

# **Organic Amendments Influence the Yield of Vegetables and Soil Properties at Charlands in Bangladesh**

## **ABSTRACT**

The experiment was conducted at the farmer's fields of three Charlands in Bangladesh during November 2021 to March 2022 having the objectives of assessing the effects of organic amendments on yield of different crops and soil properties at Charlands in Bangladesh. The experiments were established in a randomized complete block design using six treatments and three replications. Treatments of the experiments were  $T_1$  = FP (Farmers' Practice) (Control),  $T_2$  = RF (Recommended Fertilizer) + Vermicompost (3t/ha),  $T_3$  = RF (Recommended Fertilizer) + Quick Compost (3t/ha),  $T_4$  = RF (Recommended Fertilizer) + Standard Organic Fertilizers (3t/ha),  $T_5$  = RF (Recommended Fertilizer) + Poultry Manure (3t/ha) and  $T_6$  = RF (Recommended Fertilizer) + Biochar (3t/ha). Results of the experiment reveal that application of organic manures along with inorganic fertilizers produced significant ( $p < 0.05$ ) variation in production of pumpkin and sweet potato and post-harvest soil nutrient status compared to Farmer's practice treatment. In pumpkin experiments, among the Charlands, the maximum yield per plant 85.61kg was recorded in  $T_6$  treatment from Naobhangar Char and the minimum 27.24kg in  $T_1$  treatment from Majibari Char. The highest BCR 3.40 was recorded in  $T_6$  treatment from Naobhangar Char and the lowest BCR 1.06 in  $T_1$  treatment from Majibari Char. In sweet potato experiment, among the Charlands, the maximum fresh yield of tuber 94.00t/ha was recorded in  $T_6$  treatment and the minimum 39.29t/ha in  $T_1$  treatment from Majibari Char. The highest BCR 3.54 was recorded in  $T_6$  treatment from Char Shaluka and the lowest BCR 1.20 in  $T_1$  treatment from Majibari Char. Among the Charlands, the highest soil pH (7.36) was found in  $T_6$  treatment from Char Shaluka (0-15cm soil depth) and the lowest soil pH (6.74) in  $T_1$  treatment from Naobhangar Char (15-30cm soil depth). The highest soil OC (1.82 %) was recorded in  $T_6$  treatment from both Char Shaluka and Majibari Char (0-15cm soil depth) and the lowest soil OC (0.69%) in  $T_1$  treatment from Char Shaluka (15-30cm soil depth). The highest soil total N (0.145%) was found in  $T_6$  treatment from Char Shaluka (0-15cm soil depth) and the lowest soil total N (0.074%) in  $T_1$  treatment from both Naobhangar Char and Majibari Char (15-30cm soil depth). However, among the Charlands, the highest soil available P (17.66mg/kg) was obtained in  $T_6$  treatment from Char Shaluka (0-15cm soil depth) and the lowest soil available P (7.49mg/kg) in  $T_1$  treatment from Majibari Char (15-30cm soil depth). The highest soil available S (17.81mg/kg) was found in  $T_6$  treatment from Naobhangar Char (0-15cm soil depth) and the lowest soil available S (9.55mg/kg) in  $T_1$  treatment from Majibari Char (15-30cm soil depth). The maximum soil Zn (1.134mg/kg) was found in  $T_6$  treatment from both Naobhangar Char and Majibari Char (0-15cm soil depth) and the minimum soil Zn (0.536mg/kg) in  $T_1$  treatment from Naobhangar Char (15-30cm soil depth). With the application of organic manures in the crop land field, the yield of different crop was increased as well as the soil fertility status was also improved.

**Keywords:** Charlands; organic amendments; soil nutrient status and crop yields.

## **1. INTRODUCTION**

Charlands are newly established land in river beds which status is poor in fertility [1, 2]. Charlands, the riverine sand and silt landmasses, perform as a result of the dynamics

of erosion and deposition in the rivers. With an estimated to be 0.72 m ha in Bangladesh, which is about 5% of the country area and about 6.5 m people (5% of the country's population) live in the charlands [3]. The chars are one of the most susceptible agroecosystems in Bangladesh and

home to the poorest and marginal people [4]. The char dwellers mainly depend on agriculture and agriculture-related activities, as opportunities for off-farm activities are very minimum there [5]. The char economy is predominantly agricultural, relying on the floods to sustain fertility [6]. Most of the plant nutrients viz. N, P, K, Zn, S and B were found below the critical level for crop production, though variations of the nutrient status within a field of each char were conspicuous [6]. An estimated 5 to 10 million char dwellers, who live mostly on agriculture, are some of the poorest and most vulnerable people particularly those who live on the island/attached river chars in Bangladesh [7, 8].

Farmers use organic materials such as poultry manure, compost, cowdung, rice straw and others for their beneficial effects on soil health by improving soil physicochemical properties and by increasing macro and micro nutrient availability [9, 10, 11]. Moreover, the integrated nutrient management i.e., minimum usages of chemical fertilizers with organic materials such as value-added bio-organic fertilizer, animal manures, crop residues, green manuring and composts are alternatives to avoid excessive usages of nitrogenous and phosphorus contained fertilizers that have enough chance to pollute our soil and environment [12, 13, 14]. Thus, use of organic materials might be effective to enhance the soil fertility of the charlands. Vermicompost (VC) amendment acts as a slow-release fertilizer and can directly increase crop production through increased availability of plant nutrients. It indirectly promotes soil quality by improving soil structure and stimulating microbial activity relative to conventional chemical fertilization [15, 16, 17]. Biochar application

The experiment was conducted at the farmer's field in Char Shaluka of Sariakandi upazila under Bogura district, Naobhangar Char of Jamalpur Sadar upazila in Jamalpur district and Majibari Char of Kazipur upazila in Sirajgonj district during November 2021 to March 2022 to investigate the effects of different organic fertilizers along with inorganic fertilizers application on yield of different crops (pumpkin and sweet potato) and soil properties. Geographically Char Shaluka is located in between 24° 44' to 25° 04' north latitude and 69° 45' to 89° 31' east longitude, Naobhangar Char in between 24°42' and 24°58' north latitudes and in between 89°52' and 90°12' east longitudes, Majibari Char in between 24°32' and 24°46' north latitudes and in between 89°32' and 89°48' east longitudes. The post-harvest soil samples were collected from a depth of surface (0-15 cm)

decreased soil bulk density, whereas increased porosity, available soil water content, organic carbon (OC), soil pH, available P, cation exchange capacity (CEC), exchangeable K, and Ca [18]. The incorporation of biochar derived from rice husk into soils could significantly improve soil physicochemical properties [19], such as soil moisture content, water holding capacity, BD, available-N nutrients, etc., in paddy fields, [20] and thereby increase crop yield [21, 22]. Biochar, a carbon-rich compound, resulting from the pyrolysis process of different biomasses acts as an alternative or complementary organic amendment [23, 24]. Positive effects of biochar application on soil physical, chemical and biological properties and on crop yield were reported in the study [25, 26, 27, 28]. Biochar and 50% of recommended dose of NPK was most effective for improving soil physico-chemical properties viz., BD, particle density, porosity, pH, EC, organic matter, SOC, total N, available P, K, soil microbial biomass C, and soil microbial biomass N at 0–30 cm depth [30]. The efficiency of nutrients can be increased through the integrated use of organic manures and chemical fertilizers [1, 31]. Due to the poor soil fertility status of the charlands of Bangladesh, it is crucial to apply available organic materials in combination with synthetic chemical fertilizers for better agricultural production and soil fertility improvement. Therefore, the objective of this study was to determine the effects of organic fertilizers on soil properties and yield of different crops at Charlands in Bangladesh.

## 2. MATERIALS AND METHODS

and sub-surface (15-30 cm) from the selected experimental plot to assess the nutrient status of the Charlands soil for pH, organic carbon (%), total N (%), available P (mg/kg), available S (mg/kg), Zn (mg/kg), exchangeable K (cmol (+)/kg), exchangeable Ca (cmol (+)/kg), exchangeable Mg (cmol (+)/kg) and CEC (cmol (+)/kg) by following the standard methods. The soil samples were analyzed in the laboratory of the Department of Soil Science of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU).

