±0.027a
Soil + Coco	2.03±0.12b	1.08±0.06b	4.55±0.01ab	0.424±0.045b	0.729±0.183a
Soil + Vermi	2.20±0.07a	1.25±0.07a	4.74±0.27a	0.558±0.035a	0.642±0.025a
Vermi + Coco	2.07±0.04ab	1.12±0.03b	4.03±0.26c	0.488±0.079ab	0.709±0.057a

Table 9. Micro nutrient content (gm/100gm dry weight) and Vitamin C (mg/100 g FW of leaves) of Pak-choi in winter season

Culture media	Fe	Mn	Zn	B	Na	Vit. C
Soil	0.0333±0.0017a	0.0095±0.0005a	0.0082±0.0006a	0.0019±0.0001a	0.382±0.016b	72.02a
Soil + Coco	0.0344±0.0026a	0.0104±0.0014a	0.0086±0.0006a	0.0019±0.0001a	0.458±0.022a	63.62a
Soil + Vermi	0.0391±0.0046a	0.0115±0.0012a	0.0092±0.0005a	0.0021±0.0004a	0.464±0.009a	70.37a
Vermi + Coco	0.0370±0.0008a	0.0109±0.0004a	0.0088±0.0004a	0.0017±0.0001a	0.440±0.035a	78.37a

Spinach (*Spinacia oleracea*)

Spinach produce maximum shoot length (9.04 cm), no. of leaf plant⁻¹ (7.33) and leaf area (11.68 mm²) when grown in soil + vermicompost culture media; minimum shoot length (6.24 cm), leaf area (5.32 mm²) were produced in soil + coco culture media and no. of leaf plant⁻¹ (5.67) were found when grown in vermin + coco culture media (**Table 10**). Maximum shoot fresh and dry weight of spinach were also recorded in soil + vermicompost culture media and minimum results of shoot fresh and dry weight were recorded in soil + coco culture media (**Figure 5**).



Picture 9. Effects of culture media on growth of Spinach at harvest in winter season

Table10. Effects of culture media on shoot length, No. of leaf plant⁻¹ and leaf area of Spinach at harvest in winter season

Culture media	Shoot length (cm)	No. of leaf plant ⁻¹	Leaf area (cm ²)
Soil	6.50±0.47bc	6.33±0.50b	6.25±0.84b
Soil + Coco	6.24±0.53c	5.93±0.76b	5.32±1.63b
Soil + Vermi ^y	9.04±1.70a	7.73±0.50a	11.68±1.80a
Vermi + Coco	8.01±1.02ab	5.67±0.81b	8.45±4.86ab
CV	13.43	9.97	31.37
LS	**	**	**

CV=coefficient of variance, LS=level of significance; **Significant at 5% level; ^y=Soil + Vermicompost (Soil + vermi), Soil + Coconut coir (Soil + coco), Vermicompost + Coconut coir (Vermi + coco)

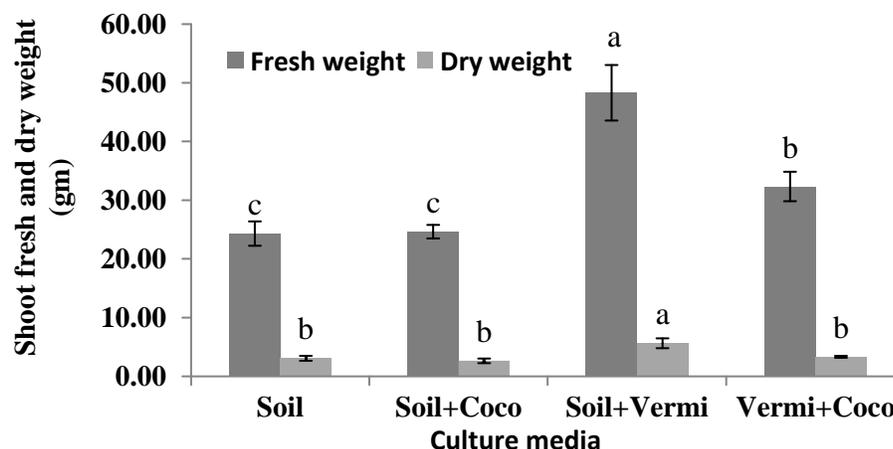


Figure 5: Effects of culture media on shoot fresh and dry weight of Spinach at harvest

It was reported that that higher amount of macro nutrient content (Ca-2.40 g, Mg-1.26 g, P-0.689 g and S-0.681 g) was found in spinach grown in soil + vermicompost culture media whereas, higher K (4.25 g) content was measured in vermin + coco (**Table 11**). Higher concentration of micro nutrients content (Fe-0.0587 g, Mn-0.0170 g and B-0.0047 g) of spinach were also found in soil + vermicompost culture media, whereas Zn (0.0163 g) and Na (0.592 g) recorded higher in vermin + coco (**Table 12**). Vitamin C content of spinach varied significantly when it was grown either soil or soil + vermicompost culture media (**Table 12**).

Table 11. Macro nutrient content (gm/100gm dry weight) of spinach in winterseason

Culture media	Ca	Mg	K	P	S
Soil	2.22±0.06c	1.20±0.05a	4.00±0.38a	0.636±0.022a	0.664±0.027a
Soil + Coco	2.29±0.02bc	1.22±0.02a	4.10±0.16a	0.560±0.153a	0.581±0.325a
Soil + Vermi	2.40±0.08a	1.26±0.06a	4.07±0.37a	0.689±0.021a	0.681±0.035a
Vermi + Coco	2.33±0.04ab	1.23±0.01a	4.25±0.17a	0.666±0.023a	0.656±0.045a

Table 12. Micro nutrient content (gm/100gm dry weight) and Vitamin C (mg/100 g FW of leaves) of spinach in winter season

Culture media	Fe	Mn	Zn	B	Na	Vit. C
Soil	0.0563±0.0013a	0.0161±0.0009a	0.0136±0.0012a	0.0042±0.0005a	0.560±0.021a	93.83a
Soil + Coco	0.0567±0.0006a	0.0162±0.0007a	0.0138±0.0009a	0.0040±0.0003a	0.576±0.042a	74.94b
Soil + Vermi	0.0587±0.0010a	0.0170±0.0006a	0.0150±0.0010a	0.0047±0.0004a	0.584±0.017a	98.81a
Vermi + Coco	0.0537±0.0041a	0.0154±0.0012a	0.0163±0.0014a	0.0044±0.0001a	0.592±0.028a	75.13b

French bean (*Phaseolus vulgaris*)

Four types of culture media were used to evaluate the growth performance of French bean. The highest no. of cluster plant⁻¹ (6.10), no. of pod cluster⁻¹ (5.87), fruit length (15.33 cm) and fruit breadth (1.20 cm) of French bean were observed in soil + vermicompost culture media; on the other hand minimum no. of cluster plant⁻¹ (3.47), no. of pod cluster⁻¹ (3.53), fruit length (12.83 cm) were found in soil at the same time minimum fruit breadth (1.01 cm) was measured in soil + coconut coir culture media (**Table 13**). Highest Pod fresh and dry weight of French bean were also recorded in Vermicompost + coconut coir culture media and minimum pod fresh and dry weight were recorded in soil (**Figure 5**).