Soil pH was measured potentiometrically using a digital pH meter in the supernatant suspension of soil to water ratio of 1:2.5 [32]. Organic carbon was determined following the wet oxidation method [32]. The percentage total nitrogen was obtained by using the micro Kjeldahl technique [33]. Available P was

calculated following Olsen method [34]. Available S was measured by turbidity method using  $\text{BaCl}_2$  [35]. Available Zn was determined by DTPA method [36]. Exchangeable K, Ca, Mg and CEC were determined by 1N  $\text{NH}_4\text{OAc}$  method [37]. The experiments were established in a randomized complete block design by using six treatments and three replications. Treatments of the experiments were  $T_1$  = FP (Farmers' Practice) (Control),  $T_2$  = RF (Recommended Fertilizer) + Vermicompost (3t/ha),  $T_3$  = RF (Recommended Fertilizer) + Quick Compost (3t/ha),  $T_4$  = RF (Recommended Fertilizer) + Standard Organic Fertilizers (3t/ha),  $T_5$  = RF (Recommended Fertilizer) + Poultry Manure (3t/ha) and  $T_6$  = RF (Recommended Fertilizer) + Biochar (3t/ha). In all the plots,

chemical fertilizer was applied in line with the fertilizer recommendation guide of the Bangladesh Agricultural Research Council [38]. For pumpkin the required amount of urea, TSP, MoP, gypsum, zinc sulphate and boric acid were as follows: Recommended Fertilizer (RF): N-P-K-S-Zn-B @ 100-48-80-28-3-2.1 kg/ha. For sweet potato the required amount of urea, TSP, MoP, gypsum and zinc sulphate were as follows: Recommended Fertilizer (RF): N-P-K-S-Mg-Zn-B @ 140-60-140-20-12-3.0-1.5 kg/ha. Experimental crops yield data were collected and analyzed statistically with the help of computer package STATISTIX 10. The mean differences of the treatments were obtained from least significant difference (LSD) test at 5% level of probability for the interpretation of results [39].

### 3. RESULTS AND DISCUSSION

#### 3.1 Results of the field trial pumpkin at the Charlands

The field trials were conducted at the three selected sites (Char Shaluka, Naobhangar Char and Majbari Char). The test crops under the trial were pumpkin and sweet potato. The yield data of the crops have been described under the following sub headings.

##### 3.1.1 Average fruit weight (kg) of pumpkin at the Charlands

The pumpkin experiments presented a significant variation with regard to average fruit weight at all the Charlands (Table 1). In Char Shaluka, the average fruit weight ranged from 3.72 to 6.15kg and the highest average fruit weight 6.15kg was recorded in  $T_6$  (RF+ Biochar) treatment which was closely followed by  $T_5$  treatment but the lowest average fruit weight 3.72kg was obtained from  $T_1$  (Farmers' practice) treatment. In Naobhangar Char, the average fruit weight ranged from 3.80 to 6.25kg and the maximum average fruit weight 6.25kg was recorded in  $T_6$  (RF+ Biochar) treatment but the minimum average fruit weight 3.80kg was obtained from  $T_1$  (Farmers' practice) treatment. In Majbari Char, the average fruit weight ranged from 3.46 to 6.28kg and the highest average fruit weight 6.28kg was recorded in  $T_6$  (RF+ Biochar) treatment which was closely followed by  $T_5$  treatment but the lowest average fruit weight 3.46kg was obtained from  $T_1$  (Farmers' practice) treatment. In a study, significant variation was present of average fruit weight that ranged from 1.51 to 4.20 kg [40]. From an experiment it was obtained the average fruit weight of pumpkin in the range of 1.33 to 9.10 kg [41]. The average fruit weight ranged from 1.41 to 5.78 kg in the study [42].

##### 3.1.2 Fresh fruit yield per plant (kg) of pumpkin at the Charlands

The pumpkin experiments exhibited a significant variation with regard to fruit yield per plant at all the Charlands (Table 2). In Char Shaluka, the fruit yield per plant ranged from 35.08 to 81.41kg and the maximum yield per plant 81.41kg was recorded in  $T_6$  (RF+ Biochar) treatment but the minimum yield per plant 35.08kg was obtained from  $T_1$  (Farmers' practice) treatment. In Naobhangar Char, the fruit yield per plant ranged from 32.33 to 85.61kg and the highest yield per plant 85.61kg was recorded in  $T_6$  (RF+ Biochar) treatment while the lowest yield per plant 32.33kg was obtained from  $T_1$  (Farmers' practice) treatment. In Majbari Char, the fruit yield per plant ranged from 27.24 to 80.45kg and the highest yield per plant 80.45kg was recorded in  $T_6$  (RF+ Biochar) treatment which was closely followed by  $T_3$  and  $T_5$  treatments but the lowest yield per plant 27.24kg was obtained from  $T_1$  (Farmers' practice) treatment. It was found significant variation in yield per plant in different Pumpkin genotypes in the range of 5.94 to 36.12 kg [40].

##### 3.1.3 Total income (tk/ha) of pumpkin at the Charlands

The pumpkin experiments showed a significant variation due to long term incorporation of different organic amendments with regard to total income at all the Charlands (Table 3). In Char Shaluka, the total income ranged from 526217.00 to 1220000.00tk/ha and the maximum total income 1220000.00tk/ha was recorded in  $T_6$  (RF+ Biochar) treatment but the minimum total income 526217.00tk/ha was obtained from  $T_1$  (Farmers' practice) treatment. In Naobhangar Char, the total income ranged from 484971.00 to 1280000.00tk/ha and the

highest total income 1280000.00tk/ha was recorded in T<sub>6</sub> (RF+ Biochar) treatment while the lowest total income 484971.00tk/ha was obtained from T<sub>1</sub>(Farmers' practice) treatment. In Maijbari Char, the total income ranged from 408599.00 to 1210000.00tk/ha and the highest total income 1210000.00tk/ha was recorded in T<sub>6</sub> (RF+ Biochar) treatment which was statistically similar with T<sub>3</sub> and T<sub>5</sub> treatments but the lowest total income 408599.00 tk/ha was obtained from T<sub>1</sub>(Farmers' practice) treatment.

### 3.1.4 Total cost (tk/ha) of pumpkin at the Charlands

The pumpkin experiments presented a variation with regard to total cost at all the Charlands (Table 4). In the Charlands, the total cost in T<sub>1</sub> (385559.00 tk/ha), T<sub>2</sub> (369233.32 tk/ha), T<sub>3</sub> (375233.32 tk/ha), T<sub>4</sub> (378233.32 tk/ha), T<sub>5</sub> (369233.32 tk/ha) and T<sub>6</sub> (378233.32 tk/ha). Moreover, the maximum total cost was recorded in T<sub>1</sub> (385559.00 tk/ha) treatment and minimum total cost was obtained from T<sub>2</sub> and T<sub>5</sub> (369233.32 tk/ha) treatments.

### 3.1.5 Benefit cost ratio (BCR) (Total cost basis) of pumpkin at the Charlands

The pumpkin experiments revealed a significant variation due to long term incorporation of different organic amendments with regard to BCR (Total cost basis) at all the Charlands (Table 5). In Char Shaluka, the BCR ranged from 1.37 to 3.23 and the maximum BCR 3.23 was recorded in T<sub>6</sub> (RF+ Biochar) treatment which is statistically similar to T<sub>5</sub> treatment but the minimum BCR 1.37 was obtained from T<sub>1</sub> (Farmers' practice) treatment. In Naobhangar Char, the BCR ranged from 1.26 to 3.40 and the highest BCR 3.40 was recorded in T<sub>6</sub> (RF+ Biochar) treatment which is statistically similar to T<sub>5</sub> treatment while the lowest BCR 1.26 was obtained from T<sub>1</sub> (Farmers' practice) treatment. In Maijbari Char, the BCR ranged from 1.06 to 3.19 and the highest BCR 3.19 was recorded in T<sub>6</sub> (RF+ Biochar) treatment which was closely followed by T<sub>5</sub> treatment but the lowest BCR 1.06 was obtained from T<sub>1</sub> (Farmers' practice) treatment.

**Table 1. Effects of different organic manures for pit experiments with average fruit weight of pumpkin at the Charlands**

| Treatments     | Average fruit weight (kg) |                 |               |
|----------------|---------------------------|-----------------|---------------|
|                | Char Shaluka              | Naobhangar Char | Maijbari Char |
| T <sub>1</sub> | 3.72d                     | 3.80e           | 3.46d         |
| T <sub>2</sub> | 5.44c                     | 5.58c           | 5.61b         |
| T <sub>3</sub> | 5.34c                     | 5.25d           | 5.29c         |
| T <sub>4</sub> | 5.85b                     | 5.99b           | 5.49bc        |
| T <sub>5</sub> | 5.96ab                    | 6.06b           | 6.10a         |
| T <sub>6</sub> | 6.15a                     | 6.25a           | 6.28a         |
| CV (%)         | 2.12                      | 1.79            | 2.38          |
| SE (±)         | 0.09                      | 0.08            | 0.10          |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

**Table 2. Effects of different organic manures for pit experiments with fresh fruit yield per plant of pumpkin at the Charlands**

| Treatments     | Fresh fruit yield per plant (kg) |                 |               |
|----------------|----------------------------------|-----------------|---------------|
|                | Char Shaluka                     | Naobhangar Char | Maijbari Char |
| T <sub>1</sub> | 35.08d                           | 32.33d          | 27.24d        |
| T <sub>2</sub> | 64.55c                           | 67.25bc         | 65.83bc       |
| T <sub>3</sub> | 65.72bc                          | 63.73c          | 69.77abc      |
| T <sub>4</sub> | 70.67bc                          | 70.34bc         | 62.67c        |
| T <sub>5</sub> | 72.84b                           | 73.91b          | 77.03ab       |
| T <sub>6</sub> | 81.41a                           | 85.61a          | 80.45a        |
| CV (%)         | 6.67                             | 8.33            | 12.34         |
| SE (±)         | 3.54                             | 4.46            | 6.43          |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF=

Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

**Table 3. Effects of different organic manures for pit experiments with total income (tk/ha) of pumpkin at the Charlands**

| Treatments     | Total income (tk/ha) |                 |               |
|----------------|----------------------|-----------------|---------------|
|                | Char Shaluka         | Naobhangar Char | Maijbari Char |
| T <sub>1</sub> | 526217.00d           | 484971.00d      | 408599.00d    |
| T <sub>2</sub> | 968229.00c           | 1010000.00bc    | 987426.00bc   |
| T <sub>3</sub> | 985732.00bc          | 955960.00c      | 1050000.00abc |
| T <sub>4</sub> | 1060000.00bc         | 1060000.00bc    | 940022.00c    |
| T <sub>5</sub> | 1090000.00b          | 1110000.00b     | 1160000.00ab  |
| T <sub>6</sub> | 1220000.00a          | 1280000.00a     | 1210000.00a   |
| CV (%)         | 6.67                 | 8.33            | 12.34         |
| SE (±)         | 53124.00             | 66854.00        | 96477.00      |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

**Table 4. Effects of different organic manures for pit experiments with Total cost (tk/ha) of pumpkin at the Charlands**

| Treatments     | Total cost (tk/ha) at the Charlands |
|----------------|-------------------------------------|
| T <sub>1</sub> | 385559.00                           |
| T <sub>2</sub> | 369233.32                           |
| T <sub>3</sub> | 375233.32                           |
| T <sub>4</sub> | 378233.32                           |
| T <sub>5</sub> | 369233.32                           |
| T <sub>6</sub> | 378233.32                           |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer.

**Table 5. Effects of different organic manures for pit experiments with BCR (total cost basis) of pumpkin at the Charlands**

| Treatments     | BCR (Total cost basis) |                 |               |
|----------------|------------------------|-----------------|---------------|
|                | Char Shaluka           | Naobhangar Char | Maijbari Char |
| T <sub>1</sub> | 1.37d                  | 1.26d           | 1.06c         |
| T <sub>2</sub> | 2.63c                  | 2.73bc          | 2.67ab        |
| T <sub>3</sub> | 2.63c                  | 2.54c           | 2.79ab        |
| T <sub>4</sub> | 2.80bc                 | 2.79bc          | 2.49b         |
| T <sub>5</sub> | 2.96ab                 | 3.00ab          | 3.13a         |
| T <sub>6</sub> | 3.23a                  | 3.40a           | 3.19a         |
| CV (%)         | 6.68                   | 8.31            | 12.34         |
| SE (±)         | 0.14                   | 0.18            | 0.26          |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

### 3.2 Results of the field trial sweet potato at the Charlands

#### 3.2.1 Number of tuberous roots per plant of sweet potato at the Charlands

The yellow sweet potato experiments showed a significant variation with regard to number of tubers roots per plant at all the Charlands (Table 6). In Char Shaluka, the number of tubers roots

per plant ranged from 32.91 to 54.68 and the maximum number of tubers roots per plant 54.68 was recorded in T<sub>6</sub> (RF+ Biochar) treatment which was closely followed by T<sub>5</sub> treatment but the lowest number of tubers roots per plant 32.91 was obtained from T<sub>1</sub>(Farmers' practice) treatment. In Naobhangar Char, the number of tubers roots per plant ranged from 33.49 to 53.25 and the maximum number of tubers roots

per plant 53.25 was recorded in T<sub>6</sub> (RF+ Biochar) treatment which was closely followed by T<sub>5</sub> treatment but the lowest number of tubers roots per plant 33.49 was gotten from T<sub>1</sub> (Farmers' practice) treatment. In Maijbari Char, the number of tubers roots per plant ranged from 32.63 to 54.05 and the maximum number of tubers roots per plant 54.05 was recorded in T<sub>6</sub> (RF+ Biochar) treatment which was closely followed by T<sub>5</sub> treatment but the lowest number of tubers roots per plant 32.63 was obtained from T<sub>1</sub>(Farmers' practice) treatment. In the study report it was found that the number of tuberous roots per plant was 6.53 [43].

### **3.2.2 Fresh yield of biomass (t/ha) of sweet potato at the Charlands**

The sweet potato experiments indicated a significant variation with regard to fresh yield of biomass at all the Charlands (Table 7). In Char Shaluka, the fresh yield of biomass ranged from 21.46 to 41.65 t/ha and the maximum fresh yield of biomass 41.65 t/ha was recorded in T<sub>6</sub> (RF+ Biochar) treatment but the lowest fresh yield of biomass 21.46t/ha was obtained from T<sub>1</sub>(Farmers' practice) treatment. In Naobhangar Char, the fresh yield of biomass ranged from 22.25 to 42.27 t/ha and the maximum fresh yield of biomass 42.27 t/ha was recorded in T<sub>6</sub> treatment but the lowest fresh yield of biomass 22.25t/ha was obtained from T<sub>1</sub>(Farmers' practice) treatment. In Maijbari Char, the fresh yield of biomass ranged from 22.46 to 42.32t/ha and the maximum fresh yield of biomass 42.32t/ha was recorded in T<sub>6</sub> treatment but the lowest fresh yield of biomass 22.46t/ha was obtained from T<sub>1</sub>(Farmers' practice) treatment.

### **3.2.3 Fresh yield of tuber (t/ha) of sweet potato at the Charlands**

The sweet potato experiments showed a significant variation with regard to fresh yield of tuber at all the Charlands (Table 8). In Char Shaluka, the fresh yield of tuber ranged from 40.32 to 92.62t/ha and the maximum fresh yield of tuber 92.62t/ha was recorded in T<sub>6</sub> treatment which was statistically similar with T<sub>5</sub> treatment but the lowest fresh yield of tuber 40.32t/ha was found from T<sub>1</sub> (Farmers' practice) treatment. In Naobhangar Char, the fresh yield of tuber ranged from 39.74 to 91.99t/ha and the maximum fresh yield of tuber 91.99t/ha was recorded in T<sub>6</sub> treatment which was statistically similar with T<sub>5</sub> treatment but the lowest fresh yield of tuber 39.74t/ha was obtained from T<sub>1</sub> (Farmers' practice) treatment. In Maijbari Char, the fresh yield of tuber ranged from 39.29 to 94.00t/ha and the maximum fresh yield of tuber 94.00t/ha was recorded in T<sub>6</sub> treatment which was similarly followed by T<sub>5</sub> treatment. On the

other hand, the lowest fresh yield of tuber 39.29t/ha was obtained from T<sub>1</sub> (Farmers' practice) treatment. It was showed 23.12 t/ha average production of tuber in a report [44]. It was found yield of tuber 22.83 t/ha in the experiment [43].

### **3.2.4 Total income (tk/ha) of sweet potato at the Charlands**

The sweet potato experiments showed a significant variation due to long term incorporation of different organic amendments with regard to total income at all the Charlands. In Char Shaluka, the total income ranged from 604850.00 to 1390000.00tk/ha and the maximum total income 1390000.00tk/ha was recorded in T<sub>6</sub> treatment which was similarly followed by T<sub>5</sub> treatment but the minimum total income 604850.00tk/ha was obtained from T<sub>1</sub> (Farmers' practice) treatment. In Naobhangar Char, the total income ranged from 596100.00 to 1380000.00tk/ha and the highest total income 1380000.00tk/ha was recorded in T<sub>6</sub> treatment which was similarly followed by T<sub>5</sub> treatment while the lowest total income 596100.00tk/ha was obtained from T<sub>1</sub>(Farmers' practice) treatment. In Maijbari Char, the total income ranged from 589400.00 to 1410000.00tk/ha and the highest total income 1410000.00tk/ha was recorded in T<sub>6</sub> treatment which was similar with T<sub>5</sub> treatment but the lowest total income 589400.00tk/ha was obtained from T<sub>1</sub>(Farmers' practice) treatment (Table 9).

### **3.2.5 Total cost (tk/ha) at the Charlands of sweet potato at the Charlands**

The sweet potato experiments presented a variation with regard to total cost at all the Charlands. In the Charlands, the total cost in T<sub>1</sub> (491559.00 tk/ha), T<sub>2</sub> (391683.48 tk/ha), T<sub>3</sub> (397683.48 tk/ha), T<sub>4</sub> (400683.48 tk/ha), T<sub>5</sub> (391683.48 tk/ha) and T<sub>6</sub> (400683.48 tk/ha). Moreover, the maximum total cost was recorded in T<sub>1</sub> (491559.00 tk/ha) treatment and minimum total cost was obtained from T<sub>2</sub>, T<sub>3</sub> and T<sub>5</sub> (391683.48 tk/ha) treatments (Table 10).