Table 13. No of cluster plant⁻¹, no. of pod cluster⁻¹, fruit length and fruit breadth of French bean at harvest

Culture media	No of cluster plant ⁻¹	No. of pod cluster ⁻¹	Fruit length (cm)	Fruit breadth (cm)
Soil	3.47±0.31d	3.53±0.12c	12.83±1.26a	1.03±0.02b
Soil + Coco	4.10±0.30c	4.00±0.20bc	13.17±0.76ab	1.01±0.05b
Soil + Vermi ^Y	6.10±0.46a	5.87±1.01a	15.33±1.61a	1.20±0.12a
Vermi + Coco	5.33±0.12b	4.73±0.64b	14.50±0.87ab	1.07±0.04ab
CV	7.46	13.15	9.45	7.15
LS	**	**	**	**

C

V=coefficient of variance, LS=level of significance; **Significant at 5% level; ^Y=Soil + Vermicompost (Soil + vermi), Soil + Coconut coir (Soil + coco), Vermicompost + Coconut coir (Vermi + coco)



Picture 10. Effects of culture media on growth of French bean at harvest in winter season

Maximum macro nutrients content (Ca-1.43 g, Mg-0.76 g, K-2.45 g and S-0.207 g) were found in French bean when french bean was grown in soil + vermicompost culture media, whereas higher amount of P (0.633 g) found in vermicompost + coconut coir (**Table 14**). Higher amount of micro nutrients content (Fe-0.0264 g, Mn-0.0076 g and Zn-0.0055 g) of French bean were found in soil + vermicompost culture media, whereas B (0.0015 g) and Na (0.211

g) found maximum in vermicompost + coconut coir and soil + coconut coir, respectively (Table 15). Vitamin C content of french bean did not show any significant variation grown in different culture media (Table 15).

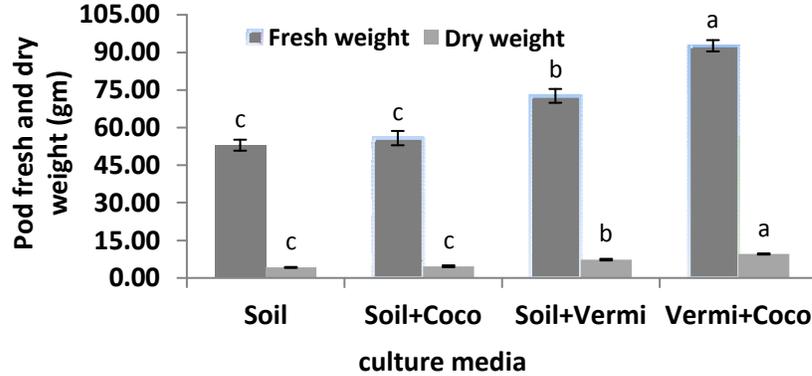


Figure 6: Effects of culture media on shoot fresh and dry weight of French bean at harvest

Table 14. Macro nutrient content (gm/100gm dry weight) of French bean in winter season

Culture media	Ca	Mg	K	P	S
Soil	1.21±0.10b	0.64±0.06b	2.21±0.22a	0.423±0.01d	0.150±0.02b
Soil + Coco	1.37±0.21a	0.73±0.12ab	2.29±0.10a	0.498±0.02c	0.163±0.01b
Soil + Vermi	1.43±0.17a	0.76±0.09a	2.45±0.02a	0.549±0.04b	0.207±0.01a
Vermi + Coco	1.33±0.08ab	0.71±0.09ab	2.20±0.09a	0.633±0.02a	0.162±0.02b

Table 15. Micro nutrient content (gm/100gm dry weight) and Vitamin C (mg/100 g FW of leaves) of French bean in winter season

Culture media	Fe	Mn	Zn	B	Na	Vit.C
Soil	0.0253±0.0006a	0.0071±0.0003a	0.0048±0.0004a	0.0014±0.0002a	0.198±0.004a	70.56a
Soil + Coco	0.0255±0.0009a	0.0072±0.0001a	0.0050±0.0002a	0.0009±0.0001a	0.211±0.012a	62.28a
Soil + Vermi	0.0264±0.0012a	0.0076±0.0003a	0.0055±0.0003a	0.0008±0.0000a	0.202±0.009a	75.38a
Vermi + Coco	0.0241±0.0026a	0.0069±0.0007a	0.0053±0.0000a	0.0015±0.0001a	0.161±0.009b	64.89a



Picture 11. Pak-choi and french bean grown in four culture media in vertical frame

Comparing the the overall results, it was found that in vertical frame growth of Lettuce, Red amaranth, Pak-choi and Spinach were found better in soil + vermicompost culture media and French bean performed well in soil + coconut coir culture media during winter season. Macro and micro nutrient content of lettuce, red amaranth, pak-choi, spinach and french bean in winter season were varied when these were grown in different culture media in winter season. Among the five vegetables, it was found that red amaranth found as Ca, Mg and P rich vegetable, Pak-choi as K and S rich vegetable, Lettuce as Fe, Mn and Zn rich vegetable, Spinach as Na and B rich vegetable.