### **3.2.6 Benefit cost ratio (BCR) (Total cost basis) of sweet potato at the Charlands**

The sweet potato experiments unveiled a significant variation due to long term incorporation of different organic amendments with regard to BCR (Total cost basis) at all the Charlands. In Char Shaluka, the BCR ranged from 1.23 to 3.54 and the maximum BCR 3.54 was recorded in T<sub>5</sub> (RF+ Poultry Manure) treatment which was similarly followed by T<sub>6</sub> treatment but the minimum BCR 1.23 was obtained from T<sub>1</sub> (Farmers' practice) treatment. In Naobhangar Char, the BCR ranged from 1.21

to 3.51 and the highest BCR 3.51 was recorded in T<sub>5</sub> treatment which was similarly followed by T<sub>6</sub> treatment while the lowest BCR 1.21 was obtained from T<sub>1</sub> (Farmers' practice) treatment. In Maijbari Char, the BCR ranged from 1.20 to

3.52 and the highest BCR 3.52 was recorded in T<sub>5</sub> and T<sub>6</sub> treatments but the lowest BCR 1.20 was obtained from T<sub>1</sub> (Farmers' practice) treatment (Table 11).

**Table 6. Effects of different organic manures for field experiments with Number of tuberous roots per plant of sweet potato at the Charlands**

| Treatments     | Number of tuberous roots per plant |                 |               |
|----------------|------------------------------------|-----------------|---------------|
|                | Char Shaluka                       | Naobhangar Char | Maijbari Char |
| T <sub>1</sub> | 32.91c                             | 33.49c          | 32.63c        |
| T <sub>2</sub> | 47.56b                             | 46.28b          | 46.64b        |
| T <sub>3</sub> | 47.28b                             | 46.29b          | 46.51b        |
| T <sub>4</sub> | 48.57b                             | 47.61b          | 48.03b        |
| T <sub>5</sub> | 53.41a                             | 52.92a          | 52.50a        |
| T <sub>6</sub> | 54.68a                             | 53.25a          | 54.05a        |
| CV (%)         | 2.12                               | 2.04            | 2.19          |
| SE (±)         | 0.82                               | 0.78            | 0.84          |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

**Table 7. Effects of different organic manures for field experiments with fresh yield of biomass of sweet potato at the Charlands**

| Treatments     | Fresh yield of biomass (t/ha) |                 |               |
|----------------|-------------------------------|-----------------|---------------|
|                | Char Shaluka                  | Naobhangar Char | Maijbari Char |
| T <sub>1</sub> | 21.46d                        | 22.25c          | 22.46e        |
| T <sub>2</sub> | 35.82bc                       | 35.02b          | 34.58d        |
| T <sub>3</sub> | 37.24b                        | 36.25b          | 36.83c        |
| T <sub>4</sub> | 35.48c                        | 34.75b          | 35.60cd       |
| T <sub>5</sub> | 40.36a                        | 41.10a          | 40.05b        |
| T <sub>6</sub> | 41.65a                        | 42.27a          | 42.32a        |
| CV (%)         | 2.66                          | 2.84            | 3.05          |
| SE (±)         | 0.77                          | 0.82            | 0.88          |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

**Table 8. Effects of different organic manures for field experiments with fresh yield of tuber of sweet potato at the Charlands**

| Treatments     | Fresh yield of tuber (t/ha) |                 |               |
|----------------|-----------------------------|-----------------|---------------|
|                | Char Shaluka                | Naobhangar Char | Maijbari Char |
| T <sub>1</sub> | 40.32c                      | 39.74c          | 39.29c        |
| T <sub>2</sub> | 81.30b                      | 80.45b          | 80.20b        |
| T <sub>3</sub> | 80.92b                      | 80.16b          | 80.94b        |
| T <sub>4</sub> | 80.88b                      | 79.65b          | 80.98b        |
| T <sub>5</sub> | 92.32a                      | 91.54a          | 91.96a        |
| T <sub>6</sub> | 92.62a                      | 91.99a          | 94.00a        |
| CV (%)         | 2.16                        | 2.28            | 2.31          |
| SE (±)         | 1.37                        | 1.44            | 1.47          |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

**Table 9. Effects of different organic manures for field experiments with total income (tk/ha) of sweet potato at the Charlands**

| Treatments     | Total income (tk/ha) |                 |               |
|----------------|----------------------|-----------------|---------------|
|                | Char Shaluka         | Naobhangar Char | Maijbari Char |
| T <sub>1</sub> | 604850.00c           | 596100.00c      | 589400.00c    |
| T <sub>2</sub> | 1220000.00b          | 1210000.00b     | 1200000.00b   |
| T <sub>3</sub> | 1210000.00b          | 1200000.00b     | 1210000.00b   |
| T <sub>4</sub> | 1210000.00b          | 1190000.00b     | 1210000.00b   |
| T <sub>5</sub> | 1380000.00a          | 1370000.00a     | 1380000.00a   |
| T <sub>6</sub> | 1390000.00a          | 1380000.00a     | 1410000.00a   |
| CV (%)         | 2.16                 | 2.28            | 2.31          |
| SE (±)         | 20621.00             | 21555.00        | 22032.00      |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

**Table 10. Effects of different organic manures for field experiments with Total cost (tk/ha) of sweet potato at the Charlands**

| Treatments     | Total cost (tk/ha) at the Charlands |
|----------------|-------------------------------------|
| T <sub>1</sub> | 491559.00                           |
| T <sub>2</sub> | 391683.48                           |
| T <sub>3</sub> | 397683.48                           |
| T <sub>4</sub> | 400683.48                           |
| T <sub>5</sub> | 391683.48                           |
| T <sub>6</sub> | 400683.48                           |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer.

**Table 11. Effects of different organic manures for field experiments with BCR (total cost basis) of sweet potato at the Charlands**

| Treatments     | BCR (Total cost basis) |                 |               |
|----------------|------------------------|-----------------|---------------|
|                | Char Shaluka           | Naobhangar Char | Maijbari Char |
| T <sub>1</sub> | 1.23c                  | 1.21c           | 1.20c         |
| T <sub>2</sub> | 3.11b                  | 3.08b           | 3.07b         |
| T <sub>3</sub> | 3.05b                  | 3.03b           | 3.05b         |
| T <sub>4</sub> | 3.03b                  | 2.98b           | 3.03b         |
| T <sub>5</sub> | 3.54a                  | 3.51a           | 3.52a         |
| T <sub>6</sub> | 3.47a                  | 3.44a           | 3.52a         |
| CV (%)         | 2.16                   | 2.32            | 2.32          |
| SE (±)         | 0.05                   | 0.05            | 0.05          |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

### 3.3 Effect of different organic amendment on soil chemical properties in the Charlands

The post-harvest samples were collected from the three selected Charlands (Char Shaluka, Naobhangar Char and Majibari Char) in two different depths i.e., 0-15cm and 15-30cm. Chemical analyses of the collected soil samples were completed in the laboratory of the Department of Soil Science at BSMRAU.

#### 3.3.1 Soil pH at the Charlands

The effects of different treatments on soil pH in the research field of the Charlands is presented in table 12. After three-year judicious application of organic fertilizers, soil pH significantly influenced by different organic matter treated treatments. At 0-15cm soil depth, in Char Shaluka, the soil pH ranged from 7.16 to 7.36. The maximum soil pH (7.36) was in the T<sub>2</sub> and T<sub>6</sub> treatments which was statistically similar with T<sub>3</sub>, T<sub>4</sub> and T<sub>5</sub> treatments, while the lowest soil pH value (7.16) was in T<sub>1</sub> treatment. In Naobhangar Char, the soil pH ranged from 7.19 to 7.35. The maximum soil pH (7.35) was in the T<sub>2</sub> and T<sub>4</sub> treatments which was statistically similar with T<sub>3</sub>, T<sub>5</sub> and T<sub>6</sub> treatments, while the lowest soil pH value (7.19) was in T<sub>1</sub> treatment. In Majibari Char, the soil pH ranged from 7.17 to 7.34. The maximum soil pH (7.34) was in the T<sub>5</sub> and T<sub>6</sub> treatments which was statistically similar with T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub> treatments, while the lowest soil pH value (7.17) was in T<sub>1</sub> treatment. At 15-30cm soil depth, in Char Shaluka, the soil pH ranged from 6.76 to 6.96. The maximum soil pH (6.96) was in the T<sub>3</sub>, T<sub>4</sub> and T<sub>6</sub> treatments which was statistically similar with T<sub>2</sub> and T<sub>5</sub> treatments, while the lowest soil pH value (6.76) was in T<sub>1</sub> treatment. In Naobhangar Char, the soil pH ranged from 6.74 to 6.98. The maximum soil pH (6.98) was in the T<sub>2</sub> treatment which was statistically similar with T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub> and T<sub>6</sub> treatments, while the lowest soil pH value (6.74) was in T<sub>1</sub> treatment. In Majibari Char, the soil pH ranged from 6.75 to 6.95. The maximum soil pH (6.95) was in the T<sub>2</sub>, T<sub>3</sub> and T<sub>6</sub> treatments which was statistically similar with T<sub>4</sub> treatment, while the lowest soil pH value (6.75) was in T<sub>1</sub> treatment. The pH ranged from (6.99 to 8.2) in the charland soil of the study [7]. The range of pH (5.62-7.80) in the charland soil of the study [17].