Table 16. pH, Total-N and OM in initial culture media

Culture media	pH	% Total-N
Soil	4.80	0.22
Coconut coir	5.40	0.57
Vermicompost	6.60	0.79
Soil + Coconut coir	5.80	0.71
Soil + Vermicompost	5.50	0.48
Vermicompost + Coconut coir	6.10	0.58

Table 17. Macro nutrients in initial culture media

Culture media	gm/kg			mg/kg		
	Ca	Mg	K	P	Cu	S
Soil	1.583	0.262	0.047	27.83	0.93	24.00
Coconut coir	4.809	0.773	1.345	51.98	-	16.00
Vermicompost	7.182	0.773	0.368	217.53	-	132.00
Soil + Coconut coir	2.741	0.510	0.500	36.24	-	43.00
Soil + Vermicompost	3.759	0.588	0.160	70.08	0.99	33.00
Vermicompost + Coconut coir	7.342	0.790	0.719	151.25	-	104.00

Table 18. Micro nutrients in initial culture media

Culture media	mg/kg		
	Fe	Mn	Zn
Soil	119.65	12.21	7.75
Coconut coir	-	-	-
Vermicompost	-	-	-
Soil + Coconut coir	-	-	-
Soil + Vermicompost	122.40	14.90	11.40
Vermicompost + Coconut coir	-	-	-

Table19. pH and Total-N in the soil after harvest of French bean, Pak-choi, Spinach, Red amaranth and Lettuce in winter season

Vegetables	Treatment	pH	Total-N (%)
French bean	Soil	5.20	0.18
	Soil + Coco	4.90	0.29
	Soil + Vermi	5.70	0.48
	Vermi + Coco	5.60	0.08
Pak-choi	Soil	5.60	0.21
	Soil + Coco	5.50	0.38
	Soil + Vermi	6.30	0.78
	Vermi + Coco	5.80	0.42
Spinach	Soil	5.30	0.22
	Soil + Coco	5.20	0.57
	Soil + Vermi	6.20	0.56
	Vermi + Coco	5.80	0.69
Red amaranth	Soil	5.50	0.21
	Soil + Coco	5.30	0.32
	Soil + Vermi	6.00	0.51
	Vermi + Coco	6.30	0.14
Lettuce	Soil	5.20	0.27
	Soil + Coco	5.10	0.31
	Soil + Vermi	6.10	0.51
	Vermi + Coco	5.90	0.59

Table 20. Micro nutrient contents in the soil after harvest of French bean, Pak-choi, Spinach, Red amaranth and Lettuce in winter season

Vegetables	Treatment	mg/kg		
		Fe	Mn	Zn
French bean	Soil	120.15	8.60	8.85
	Soil + Coco	196.00	27.60	15.60
	Soil + Vermi	119.70	21.80	15.09
	Vermi + Coco	60.50	7.00	
Batishak	Soil	111.80	27.80	9.01
	Soil + Coco	142.19	46.80	15.60
	Soil + Vermi	73.00	80.20	16.09
	Vermi + Coco	-	-	-
Palongshak	Soil	118.21	18.40	8.80
	Soil + Coco	133.60	40.60	15.15
	Soil + Vermi	68.20	55.60	15.10
	Vermi + Coco	-	-	-
Red amaranth	Soil	110.00	19.12	11.90
	Soil + Coco	164.80	34.27	16.09
	Soil+ Vermi	69.00	49.40	15.15
	Vermi + Coco	-	-	-
Lettuce	Soil	98.00	14.25	9.00
	Soil + Coco	109.00	33.00	12.10
	Soil + Vermi	54.00	39.00	14.19
	Vermi + Coco	-	-	-

Table 21. Macro nutrient contents in the soil after harvest of French bean, Pak-choi, Spinach, Red amaranth and Lettuce in winter season

Vegetables	Culture media	gm/kg			mg/kg		
		Ca	Mg	K	P	Cu	S
French bean	Soil	1.820	0.275	0.055	30.69	1.25	59
	Soil + Coco	1.992	0.394	0.172	38.82	1.75	82
	Soil + Vermi	5.795	0.756	0.336	112.52	2.05	227
	Vermi + Coco	6.485	0.792	0.751	214.11	-	259
Pak-choi	Soil	1.808	0.292	0.043	29.03	0.92	41
	Soil + Coco	2.653	0.491	0.219	64.26	1.18	54
	Soil + Vermi	5.831	0.773	0.438	156.00	1.28	109
	Vermi + Coco	6.156	0.792	0.774	222.54	-	233
Spinach	Soil	2.048	0.311	0.043	34.28	0.78	38
	Soil + Coco	2.116	0.418	0.285	43.56	1.25	61
	Soil + Vermi	4.072	0.722	0.235	146.79	0.93	102
	Vermi + Coco	6.376	0.729	0.813	190.11	-	278
Red amaranth	Soil	1.711	0.287	0.047	48.85	0.70	40
	Soil + Coco	2.040	0.365	0.184	39.84	1.46	65
	Soil + Vermi	3.687	0.685	0.164	138.14	0.90	134
	Vermi + Coco	6.012	0.783	0.876	215.66	-	211
Lettuce	Soil	1.880	0.328	0.047	30.99	0.68	48
	Soil + Coco	1.523	0.333	0.160	35.60	1.79	59
	Soil + Vermi	4.641	0.727	0.211	130.70	0.60	78
	Vermi + Coco	5.863	0.780	0.618	153.65	-	158

Results of summer vegetable cultivation in vertical frames:

Four types of culture media were used to find out the suitable media/substrate for production of Indian mint (*Mentha Aquatica*), Red amaranth (*Amaranthus gangeticus*), Thankuni (*Centella asiatica*), Water spinach (*Ipomoea aquatica*) and Indian spinach (*Basella alba*) following the RCBD design in vertical frames. Data on growth parameters, vitamin C, different macro and micro minerals contents of the vegetables were measured to compare growth and nutritional contents of tested vegetable. Due to the heavy monsoon rainfalls just after germination all red amaranth were unable to grow in the trays within the vertical frames.

Indian spinach (*Basella alba*): Results showed that Indian spinach increased its shoot length (27.27 cm), no. of leaf plant⁻¹ (14.0) and leaf area (26.01) in soil + vermicompost culture media (**Table 22**). Compared to all culture media Indian spinach shoot fresh weight and dry weight was increased when it was grown in soil + vermicompost (**Figure 7**).

Table 22. Effects of culture media on shoot length, no. of leaf plant⁻¹ and leaf area of Indian spinach at harvest in summer season

Culture media	Shoot length (cm)	No. of leaf plant ⁻¹	Leaf area (cm ²)
Soil	16.03±2.11b	10.13±2.11b	9.08±2.11b
Soil + Coco	17.17±3.02b	10.67±3.02b	13.49±3.02b
Soil + Vermi ^Y	27.27±2.60a	14.00±2.60a	26.01±2.60a
Vermi + Coco	25.77±2.27a	12.02±2.27ab	23.74±2.27a
CV	13.53	10.14	15.71
LS	***	**	**

CV=coefficient of variance, LS=level of significance; **Significant at 5% level; ^Y=Soil + Vermicompost (Soil + vermi), Soil + Coconut coir (Soil + coco), Vermicompost + Coconut coir (Vermi + coco)

We analyzed macro and micro nutrient contents of all the summer vegetables grown in four culture media to evaluate the nutritional differences due to culture media. In case of Indian spinach, higher amount of K (3.01 gm/100gm dry wt. basis) and P (0.729gm/100gm dry wt. basis) was found in soil + vermicompost culture media. Higher P was also found in soil + coconut coir substrate (**Table 23**). Among the analyzed micro nutrient Na (0.212 729gm/100gm dry wt. basis) content was higher in Indian spinach when it was grown in soil + vermicompost culture media (**Table 24**). Vitamin C content differ significantly (**Table 21**).



Picture 12. Effects of culture media on growth of Indian spinach at harvest in summer

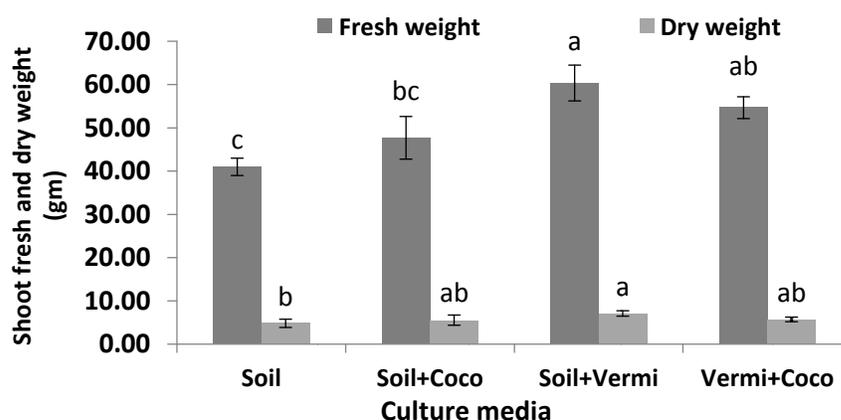


Figure 7. Effects of culture media on shoot fresh and dry weight of Indian spinach at harvest in summer season

Table 23. Macro nutrient content (gm/100gm dry weight) of Indian spinach in summer season

Culture media	Ca	Mg	K	P	S
Soil	2.21±0.09a	1.24±0.10a	2.71±0.07c	0.323±0.046b	0.556±0.047a
Soil + Coco	2.30±0.11a	1.28±0.05a	2.77±0.12bc	0.700±0.087a	0.590±0.087a
Soil + Vermi	2.44±0.27a	1.33±0.10a	3.01±0.23a	0.729±0.113a	0.469±0.097a
Vermi + Coco	2.16±0.27a	1.17±0.11a	2.90±0.17ab	0.767±0.115a	0.586±0.078a

Table 24. Micro nutrient content (gm/100gm dry weight) and Vitamin C (mg/100 g FW of leaves) of Indian spinach in summer season

Culture media	Fe	Mn	Zn	B	Na	Vit.C
Soil	0.0352±0.0034a	0.0100±0.0010a	0.0089±0.0010a	0.0022±0.0005a	0.207±0.015a	59.13a
Soil + Coco	0.0365±0.0014a	0.0106±0.0007a	0.0088±0.0013a	0.0021±0.0005a	0.196±0.036a	84.27a
Soil + Vermi	0.0383±0.0008a	0.0110±0.0003a	0.0097±0.0004a	0.0022±0.0002a	0.212±0.005a	67.36a
Vermi + Coco	0.0376±0.0025a	0.0107±0.0007a	0.0091±0.0015a	0.0024±0.0002a	0.165±0.015b	75.61a

Indian Mint (*Mentha Aquatica*)

It was evidenced that shoot length, no. of branch per plant and no. of leaves of mint increased when mint cutting were grown in soil + vermicompost and vermicompost + Coconut coir culture media (Table 25) . Fresh weight and dry weight of leaves also showed the same pattern (Figure 8).

Table 25. Effects of culture media on shoot length, no. of leaf plant⁻¹ and leaf area of Indian spinach in summer season

Culture media	Shoot length (cm)	No. of branch plant ⁻¹	No. of leaf plant ⁻¹
Soil	18.00±1.59b	3.50±0.17b	40.22±1.35b
Soil + Coco	19.00±2.24b	3.78±0.51b	43.56±4.55b
Soil + Vermi ^Y	27.39±3.73a	7.80±0.31a	79.33±2.65a
Vermi + Coco	24.22±2.83a	8.17±0.76a	83.00±13.87a
CV	9.47	9.72	18.76
LS	**	**	**

CV=coefficient of variance, LS=level of significance; **Significant at 5% level; ^Y=Soil + Vermicompost (Soil + vermi), Soil + Coconut coir (Soil + coco), Vermicompost + Coconut coir (Vermi + coco)



Picture 13. Effects of culture media on growth of Indian Mint at harvest in summer

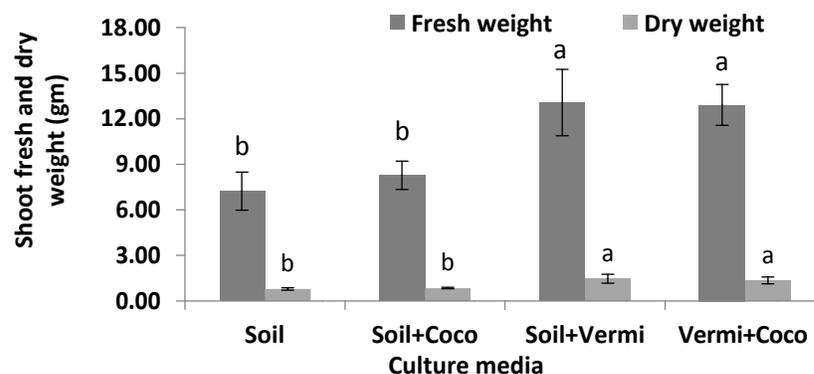


Figure 8. Effects of culture media on shoot fresh and dry weight of Mint at harvest in summer season

Table 26. Macro nutrient content (gm/100gm dry weight) of Mint in summer season

Culture media	Ca	Mg	K	P	S
Soil	1.82±0.23a	1.03±0.12a	1.80±0.25a	0.309±0.009a	0.549±0.062a
Soil + Coco	1.71±0.14a	0.96±0.08a	2.40±0.36a	0.315±0.027a	0.588±0.054a
Soil + Vermi	1.91±0.13a	1.07±0.08a	1.95±0.16a	0.333±0.020a	0.581±0.006a
Vermi + Coco	1.85±0.16a	0.96±0.12a	2.10±1.12a	0.339±0.036a	0.560±0.052a