#### 3.3.2 Soil organic carbon at the Charlands

The OC content of the Charlands soil was significantly increased by different organic amendment treatments after three-year application (Table 13). At 0-15cm soil depth, in Char Shaluka, the soil OC was extended from 0.97 to 1.82 (%). The significantly highest soil OC content (1.82%) was observed in the T<sub>6</sub> treatment. The lowest soil OC content (0.97%) was noted in T<sub>1</sub> treatment. In Naobhangar Char, the soil OC was extended from 0.97 to 1.80 (%). The significantly highest soil OC content (1.80%) was observed in the T<sub>6</sub> treatment which was statistically similar to T<sub>4</sub> and T<sub>5</sub> treatments. The lowest soil OC content (0.97%) was noted in T<sub>1</sub> treatment. In Majibari Char, the soil OC was extended from 0.94 to 1.82 (%). The significantly highest soil OC content (1.82%) was observed in the T<sub>6</sub> treatment. The lowest soil OC content (0.94%) was noted in T<sub>1</sub> treatment. At 15-30cm soil depth, in Char Shaluka, the soil OC was extended from 0.69 to 1.62 (%). The significantly highest soil OC content (1.62%) was observed in the T<sub>6</sub> treatment. The lowest soil OC content (0.69%) was noted in T<sub>1</sub> treatment. In Naobhangar Char, the soil OC was extended from 0.73 to 1.59 (%). The significantly highest soil OC content (1.59%) was observed in the T<sub>6</sub> treatment which was statistically similar to T<sub>2</sub> and T<sub>5</sub> treatments. The lowest soil OC content (0.73%) was noted in T<sub>1</sub> treatment. In Majibari Char, the soil OC was extended from 0.72 to 1.59 (%). The significantly highest soil OC content (1.59%) was observed in the T<sub>6</sub> treatment which was statistically similar to T<sub>2</sub>, T<sub>4</sub> and T<sub>5</sub> treatments. The lowest soil OC content (0.72%) was noted in T<sub>1</sub> treatment. The OC ranged from 0.99 to 1.02% in the charland soil of the study [7]. The range of OC (0.28-1.56%) in the charland soil of the study [17].

#### 3.3.3 Total nitrogen (%) at the Charlands

Soil total N content was significantly increased by different treatments after three-year application with organic fertilizers (Table 14). At 0-15cm soil depth, in Char Shaluka, the soil total N was varied from 0.095 to 0.145 (%). The significantly highest soil total N content (0.145%) was found in the T<sub>6</sub> treatment which was statistically similar with T<sub>4</sub> and T<sub>5</sub> treatments. The lowest soil total N content (0.095%) was recorded in T<sub>1</sub> treatment. In Naobhangar Char, the soil total N was varied from 0.095 to 0.144 (%). The significantly highest soil total N content (0.144%) was found in the T<sub>6</sub> treatment which

was statistically similar with T<sub>5</sub> treatment. The lowest soil total N content (0.095%) was recorded in T<sub>1</sub> treatment. In Maijbari Char, the soil total N was varied from 0.096 to 0.144 (%). The significantly highest soil total N content (0.144%) was found in the T<sub>6</sub> treatment which was statistically similar with T<sub>5</sub> treatments. The lowest soil total N content (0.096%) was recorded in T<sub>1</sub> treatment. At 15-30cm soil depth, in Char Shaluka, the soil total N was varied from 0.075 to 0.108 (%). The significantly highest soil total N content (0.108%) was found in the T<sub>6</sub> treatment which was statistically similar with T<sub>5</sub> treatment. The lowest soil total N content (0.075%) was recorded in T<sub>1</sub> treatment. In Naobhangar Char, the soil total N was varied from 0.074 to 0.108 (%). The significantly highest soil total N content (0.108%) was found in the T<sub>5</sub> and T<sub>6</sub> treatments which was statistically similar with T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub> treatments. The lowest soil total N content (0.074%) was recorded in T<sub>1</sub> treatment. In Maijbari Char, the soil total N was varied from 0.074 to 0.103 (%). The significantly highest soil total N content (0.103%) was found in the T<sub>6</sub> treatment which was statistically similar with T<sub>5</sub> treatment. The lowest soil total N content (0.074%) was recorded in T<sub>1</sub> treatment. Soil N content was 0.11 % in the charland soil of the study [7]. The range of N (0.02-0.21%) in the charland soil of the study [17].

### **3.3.4 Available phosphorus (mg/kg) at the Charlands**

The soil available P was remarkably influenced by different treatments after three-year application of organic fertilizers (Table 15). At 0-15cm soil depth, in Char Shaluka, the soil available P was ranged from 9.42 to 17.66 (mg/kg). The significantly highest soil available P (17.66mg/kg) was found in the T<sub>6</sub> treatment. The lowest soil available P (9.72mg/kg) was noted in T<sub>1</sub> treatment. In Naobhangar Char, the soil available P was ranged from 9.41 to 17.36 (mg/kg). The significantly highest soil available P (17.36mg/kg) was found in the T<sub>6</sub> treatment. The lowest soil available P (9.41mg/kg) was noted in T<sub>1</sub> treatment. In Maijbari Char, the soil available P was ranged from 9.66 to 17.29 (mg/kg). The significantly highest soil available P (17.29mg/kg) was found in the T<sub>6</sub> treatment which was statistically similar to T<sub>2</sub> and T<sub>3</sub> treatments. The lowest soil available P (9.66mg/kg) was noted in T<sub>1</sub> treatment. At 15-30cm soil depth, in Char Shaluka, the soil available P was ranged from 7.90 to 14.59 (mg/kg). The significantly highest soil available P (14.59mg/kg) was found in the T<sub>6</sub> treatment which was statistically similar to T<sub>3</sub>, T<sub>4</sub> and T<sub>5</sub> treatments. The lowest soil available P

(7.90mg/kg) was noted in T<sub>1</sub> treatment. In Naobhangar Char, the soil available P was ranged from 7.71 to 14.35 (mg/kg). The significantly highest soil available P (14.35mg/kg) was found in the T<sub>6</sub> treatment which was statistically similar to T<sub>3</sub> and T<sub>4</sub> treatments. The lowest soil available P (7.71mg/kg) was noted in T<sub>1</sub> treatment. In Maijbari Char, the soil available P was ranged from 7.49 to 14.45 (mg/kg). The significantly highest soil available P (14.45mg/kg) was found in the T<sub>6</sub> treatment which was statistically similar to T<sub>3</sub> and T<sub>5</sub> treatments. The lowest soil available P (7.49mg/kg) was noted in T<sub>1</sub> treatment. The P content varied from 10 to 18 mg/kg in the charland soil of the study [7]. The range of P (3.00-20.00 mg/kg) in the charland soil of the study [17].

### **3.3.5 Available sulphur (mg/kg) at the Charlands**

Three-year application of organic fertilizers had significant effect on the available S content in the Charlands soil (Table 16). At 0-15cm soil depth, in Char Shaluka, the soil available S was ranged from 11.53 to 17.74 (mg/kg). Among the treatments, T<sub>6</sub> gave the significantly highest soil available S (17.74mg/kg) content. The lowest soil available S (11.53mg/kg) was detected in T<sub>1</sub> treatment. In Naobhangar Char, the soil available S was ranged from 11.62 to 17.81 (mg/kg). Among the treatments, T<sub>6</sub> gave the significantly highest soil available S (17.81mg/kg) content which was statistically similar to T<sub>2</sub> treatment. The lowest soil available S (11.62mg/kg) was detected in T<sub>1</sub> treatment. In Maijbari Char, the soil available S was ranged from 11.43 to 17.68 (mg/kg). Among the treatments, T<sub>6</sub> gave the significantly highest soil available S (17.68mg/kg) content which was statistically similar to T<sub>2</sub> and T<sub>3</sub> treatments. The lowest soil available S (11.43mg/kg) was detected in T<sub>1</sub> treatment. At 15-30cm soil depth, in Char Shaluka, the soil available S was ranged from 9.70 to 14.62 (mg/kg). Among the treatments, T<sub>6</sub> gave the significantly highest soil available S (14.62mg/kg) content. The lowest soil available S (9.70mg/kg) was detected in T<sub>1</sub> treatment. In Naobhangar Char, the soil available S was ranged from 9.56 to 14.47 (mg/kg). Among the treatments, T<sub>6</sub> gave the significantly highest soil available S (14.47mg/kg) content. The lowest soil available S (9.56mg/kg) was detected in T<sub>1</sub> treatment. In Maijbari Char, the soil available S was ranged from 9.55 to 14.48 (mg/kg). Among the treatments, T<sub>6</sub> gave the significantly highest soil available S (14.47mg/kg) content. The lowest soil available S (9.55mg/kg) was detected in T<sub>1</sub>

treatment. while S ranged from 2.84 in to 14.81 mg/kg in the charland soil of the study [7]. The range of S (2.05-56.40 mg/kg) in the charland soil of the study [17].