Table 27. Micro nutrient content (gm/100gm dry weight) and Vitamin C (mg/100 g FW of leaves) of Mint in summer season

Culture media	Fe	Mn	Zn	B	Na	Vit.C
Soil	0.1065±0.0121a	0.0314±0.0019a	0.0054±0.0002a	0.0016±0.0002a	0.152±0.016a	46.94a
Soil + Coco	0.1193±0.0071a	0.0341±0.0034a	0.0055±0.0001a	0.0020±0.0003a	0.190±0.026a	57.84a
Soil + Vermi	0.1261±0.0120a	0.0361±0.0034a	0.0058±0.0003a	0.0023±0.0002a	0.186±0.023a	56.47a
Vermi + Coco	0.1202±0.0029a	0.0343±0.0037a	0.0055±0.0001a	0.0021±0.0003a	0.183±0.016a	44.00a

When, Indian mint grown in four culture media macro and micro nutrients and vitamin C did not differ significantly (**Table 26, 27**).



Picture 14. Effects of culture media on growth of Indian Mint at harvest in summer

Thankuni /Asiatic pennywort (*Centella asiatica*)

Thankuni plants were also grown in different culture media to evaluate best growth performance. It was found that no. of leaf per plant and leaf area of thankuni plants were better performed in soil + vermicompost and vermicompost + coconutcoir. However, shoot length only increased in soil + vermicompost (**Table 28**). Higher fresh weight and dry weight of thankuni were measured in soil + vermicompost (**Figure 9**).

Table 28. Effects of culture media on shoot length, no. of leaf plant⁻¹ and leaf area of Thankuni (Asiatic pennywort) at harvest in summer season

Culture media	Shoot length (cm)	No. of leaf plant ⁻¹	Leaf area (cm ²)
Soil	3.87±0.15c	8.72±0.63c	2.23±0.26b
Soil + Coco	4.58±0.52bc	10.00±1.74bc	2.67±0.30ab
Soil + Vermi	6.64±0.86a	13.22±1.64a	3.14±0.23a
Vermi + Coco	5.13±1.23b	11.89±1.90ab	2.88±0.29a
CV	12.55	11.72	10.61
LS	**	**	**

CV=coefficient of variance, LS=level of significance; **Significant at 5% level; ^y=Soil + Vermicompost (Soil + vermi), Soil + Coconut coir (Soil + coco), Vermicompost + Coconut coir (Vermi + coco)

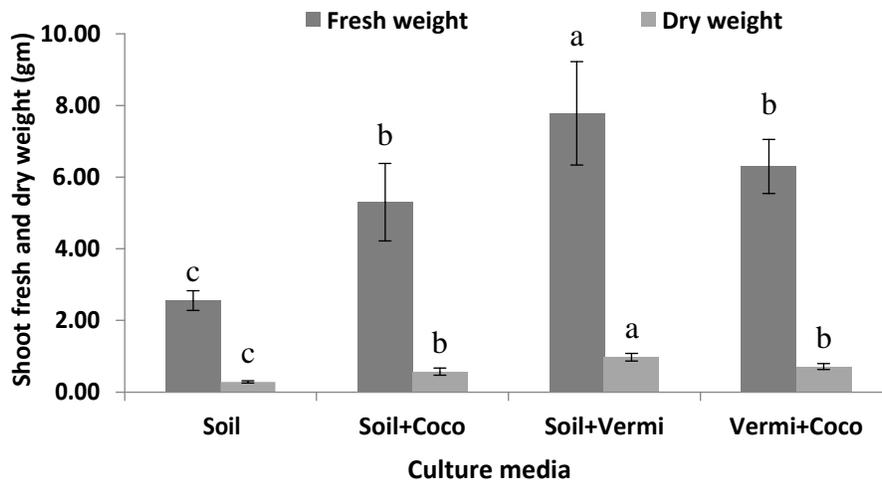


Figure 9. Effects of culture media on shoot fresh and dry weight of Thankuni (Asiatic pennywort) at harvest in summer season



Picture 15. Effects of culture media on growth of Indian Mint at harvest in summer

Table 29. Macro nutrient content (gm/100gm dry weight) of Thankuni in summer season

Culture media	Ca	Mg	K	P	S
Soil	2.32±0.28a	1.56±0.14a	3.58±0.14ab	0.413±0.037ab	0.583±0.027a
Soil + Coco	2.41±0.20a	1.36±0.11a	3.33±0.33bc	0.388±0.028b	0.656±0.049a
Soil + Vermi	2.52±0.13a	1.45±0.07a	3.72±0.13a	0.460±0.009a	0.589±0.007a
Vermi + Coco	2.39±0.25a	1.35±0.14a	3.05±0.35c	0.405±0.035b	0.658±0.100a

Table 30. Micro nutrient content (gm/100gm dry weight) and Vitamin C (mg/100 g FW of leaves) of Thankuni in summer season

Culture media	Fe	Mn	Zn	B	Na	Vit.C
Soil	0.1418±0.0075a	0.0400±0.0030a	0.0324±0.0016a	0.0030±0.0004a	0.226±0.008a	83.06a
Soil + Coco	0.1306±0.0093a	0.0400±0.0054a	0.0308±0.0008a	0.0020±0.0004a	0.227±0.001a	70.24a
Soil + Vermi	0.1513±0.0088a	0.0415±0.0029a	0.0305±0.0025a	0.0024±0.0003a	0.220±0.009a	70.98a
Vermi + Coco	0.1478±0.0133a	0.0380±0.0022a	0.0315±0.0009a	0.0022±0.0003a	0.224±0.006a	65.08b

In case of Thankuni, K and P contents were significantly increased in soil + vermicompost (Table 29). However, Thankuni grown in different culture media did not influence micronutrient content. Vitamin-C content of Thankuni did not differ among the three culture media viz. soil+ coconut coir, soil + vermicompost whereas it was reduce in vermicompost + coconut coir culture media (Table 30).

Water spinach (*Ipomoea aquatica*)

In summer we also cultivated water spinach by using four culture media in vertical frame of roof top agriculture. Compare to general soil water spinach grown better in soil + vermicompost and soil + coconut coir by increasing its leaf number and leaf area (**Table 31**). Higher shoot fresh weight and dry weight was recorded in soil + vermicompost culture media (**Figure 10**).



Picture 16. Effects of culture media on growth of Indian water spinach at harvest in summer

Table 31. Effects of culture media on growth parameter of Thankuni (Asiatic pennywort) harvest in summer season

Culture media	Shoot length (cm)	No. of leaf plant ⁻¹	Leaf area (cm ²)
Soil	23.60±2.65c	8.93±0.46b	3.96±0.82c
Soil + Coco	24.03±1.34bc	7.64±0.67c	5.55±0.93bc
Soil + Vermi ^Y	30.47±1.73a	11.60±0.40a	10.27±1.91a
Vermi + Coco	25.91±1.30bc	9.89±0.74b	7.23±0.82b
CV	4.04	6.12	14.64
LS	**	**	**

CV=coefficient of variance, LS=level of significance; **Significant at 5% level; ^Y=Soil + Vermicompost (Soil + vermi), Soil + Coconut coir (Soil + coco), Vermicompost + Coconut coir (Vermi + coco)

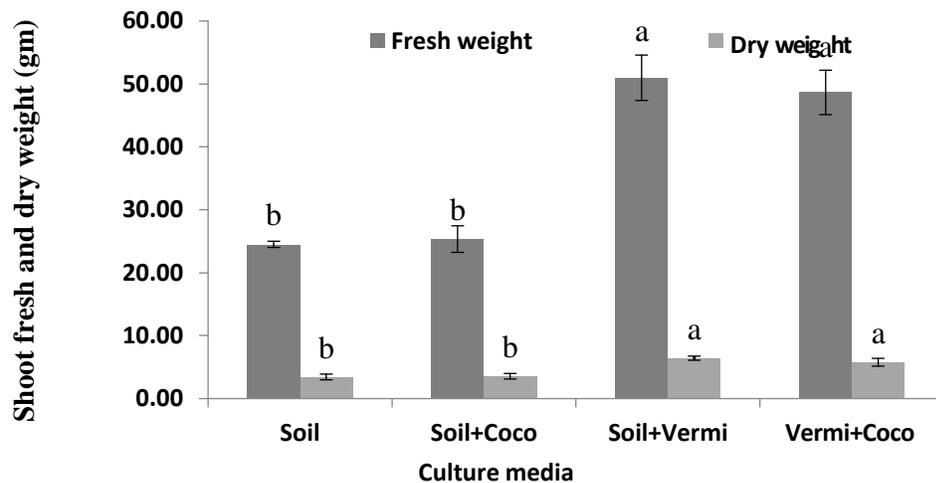


Figure 10. Effects of culture media on shoot fresh and dry weight of Water spinach at harvest

Table 32. Macro nutrient content (gm/100gm dry weight) of Thankuni in summer season

Culture media	Ca	Mg	K	P	S
Soil	1.84±0.06b	1.23±0.18b	2.39±0.21b	0.362±0.059b	0.572±0.018a
Soil + Coco	1.93±0.12b	1.65±0.06a	3.24±0.18a	0.377±0.033ab	0.582±0.043a
Soil + Vermi	2.11±0.20a	1.32±0.12ab	3.36±0.53a	0.435±0.025a	0.565±0.016a
Vermi + Coco	1.96±0.18b	1.52±0.49ab	2.81±0.24ab	0.399±0.031ab	0.600±0.079a

Table 33. Micro nutrient content (gm/100gm dry weight) and Vitamin C (mg/100 g FW of leaves) of Thankuni in summer season

Culture media	Fe	Mn	Zn	B	Na	Vit.C
Soil	0.0656±0.0052a	0.0188±0.0021a	0.0078±0.0005a	0.0029±0.0003a	0.222±0.001a	61.07a
Soil + Coco	0.0687±0.0062a	0.0196±0.0018a	0.0078±0.0005a	0.0028±0.0005a	0.224±0.005a	75.31a
Soil + Vermi	0.0714±0.0029a	0.0207±0.0014a	0.0081±0.0004a	0.0029±0.0001a	0.228±0.002a	83.16a
Vermi + Coco	0.0638±0.0089a	0.0179±0.0020a	0.0093±0.0006a	0.0032±0.0003a	0.255±0.054a	75.80a

Water spinach was grown in four different culture media and Ca, Mg, K, P contents were increased when it was grown in soil + vermicompost culture media. Mg and K contents were also increased in soil + coconut coir culture media (Table 32). Significant variation was not found in micro nutrient content level (Table 33).

Table 34. pH and Total-N in the soil after harvest of Indian mint, Water spinach, Thankuni, Indian spinach in summer season

Vegetables	Culture media	pH	% Total-N
Mint	Soil	6.10	0.13
	Soil + Coco	6.00	0.31
	Soil + Vermi	6.00	0.25
	Vermi + Coco	5.30	0.56
Water spinach	Soil	6.20	0.17
	Soil + Coco	6.20	0.27
	Soil + Vermi	5.90	0.32
	Vermi + Coco	5.20	0.01
Thankuni (Asiatic pennywort)	Soil	5.10	0.26
	Soil + Coco	6.30	0.53
	Soil + Vermi	5.80	0.34
	Vermi + Coco	5.30	0.65
Indian spinach	Soil	6.30	0.14
	Soil + Coco	6.20	0.28
	Soil + Vermi	6.30	0.26
	Vermi + Coco	5.20	0.15

Table 35. Macro nutrient contents in the soil after harvest of Indian mint, Water spinach, Thankuni, Indian spinach in summer season

Vegetables	Culture media	gm/kg			mg/kg		
		Ca	Mg	K	P	Cu	S
Mint	Soil	3.807	0.442	0.043	7.43	0.60	26
	Soil + Coco	2.781	0.486	0.074	16.34	1.20	37
	Soil + Vermi	4.272	0.603	0.070	47.68	1.79	118
	Vermi + Coco	5.643	0.734	0.047	90.81	1.82	225
Water spinach	Soil	2.321	0.343	0.027	11.32	0.62	26
	Soil + Coco	3.038	0.620	0.074	37.78	0.95	36
	Soil + Vermi	3.002	0.523	0.074	38.58	1.05	33
	Vermi + Coco	8.657	0.795	0.149	81.46	3.09	213
Thankuni (Asiatic pennywort)	Soil	1.146	0.112	0.020	30.21	1.28	26
	Soil + Coco	3.030	0.612	0.094	30.50	0.68	35
	Soil + Vermi	3.451	0.544	0.098	47.04	1.06	32
	Vermi + Coco	7.442	0.780	0.160	73.14	2.99	169
Indian spinach	Soil	2.473	0.377	0.023	9.91	0.90	20
	Soil + Coco	2.517	0.474	0.090	22.66	0.90	29
	Soil + Vermi	3.347	0.542	0.059	46.39	1.20	26
	Vermi + Coco	8.172	0.778	0.106	71.91	-	193