### 3.3.6 Available zinc (mg/kg) at the Charlands

Three-year application of organic fertilizers significantly increased the Zn content in Charlands soil (Table 17). At 0-15cm soil depth, in Char Shaluka, organic amendments were varied the Zn content from 0.783 to 1.133 (mg/kg). Among the treatments, the biochar treated treatment T<sub>6</sub> showed the maximum Zn content (1.133mg/kg) which was statistically similar to T<sub>5</sub> treatment and the minimum Zn content (0.783mg/kg) in T<sub>1</sub> treatment. In Naobhangar Char, organic amendments were varied the Zn content from 0.783 to 1.134 (mg/kg). Among the treatments, the biochar treated treatment T<sub>6</sub> showed the maximum Zn content (1.134mg/kg) which was statistically similar to T<sub>5</sub> treatment and the minimum Zn content (0.783mg/kg) in T<sub>1</sub> treatment. In Maijbari Char, organic amendments were varied the Zn content from 0.781 to 1.134 (mg/kg). Among the

treatments, the biochar treated treatment T<sub>6</sub> showed the maximum Zn content (1.134mg/kg) and the minimum Zn content (0.781mg/kg) in T<sub>1</sub> treatment. At 15-30cm soil depth, in Char Shaluka, organic amendments were varied the Zn content from 0.557 to 0.989 (mg/kg). Among the treatments, the biochar treated treatment T<sub>6</sub> showed the maximum Zn content (0.989mg/kg) and the minimum Zn content (0.557mg/kg) in T<sub>1</sub> treatment. In Naobhangar Char, organic amendments were varied the Zn content from 0.536 to 0.981 (mg/kg). Among the treatments, the biochar treated treatment T<sub>6</sub> showed the maximum Zn content (0.981mg/kg) which was statistically similar to T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub> and T<sub>5</sub> treatments and the minimum Zn content (0.536mg/kg) in T<sub>1</sub> treatment. In Maijbari Char, organic amendments were varied the Zn content from 0.550 to 0.988 (mg/kg). Among the treatments, the biochar treated treatment T<sub>6</sub> showed the maximum Zn content (0.988mg/kg) which was statistically similar to T<sub>2</sub> and T<sub>5</sub> treatments and the minimum Zn content (0.550mg/kg) in T<sub>1</sub> treatment. Zinc varied from 0.63 in to 0.93 mg/kg in the charland soil of the study [7]. The range of Zn (0.39-2.20 mg/kg) in the charland soil of the study [17].

**Table 12. Effect of different organic matters on post-harvest soil pH content (0-15 and 15-30cm depth) of the Charlands**

| Treatments      | Post-harvest soil pH |                 |               |                |                 |               |
|-----------------|----------------------|-----------------|---------------|----------------|-----------------|---------------|
|                 | 0-15 cm depth        |                 |               | 15-30 cm depth |                 |               |
|                 | Char Shaluka         | Naobhangar Char | Maijbari Char | Char Shaluka   | Naobhangar Char | Maijbari Char |
| T <sub>1</sub>  | 7.16b                | 7.19c           | 7.17b         | 6.76b          | 6.74b           | 6.75c         |
| T <sub>2</sub>  | 7.36a                | 7.35a           | 7.33a         | 6.94a          | 6.98a           | 6.95a         |
| T <sub>3</sub>  | 7.34a                | 7.29b           | 7.27a         | 6.96a          | 6.95a           | 6.95a         |
| T <sub>4</sub>  | 7.35a                | 7.35a           | 7.33a         | 6.96a          | 6.96a           | 6.94ab        |
| T <sub>5</sub>  | 7.34a                | 7.34ab          | 7.34a         | 6.95a          | 6.94a           | 6.94b         |
| T <sub>6</sub>  | 7.36a                | 7.34ab          | 7.34a         | 6.96a          | 6.94a           | 6.95a         |
| CV (%)          | 0.34                 | 0.39            | 0.61          | 0.18           | 0.34            | 0.10          |
| SE (±)          | 0.02                 | 0.02            | 0.04          | 0.01           | 0.02            | 0.01          |
| Critical levels | 4.50                 |                 |               |                |                 |               |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

**Table 13. Effect of different organic matters on post-harvest soil OC (%) content (0-15 and 15-30cm depth) of the Charlands**

| Treatments     | Post-harvest soil OC (%) |                 |               |                |                 |               |
|----------------|--------------------------|-----------------|---------------|----------------|-----------------|---------------|
|                | 0-15 cm depth            |                 |               | 15-30 cm depth |                 |               |
|                | Char Shaluka             | Naobhangar Char | Maijbari Char | Char Shaluka   | Naobhangar Char | Maijbari Char |
| T <sub>1</sub> | 0.97c                    | 0.97c           | 0.94c         | 0.69d          | 0.73d           | 0.72c         |
| T <sub>2</sub> | 1.65b                    | 1.65b           | 1.65b         | 1.48b          | 1.57ab          | 1.57a         |
| T <sub>3</sub> | 1.69b                    | 1.67b           | 1.67b         | 1.37c          | 1.46c           | 1.48b         |
| T <sub>4</sub> | 1.71b                    | 1.71ab          | 1.71b         | 1.52b          | 1.49bc          | 1.56ab        |
| T <sub>5</sub> | 1.71b                    | 1.70ab          | 1.70b         | 1.52b          | 1.52abc         | 1.58a         |
| T <sub>6</sub> | 1.82a                    | 1.80a           | 1.82a         | 1.62a          | 1.59a           | 1.59a         |

|                 |      |      |      |      |      |      |
|-----------------|------|------|------|------|------|------|
| CV (%)          | 3.17 | 3.89 | 3.81 | 2.43 | 3.86 | 3.05 |
| SE ( $\pm$ )    | 0.04 | 0.05 | 0.05 | 0.03 | 0.04 | 0.04 |
| Critical levels | 1.00 |      |      |      |      |      |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

**Table 14. Effect of different organic matters on post-harvest soil N (%) content (0-15 and 15-30cm depth) of the Charlands**

| Treatments      | Post-harvest soil N (%) |                 |               |                |                 |               |
|-----------------|-------------------------|-----------------|---------------|----------------|-----------------|---------------|
|                 | 0-15 cm depth           |                 |               | 15-30 cm depth |                 |               |
|                 | Char Shaluka            | Naobhangar Char | Maijbari Char | Char Shaluka   | Naobhangar Char | Maijbari Char |
| T <sub>1</sub>  | 0.095d                  | 0.095d          | 0.096d        | 0.075c         | 0.074b          | 0.074d        |
| T <sub>2</sub>  | 0.134c                  | 0.134c          | 0.135c        | 0.096b         | 0.103a          | 0.086c        |
| T <sub>3</sub>  | 0.137bc                 | 0.135bc         | 0.136bc       | 0.095b         | 0.102a          | 0.086c        |
| T <sub>4</sub>  | 0.140ab                 | 0.137bc         | 0.137bc       | 0.093b         | 0.103a          | 0.091bc       |
| T <sub>5</sub>  | 0.140ab                 | 0.141ab         | 0.141ab       | 0.107a         | 0.108a          | 0.098ab       |
| T <sub>6</sub>  | 0.145a                  | 0.144a          | 0.144a        | 0.108a         | 0.108a          | 0.103a        |
| CV (%)          | 2.36                    | 2.63            | 2.02          | 3.81           | 4.54            | 4.90          |
| SE ( $\pm$ )    | 0.003                   | 0.003           | 0.002         | 0.003          | 0.004           | 0.004         |
| Critical levels | 0.10                    |                 |               |                |                 |               |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

**Table 15. Effect of different organic matters on post-harvest soil P (mg/kg) content (0-15 and 15-30cm depth) of the Charlands**

| Treatments      | Post-harvest soil P (mg/kg) |                 |               |                |                 |               |
|-----------------|-----------------------------|-----------------|---------------|----------------|-----------------|---------------|
|                 | 0-15 cm depth               |                 |               | 15-30 cm depth |                 |               |
|                 | Char Shaluka                | Naobhangar Char | Maijbari Char | Char Shaluka   | Naobhangar Char | Maijbari Char |
| T <sub>1</sub>  | 9.42c                       | 9.41c           | 9.66c         | 7.90c          | 7.71d           | 7.49c         |
| T <sub>2</sub>  | 15.74b                      | 15.78b          | 15.70ab       | 12.40b         | 12.10c          | 13.53b        |
| T <sub>3</sub>  | 15.61b                      | 15.59b          | 15.62ab       | 13.17ab        | 13.57ab         | 13.79ab       |
| T <sub>4</sub>  | 14.95b                      | 15.25b          | 14.99b        | 13.20ab        | 13.24abc        | 13.49b        |
| T <sub>5</sub>  | 15.72b                      | 14.74b          | 14.68b        | 13.62ab        | 12.91bc         | 13.84ab       |
| T <sub>6</sub>  | 17.66a                      | 17.36a          | 17.29a        | 14.59a         | 14.35a          | 14.45a        |
| CV (%)          | 3.67                        | 4.60            | 6.28          | 7.83           | 5.56            | 3.60          |
| SE ( $\pm$ )    | 0.45                        | 0.55            | 0.75          | 0.80           | 0.56            | 0.38          |
| Critical levels | 7.00                        |                 |               |                |                 |               |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