Table 36. Micro nutrient contents in the soil after harvest of Indian mint, Water spinach, Thankuni, Indian spinach in summer season

Vegetables	Treatment	mg/kg		
		Fe	Mn	Zn
Mint	Soil	21.40	10.80	3.63
	Soil + Coco	71.50	3.60	7.89
	Soil + Vermi	139.60	7.20	8.61
	Vermi + Coco	194.60	38.60	17.43
Water spinach	Soil	39.20	12.15	2.35
	Soil + Coco	65.50	6.09	7.80
	Soil + Vermi	117.50	14.43	7.89
	Vermi + Coco	260.20	52.00	18.00
Thankuni (Asiatic pennywort)	Soil	76.40	6.69	6.57
	Soil + Coco	43.20	6.55	7.50
	Soil + Vermi	91.40	18.00	6.50
	Vermi + Coco	271.60	38.20	18.03
Indian spinach	Soil	22.60	12.55	1.59
	Soil + Coco	43.20	16.10	10.17
	Soil + Vermi	10.95	21.06	10.59
	Vermi + Coco	-	-	-

References:

- FAO, 2012. Hunger Statistics. FAO Hunger Portal. Food and Agricultural Organisation of the United Nations. [Online] Available: <http://www.fao.org/hunger/en/>.
- FAO, 2011. Plant breeding and seed systems for rice, vegetables, maize and pulses in Bangladesh. FAO Plant Production and Protection Paper 207. Food and Agriculture Organization of the United Nations, Rome.
- FAOSTAT, 2012. Database on Agriculture. [Online] Available: <http://faostat3.fao.org/home/index.html>.
- Palma, P. 2016. First national vegetables fair begins (The Daily Star: 18.01.16). <http://www.thedailystar.net/backpage/first-national-vegetables-fair-begins-203512>.)
- Schreinemachers P., Wu M., Uddin M. N., Ahmad S., Hanson P. 2016. Farmers training in off-season vegetables: Effects on income and pesticide use in Bangladesh. Food Policy, (61), 132-140.
- The world Factbook, 2015. Central Intelligence Agency. <https://www.cia.gov/library/publications/the-world-factbook/fields/2212.html>)
- UN, 2013. World Population Prospects: The 2012 Revision. [Online] Available: <http://esa.un.org/unpd/wpp/index.htm>
- AOAC International (2016) Official methods of analysis, 20th edn. (On-line). AOAC International, Rockville, MD Pegg RB, Eitenmiller RR (2017) Vitamin analysis. Ch. 20. In: Nielsen SS (ed) Food analysis, 5th edn. Springer, New York

12. Research highlight/findings:

- Out of five vegetables, lettuce, red amaranth, pak-choi and spinach showed better growth in soil + vermicompost and french bean growth significantly increase in soil + coconut coir culture media during winter season
- Among the five vegetables, red amaranth was found as Ca, Mg and P rich vegetable, pak-choi as K and S rich vegetable, lettuce as Fe, Mn and Zn rich vegetable, spinach as Na and B rich vegetable
- In summer cultivation, out of five vegetables red amaranth could not continue its growth due to heavy rain.
- Indian mint and Indian spinach growth was significantly increased in both soil + vermicompost and vermicompost + coconut coir culture media
- However, water spinach, thankuni (asiatic pennywort) growth was significantly increased only in soil + vermicompost culture media
- Among the four vegetables in summer cultivation, water spinach was found as Mg rich vegetable, Indian spinach as P rich and Thankuni (Asiatic pennywort) as Ca, K and S rich vegetable
- Out of four culture media, organic media specially soil + vermicompost and vermicompost+ coconut coir showed better performance in terms of growth and nutrient contents of the vegetable

B. Implementation Position

1. Procurement:

Description of equipment and capital items	PP Target		Achievement		Remarks
	Phy (#)	Fin (Tk)	Phy (#)	Fin (Tk)	
(a) Office equipment	100%	1,54,300	100%	1,54,300	
(b) Lab &field equipment	100%	7,36,000	96.8%	7,12,817	Unavailable fund
(c) Other capital items	100%	5,33,700	93.4%	4,98,615	Unavailable fund

2. Establishment/renovation facilities:

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	
			-	-	

3. Training/study tour/ seminar/workshop/conference organized:

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training (s)	5	15	20	02.06.2018 (One day)	Successfully completed
	19	6	25	17.07.2018 (One day)	Successfully completed
	12	13	25	12.09.2018 (One day)	Successfully completed
	22	03	25	13.09.2018 (One day)	Successfully completed
	24	01	25	14.09.2018 (One day)	Successfully completed
(b) Workshop	28	07	35	30.09.2018 (One day)	Successfully completed



Picture. 17. Participants and trainers of the training program under the sub project ID 521



Picture. 18. Participants and trainers of the training program under the sub project ID 521



Picture 19. DR. Md. Mostafizur Rahaman, Research Assistant, BSMMU, deliberating his speech in front of the participant of the annual workshop of ID 521



Picture. 20. Dr. Md. Fuad Mondal, PI of sub project ID 521, deliberating his speech in front of the participant of the annual workshop of ID 521

C. Financial and physical progress**Fig in Tk**

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	293055	293055	293055	0	100	
B. Field research/lab expenses and supplies	736000	712817	712389	23611	96.8	Unavailable fund
C. Operating expenses	235315	231901	231901	3414	98.5	Unavailable fund
D. Vehicle hire and fuel, oil & maintenance	85000	82100	82100	2900	96.6	Unavailable fund
E. Training/workshop/seminar etc.	300000	293475	293475	6525	97.8	Unavailable fund
F. Publications and printing	88000	21415	21425	66575	24.3	Unavailable fund
G. Miscellaneous	78000	76890	76890	1110	98.6	Unavailable fund
H. Capital expenses	682945	647860	647860	35085	94.9	Unavailable fund

D. Achievement of Sub-project by objectives:

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output(i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)
Increase the availability of organic vegetables all the year round	10 (five winter and five summer) vegetables were cultivated on four culture substrate	Four vegetables were grown better out of five in each season (winter & summer)	Fulfill the year round vegetable demand in the urban community
To ensure the nutritional security by consuming the fresh organic vegetables	Vegetables were grown in rooftop of Sylhet Agricultural University and those were analyzed to confirm the nutritional quality and quantity	We found red amaranth as Ca, Mg and P rich, pak-choi as K and S rich, lettuce as Fe, Mn and Zn rich, spinach as Na and B rich, water spinach as Mg rich, Indian spinach as P rich and thankuni (asiatic pennywort) as Ca, K and S rich vegetables	Urban people can consume vegetable on the basis of nutritional value of them
Using the vertical space for vegetable production in urban areas	We constructed vertical frames with multi-layer system (3 layer in each)	Evenly growth of vegetable were found in multi-layer system	Roof top garden can be used more efficiently under multi-layer farming system
Find out the suitable vegetables and soil media for the vertical agriculture	Ten vegetables viz. lettuce, red amaranth, pak-choi, spinach and French bean in winter; red amaranth, indian mint, indian spinach, water spinach and thankuni(asiatic pennywort) were grown with four types of media viz. soil, soil + vermicompost, soil + coconut coir, vermicompost + coconut coir with three replication for vegetable production in both summer and winter seasons	Out of ten vegetables, lettuce, red amaranth, pak-choi, spinach, water spinach, thankuni were found better in soil + vermicompost; french bean performed well in soil + coconut coir; Indian mint and Indian spinach growth was significantly increased in both soil + vermicompost and vermicompost + coconut coir culture media	Urban people can grow the suitable vegetables using the best culture media
To increase the land use efficiency	Vegetables were grown multi-layer vertical frames on the rooftop of the faculty of Agriculture at Sylhet Agricultural university, Sylhet	Vegetables production was increase three times in the same unit area at a time using three layer vertical frames	Urban people can increase vegetable production of their roof top more efficiently
To improve the organic farming industry	We have tried to find out the suitable culture media containing organic substrate by growing vegetables and their consequence analysis	Out of four culture media, organic media based media specially soil + vermicompost and vermicompost+ coconut coir showed better performance in terms of growth and nutrient contents of the vegetable	Entrepreneurship of organic substrate will be developed

E. Materials Development/Publication made under the Sub-project:

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.	-	-	-
Journal publication	03		
Information development			
Other publications (Conference proceeding)	03	03	<p>M F Mondal, M S ISLAM (2018). “Vertical farming: The future solutions for organic vegetables production in urban area” published in the Proc. Sylhet Agricultural University Research Progress. Vol. 5, p. 16.</p> <p>Md. Fuad Mondal, Taslima Akter, Md. Shahidul Islam (2018). “Vertical farming: The future solutions for organic vegetables production in urban area” published in the Proc Organic farming symposium 2018. p.56 Organized by Bangladesh organic Agriculture Network (BOAN).</p> <p>Md. Fuad Mondal, A. R. M. Maukeeb, M. N. Hoque, M. A. S. Abir, and M. M. Hasan (2019). “Health beneficial herb mint and thankuni production in organic culture media using vertical farmed published in the Proc. of 1st international conference on Environmental Science and Resource Management: Safe environment for better living (ICESRM) p. 39-40</p>
Other publications (Training news in local and national newspapers)	10	10	<p>News in Bengali, 15 September 2018 (Daily Prothom Alo, Shamokal, Daily Uttor Purbo, Daily Jugoverly, Daily Sylheter Dak, Daily Sylheter Bani, Sylhet mirror, Daily Jalalabad) 18 July 2018 (Daily Uttor Purbo)</p>

F. Technology/Knowledge generation/Policy Support (as applied):

- i. Generation of technology : Non commodity**
- ii. Generation of new knowledge that help in developing more technology in future**
 - Vertical space in multilayer vertical frame on rooftop can be used for the production of year round safe, nutritious and short duration vegetables in urban areas
 - Growth and nutrient contents of Lettuce (*Lactuca sativa*), Pak choi (*Brassica rapa*), Red amaranth, (*Amaranthus gangeticus*), French bean (*Phaseolus vulgaris*), Spinach (*Spinacia oleracea*), Indian spinach (*Basella alba*), Mint (*Mentha Aquatica*), Thankuni (*Centella asiatica*), Water spinach (*Ipomoea aquatica*) can significantly improve by using vermicompost as an organic substances
 - Coconut coir can also be used for the growth and nutrients improvement in French bean (*Phaseolus vulgaris*)
- iii. Technology transferred that help increased agricultural productivity and farmers' income**
 - Multilayer vertical farming system can be used in the urban areas for the year round vegetable production
 - Famers or entrepreneurs can develop small or large vermicompost production center or industry
 - Plant nutrition content can be changed by using suitable culture media
- iv. Policy Support**
 - This study will help to involve urban people for the production of nutritious safe organic vegetables by themselves
 - Small scale entrepreneurs in rural and urban areas will be developed for the production of vermicompost
 - As vermicompost produce from organic waste therefore, employment opportunity will be created for the waste management system
 - As the vegetables were grown better in multilayer vertical frame in the rooftop therefore, the rooftop of the city areas can be used more efficiently by using the multilayer vertical frames

G. Information regarding Desk and Field Monitoring

- i) **Desk /Monitoring:** Desk Monitoring was done in April 7, 2018 at faculty of Fisheries, Sylhet Agricultural University, Sylhet



Picture 21. Desk monitoring of sub projects by the monitoring team at Sylhet Agricultural University

- ii) **Field Monitoring (time & No. of visit, Team visit and output):**

Sl no.	Field monitoring team	Out put
01	Executive Chairman, BARC	Constructive
02	Director (Nutrition), BARC	Constructive
03	Monitoring team of BARC	Constructive
04	SAURES Director	Constructive
05	Faculty members	Constructive
06	Faculty students	Constructive



Picture 22: Field visit of sub project ID 521 by the executive Chairman of BARC



Picture23 : Field visit of sub project ID 521 by the director (Nutrition), BARC



Picture 24: Field visit of sub project ID 521 by the director PIU, NATP Phase-2 with monitoring team of BARC and Director, Sylhet Agricultural University Research System (SAURES)



Picture 25: Field visit of sub project ID 521 by the Faculty members of Faculty of Agriculture, and students from different faculty of Sylhet Agricultural University

H. Lesson Learned/Challenges (if any)

- i) Huge water requirement from February to April (winter cultivation)
- ii) Drainage and leaching loss of nutrient in summer vegetable cultivation

I. Challenges (if any)

- I. Drainage system and consequent leaching loss during the rainy season
- II. Irrigation system during the hot sunny days
- III. Bird infestation in winter red amaranth cultivation



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Signature of the Principal Investigator
Date

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organization/authorized representative
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