**Table 16. Effect of different organic matters on post-harvest soil available S (mg/kg) content (0-15 and 15-30cm depth) of the Charlands**

| Treatments      | Post-harvest soil S (mg/kg) |                 |               |                |                 |               |
|-----------------|-----------------------------|-----------------|---------------|----------------|-----------------|---------------|
|                 | 0-15 cm depth               |                 |               | 15-30 cm depth |                 |               |
|                 | Char Shaluka                | Naobhangar Char | Maijbari Char | Char Shaluka   | Naobhangar Char | Maijbari Char |
| T <sub>1</sub>  | 11.53d                      | 11.62c          | 11.43c        | 9.70c          | 9.56c           | 9.55d         |
| T <sub>2</sub>  | 16.54bc                     | 16.58ab         | 16.50ab       | 12.74b         | 12.19b          | 12.63bc       |
| T <sub>3</sub>  | 16.32bc                     | 16.24b          | 16.38ab       | 12.82b         | 12.85b          | 12.50bc       |
| T <sub>4</sub>  | 16.10c                      | 16.09b          | 16.05b        | 12.92b         | 12.57b          | 12.16c        |
| T <sub>5</sub>  | 16.83b                      | 15.86b          | 15.74b        | 13.32b         | 12.15b          | 13.19b        |
| T <sub>6</sub>  | 17.74a                      | 17.81a          | 17.68a        | 14.62a         | 14.47a          | 14.47a        |
| CV (%)          | 2.43                        | 4.65            | 4.72          | 4.01           | 4.73            | 3.09          |
| SE (±)          | 0.31                        | 0.60            | 0.60          | 0.42           | 0.48            | 0.31          |
| Critical levels | 8.00                        |                 |               |                |                 |               |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

**Table 17. Effect of different organic matters on post-harvest soil Zn (mg/kg) content (0-15 and 15-30cm depth) of the Charlands**

| Treatments      | Post-harvest soil Zn (mg/kg) |                 |               |                |                 |               |
|-----------------|------------------------------|-----------------|---------------|----------------|-----------------|---------------|
|                 | 0-15 cm depth                |                 |               | 15-30 cm depth |                 |               |
|                 | Char Shaluka                 | Naobhangar Char | Maijbari Char | Char Shaluka   | Naobhangar Char | Maijbari Char |
| T <sub>1</sub>  | 0.783d                       | 0.783c          | 0.781c        | 0.557c         | 0.536b          | 0.550c        |
| T <sub>2</sub>  | 1.119bc                      | 1.119b          | 1.120b        | 0.975b         | 0.973a          | 0.979ab       |
| T <sub>3</sub>  | 1.118bc                      | 1.117b          | 1.119b        | 0.976b         | 0.977a          | 0.975b        |
| T <sub>4</sub>  | 1.114c                       | 1.113b          | 1.115b        | 0.975b         | 0.973a          | 0.974b        |
| T <sub>5</sub>  | 1.128ab                      | 1.125ab         | 1.120b        | 0.973b         | 0.972a          | 0.986a        |
| T <sub>6</sub>  | 1.133a                       | 1.134a          | 1.134a        | 0.989a         | 0.981a          | 0.988a        |
| CV (%)          | 0.57                         | 0.69            | 0.70          | 0.68           | 2.19            | 0.64          |
| SE (±)          | 0.005                        | 0.006           | 0.006         | 0.005          | 0.016           | 0.005         |
| Critical levels | 0.50                         |                 |               |                |                 |               |

T<sub>1</sub>= FP (Control), T<sub>2</sub>=RF+ Vermicompost (3t/ha), T<sub>3</sub>=RF+ Quick Compost (3t/ha), T<sub>4</sub>=RF+ Standard Organic Fertilizer (3t/ha), T<sub>5</sub>=RF+ Poultry Manure (3t/ha), T<sub>6</sub>=RF+ Biochar (3t/ha), FP= Farmers' practice, RF= Recommended fertilizer, CV= Co-efficient of Variation, SE= Standard Error for Comparison, in a column figures having similar letter (s) do not differ significantly whereas figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significant.

#### 4. CONCLUSION

Results of the experiment showed that application of organic manures along with inorganic fertilizers treatments produced significant ( $p < 0.05$ ) variation in production of pumpkin and sweet potato and post-harvest soil nutrient status compared to Farmer's practice treatment. In pumpkin experiments, among the Charlands, the maximum yield per plant 85.61kg was recorded in T<sub>6</sub> treatment from Naobhangar Char and the minimum 27.24kg in T<sub>1</sub> treatment from Maijbari Char. The highest BCR 3.40 was recorded in T<sub>6</sub> treatment from Naobhangar Char and the lowest BCR 1.06 in T<sub>1</sub> treatment from Maijbari Char. In sweet potato experiments, among the Charlands, the maximum fresh yield

of tuber 94.00t/ha was recorded in T<sub>6</sub> treatment and the minimum 39.29t/ha in T<sub>1</sub> treatment from Maijbari Char. The highest BCR 3.54 was recorded in T<sub>6</sub> treatment from Char Shaluka and the lowest BCR 1.20 in T<sub>1</sub> treatment from Maijbari Char. Among the Charlands soil, the highest pH (7.36) was found in T<sub>6</sub> treatment from Char Shaluka (0-15cm soil depth) and the lowest pH (6.74) in T<sub>1</sub> treatment from Naobhangar Char (15-30cm soil depth). Among the Charlands soil, the highest OC (1.82 %) was recorded in T<sub>6</sub> treatment from both Char Shaluka and Maijbari Char (0-15cm soil depth) and the lowest OC (0.69%) in T<sub>1</sub> treatment from Char Shaluka (15-30cm soil depth). The highest soil total N (0.145%) was found in T<sub>6</sub> treatment from Char

Shaluka (0-15cm soil depth) and the lowest total N (0.074%) in T<sub>1</sub> treatment from both Naobhangar Char and Maijbari Char (15-30cm soil depth). However, among the Charlands soil, the highest available P (17.66mg/kg) was obtained in T<sub>6</sub> treatment from Char Shaluka (0-15cm soil depth) and the lowest available P (7.49mg/kg) in T<sub>1</sub> treatment from Maijbari Char (15-30cm soil depth). The highest soil available S (17.81mg/kg) was found in T<sub>6</sub> treatment from both Naobhangar Char (0-15cm soil depth) and the lowest available S (9.55mg/kg) in T<sub>1</sub>

treatment from Maijbari Char (15-30cm soil depth). The maximum soil Zn (1.134mg/kg) was found in T<sub>6</sub> treatment from both Naobhangar Char and Maijbari Char (0-15cm soil depth) and the minimum Zn (0.536mg/kg) in T<sub>1</sub> treatment from Naobhangar Char (15-30cm soil depth). After long term application of organic fertilizer in the crop land field, the yield of different crop was increased as well as the soil fertility status also improved.

## REFERENCES

1. Afrad MSI, Rahman GKMM, Alam MS, Ali MZ, Barau AA. Effects of Organic and Inorganic Fertilizers on Growth and Yield of Different Crops at Charlands in Bangladesh. *Asian Journal of Advances in Agricultural Research*. 2021;17(3):27–40.
2. Rahman MA, Jahiruddin M, Kader MA, Islam MR, Solaiman ZM. Sugarcane bagasse biochar increases soil carbon sequestration and yields of maize and groundnut in charland ecosystem. *Archives of Agronomy and Soil Science*. 2021;1–14.
3. Environment and GIS Support Project for Water Sector Planning. *Riverine Chars in Bangladesh: Environmental dynamics and management issues*. University Press. 2000.
4. Haque M. Vulnerability of the Charland Dwellers to Climate Change: Various Adaptation Practices in Bangladesh. In *Building Sustainable Communities*. Palgrave Macmillan, Singapore. 2020;75–85.
5. Islam MN, Hossain MA, Mohiuddin M, Mian MAK, Biswas M. A survey on crops and cropping of char areas in Bangladesh. *Unfavourable Eco-System: Crop Production under Charland Eco-System*. Agronomy Division, Bangladesh Agricultural Research Institute, Gazipur. 2016;55–68.
6. Roy BK, Ullah MB, Rahman MH. Climate Change Impact in Charlands in Central Area of Bangladesh: Assessing Vulnerability and Adaptation by the Farming Communities. *Journal of Environmental Science and Natural Resources*. 2014;7(2):59–63.
7. Karim MA. Upscaling mungbean-Rice pattern in the charlands of Kurigram. Pilot Project Final Report. Krishi Gobeshona Foundation-World Bank. Bangladesh Agricultural Research Council Complex (Dhaka). 2014;1–47.
8. Ashley S, Kat K, Hossain A, Nandi S. The Chars Livelihood Assistance Scoping Study Final Report. DFID (Dhaka). 2000;1–49.
9. Islam M, Islam A. A brief account of bank erosion, model studies and bank protective works in Bangladesh. *REIS Newsletter*. 1985;2:11–13.
10. Rahman MM, Alam MS, Kamal MZU, Rahman GKMM. Organic sources and tillage practices for soil management. In *Resources Use Efficiency in Agriculture*. Springer, Singapore. 2020b;283–328.
11. Ali MZ, Alam MS, Rahman GKMM, Rahman MM, Islam MM, Kamal MZ, Hossain MS. Short-term effect of rice straw application on soil fertility and rice yield. *Eurasian Journal of Soil Science*. 2021;10(1):9–16.
12. Dhaliwal SS, Naresh RK, Mandal A, Walia MK, Gupta RK, Singh R, Dhaliwal MK. Effect of manures and fertilizers on soil physical properties, build-up of macro and micronutrients and uptake in soil under different cropping systems: a review. *Journal of Plant Nutrition*. 2019;42(20):2873–2900.
13. Barua S, Molla AH, Haque MM, Alam MS. Performance of Trichoderma-enriched bio-organic fertilizer in N supplementation and bottle gourd production in field condition. *Hort. Internat. J.* 2018;2:106–114.
14. Islam MM, Urmi TA, Rana M, Alam MS, Haque MM. Green manuring effects on crop morpho-physiological characters, rice yield and soil properties. *Physiology and Molecular Biology of Plants*. 2019;25(1):303–312.
15. Rahman MM, Sultana M, Rahman GKMM, Solaiman ARM, Alam MS. Effect of different organic composts on soil fertility and tomato yield. *Bangladesh Journal of Soil Science*. 2015a;37(1):25–34.
16. Song X, Liu M, Wu D, Griffiths BS, Jiao J, Li H, Hu F. Interaction matters: Synergy between vermicompost and PGPR agents improves soil quality, crop quality and crop yield in the field. *Applied Soil Ecology*. 2015;89:25–34.
17. Karim MA, Quayyum MA, Samsuzzaman S, Higuchi H, Nawata E. Challenges and

- opportunities in crop production in different types of char lands of Bangladesh: diversity in crops and cropping. *Tropical Agriculture and Development*. 2017;61(2):77–93.
18. Chaudhuri PS, Paul TK, Dey A, Datta M, Dey SK. Effects of rubber leaf litter vermicompost on earthworm population and yield of pineapple (*Ananas comosus*) in West Tripura, India. *International Journal of Recycling of Organic Waste in Agriculture*. 2016;5(2):93–103.
  19. Masulili A, Utomo WH, Syechfani MS. Rice husk biochar for rice based cropping system in acid soil 1. The characteristics of rice husk biochar and its influence on the properties of acid sulfate soils and rice growth in West Kalimantan, Indonesia. *Journal of Agricultural Science*. 2010;2(1):39.
  20. Rahman GKMM, Rahman MM, Alam MS, Kamal MZ, Mashuk HA, Datta R, Meena RS. Biochar and organic amendments for sustainable soil carbon and soil health. In *Carbon and nitrogen cycling in soil*. Springer, Singapore. 2020a;45–85.
  21. Knoblauch C, Maarifat AA, Pfeiffer EM, Haefele SM. Degradability of black carbon and its impact on trace gas fluxes and carbon turnover in paddy soils. *Soil Biology and Biochemistry*. 2011;43(9): 1768–1778.
  22. Yamato M, Okimori Y, Wibowo IF, Anshori S, Ogawa M. Effects of the application of charred bark of *Acacia mangium* on the yield of maize, cowpea and peanut, and soil chemical properties in South Sumatra, Indonesia. *Soil science and plant nutrition*. 2006;52(4):489–495.
  23. Chan KY, Van Zwieten L, Meszaros I, Downie A, Joseph S. Using poultry litter biochars as soil amendments. *Soil Research*. 2008;46(5):437–444.
  24. Saffari N, Hajabbasi MA, Shirani H, Mosaddeghi MR, Owens G. Influence of corn residue biochar on water retention and penetration resistance in a calcareous sandy loam soil. *Geoderma*. 2021;383:114734.
  25. Irfan M, Hussain Q, Khan KS, Akmal M, Ijaz SS, Hayat R, ... Rashid M. Response of soil microbial biomass and enzymatic activity to biochar amendment in the organic carbon deficient arid soil: a 2-year field study. *Arabian Journal of Geosciences*. 2019;12(3):95.
  26. Afrad MSI, Rahman GKMM, Alam MS, Ali MZ, Barau AA. Effects of Organic Amendments on Yield Performance of Winter and Summer Seasons Vegetables at Charlands in Bangladesh. *Annals of plant sciences*. 2022;11(1):4628–4647.
  27. de Sousa LJR, de Moraes SW, de Medeiros EV, Duda GP, Corrêa MM, Martins FAP,... Hammecker C. Effect of biochar on physicochemical properties of a sandy soil and maize growth in a greenhouse experiment. *Geoderma*. 2018;319:14–23.
  28. Razzaghi F, Obour PB, Arthur E. Does biochar improve soil water retention? A systematic review and meta-analysis. *Geoderma*. 2020;361:114055.
  29. Tanure MMC, da Costa LM, Huiz HA, Fernandes RBA, Cecon PR, Junior JDP, da Luz JMR. Soil water retention, physiological characteristics, and growth of maize plants in response to biochar application to soil. *Soil and Tillage Research*. 2019;192:164–173.
  30. Khalid CU, Shahzad S, Nadir NM, Saboor A, Yaqoob S, Salim M, Khalid M. Integration of biochar and chemical fertilizer to enhance quality of soil and wheat crop (*Triticum aestivum* L.). *PeerJ PrePrints*. 2016;4:e1631v1.
  31. Kumar R, Lal M, Naresh RK, Kumar M, Yadav S, Kumar R, ... Rajput P. Influence of Balanced Fertilization on Productivity, Nutrient Use Efficiency and Profitability of Rice in Inceptisol: A Review. *International Journal of Current Microbiology and Applied Sciences*. 2020;9(1):568–590.
  32. Page AL, Keeney DR. Methods of soil analysis. American Society of Agronomy. 1982.
  33. Bremner JM. Total nitrogen. Methods of soil analysis. American Society of Agronomy, Mongrn. 1982;10,(2):594–624.
  34. Olsen SR. Estimation of available phosphorus in soils by extraction with sodium bicarbonate (No. 939). US Department of Agriculture. 1954.
  35. Fox RL, Olson RA, Rhoades HF. Evaluating the sulfur status of soils by plant and soil tests. *Soil Science Society of America Journal*. 1964;28(2):243–246.
  36. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil science society of America journal*. 1978;42(3):421–428.
  37. Jackson ML. Soil chemical analysis prentice hall of India. Pvt. Ltd. New Delhi. 1973;498.
  38. BARC (Bangladesh Agricultural Research Council). Fertilizer Recommendation Guide-2018, BARC, Bangladesh Agricultural Research Council, Farmgate, Dhaka. 2018.
  39. Gomez KA, Gomez AA. Statistical procedures for agricultural research. John Wiley & Sons. 1984.
  40. Ahamed KU, Akhter B, Islam MR, Ara N, Humauan MR. An assessment of morphology and yield characteristics of

- pumpkin (*Cucurbita moschata*) genotypes in northern Bangladesh. *Tropical Agricultural Research and Extension*. 2012;14(1).
41. Pandey S, Singh J, Upadhyay AK, Ram D, Rai M. Ascorbate and carotenoid content in an Indian collection of pumpkin (*Cucurbita moschata* Duch. Ex Poir.). *Cucurbit Genetics Cooperative Report*. 2003;26:51–53.
  42. Abdelhafez AA, Abbas MH, Li J. Biochar: the black diamond for soil sustainability, contamination control and agricultural production. *Engineering applications of biochar*, 2. (2017).
  43. Rahman H, Islam AFM, Maleque M, Tabassum R. Morpho-physiological evaluation of sweet potato (*Ipomoea batatas* L.) genotypes in acidic soil. *Asian Journal of Crop Science*. 2015b;7(4):267–276.
  44. Ahmed MT, Nath SC, Sorwar MA, Rashid MH. Cost-effectiveness and resource use efficiency of sweet potato in Bangladesh. *Journal of Agricultural Economics and Rural Development*. 2015;2(2): 026–031.

UNDER PEER REVIEW