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Soil fertility status and its possible sustainable agricultural packages in Bangladesh

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ABSTRACT

Soil fertility describes the soil's capacity to support the growth of agricultural plants for predictable yields. Consequently, the present study was conducted on twenty one soil series of Bangladesh, including Sonatala, Sherpur, Ghatail, Balina, Melandaha, Tarakanda, Gorargaon, Karail, Raipur, Ruhea, Silmandi, Dhamrai, Jamun, Ishurdi, Ranisankail, Atwari, Gangachora, Pirgachha, Sulla, Birampur, and Gopalpurand to know the fertility status and its possible sustainable agricultural packages. The textural classes of the major soils were silt loam. The soils had the particle densities ranged from 1.79 to 2.50 g cm^{-3}. The soil series from Sherpur and Gangachora had the highest particle density, while those from Karail and Gorargaon had the lowest value. Most soils reacted in a neutral to acidic manner, whereas the Ishurdi and Gopalpur series showed an alkaline response. Except Karail and Gorargaon, the organic matter status was very low to medium. The total N content of the soils ranged from 0.04 to 0.19%. The available phosphorus, exchangeable potassium, and available sulphur of soils ranged from 2.82 to 22.18 ppm, 0.09 to 0.26 meq/100g soil, and 2.90 to 20.30 ppm, respectively. The results revealed that the soils in the research area were very low to moderately fertile. Therefore, balance fertilizer must be applied in time in the study area. The fertilizer should be location-specific, cropping pattern-based, and based on soil testing. Beside this, a collection of management techniques have to be acknowledged and promoted to the farmer level as a package for sustainable agriculture that enhances food security.

Contribution/Originality: This study has been conducted to determine the soil fertility status and its possible sustainable agricultural packages. So, this study can take a new step by determining sustainable agricultural packages based on the soil fertility status of the research area.

1. INTRODUCTION

The foundation of all input-based high agricultural production methods can be found in the soil fertility status (Al-Zubaidi, Yanni, & Bashour, 2008; Parnes, 2013) . It provides the necessary physical conditions and nutrients for the growth and development of plants, (Foth & Ellis, 1997; Marschner, 2011; Velayutham & Bhattacharyya, 2000). Varying soils require different amounts of fertilizers, liming, irrigation, and tillage techniques depending on their fertility condition. An essential quality metric for sustainable agriculture is soil fertility. Sustainability is a top priority in agricultural production systems all over the world, but it is frequently jeopardized by the use of contemporary agricultural inputs, particularly artificial fertilizers. Some agricultural practices and high reliance on inorganic fertilizers have a negative impact on soil fertility. The primary factors of soil fertility are soil reaction (pH), organic matter (OM), and various macro and micronutrients. The availability of vital plant nutrients depends on the pH of the soil and the fundamental quality component for holding nutrients in the soil, which is organic matter. Additionally, organic matter is a source of plant nutrients, particularly nitrogen, and it also has a lot of phosphorus (Tyler & Olsson, 2001). In order to secure the production of sufficient quantities of nutritious food at reasonable prices for the world population's expanding requirements, sustainable agriculture entails all of the systems and practices that will enhance the conservation of the environment and natural agricultural resources. Sustainable agriculture does not necessitate total self-sufficiency. The priority that should be placed on the conservation of agricultural regions and natural resources is to apply each application in agriculture in the simplest, most cost-effective, and quickest manner possible. However, Bangladesh's soils are heavily farmed, with rice as the principal crop. To feed the population's continued growth, crops like wheat, potatoes, jute, mustard, sugarcane, and tomatoes are also farmed. As the population of Bangladesh grows daily, so does the demand for food. The farmers in Bangladesh have a formidable challenge in trying to meet the rising demand for food. By using excessive amounts of chemical fertilizers and pesticides as well as increasing cropping intensity, our nation's farmers are desperately attempting to enhance crop yields. When a particular fertilizer is applied in excess, it may make other nutrients in the soil less available to plants. Additionally, excess nutrients may be carried from crop fields to water bodies, the atmosphere, etc., where they become pollutants of the environment. To improve soil health, forecast prospective crop productivity, and manage the soil environment for sustainable agriculture, it is important to determine the size of the nutrient pool in the soils. Thus, it is essential to know the nutrient status of soil for maintaining optimal and balanced nutrient levels for the production of sustainable crops and to stop the transfer of nutrients from farmed soil to surface water, which contributes to environmental contamination. In view of the above discussion, the present study was conducted to evaluate the nutrients status of soils for determining the fertility status of that soils and to identify appropriate sustainable agricultural packages for enhancing food security.

2. MATERIALS AND METHODS

A laboratory study was conducted to assess the fertility status of twenty one soil series in Bangladesh.

2.1. Site Selection

The site of the study was selected based on different combinations of soil type (such as non-calcareous floodplain soil, calcareous soil, black terai soil, and sandy soil), as well as land type in Bangladesh.

2.2. Selection of Soil Series

In most of the cases, the soil series were identified with the help of the expert personnel from Soil Resource Development Institute (SRDI). Name of the soil series along with locations, land type and cropping pattern is given in Table 1.

2.3. Soil Samples Collection and Preparation

A number of thirty composite soil samples were taken from farmer's fields of twenty one soil series in different parts of Bangladesh, focusing on the rice-based cropping pattern. At first fifteen (0-15 cm depth) soil samples from each location were collected by means of an auger for making a composite sample. The collected soil samples were then carried to the laboratory, air dried, ground to pass through 2-mm sieve to remove debris and large aggregates. Then a composite soil sample was prepared by mixing the sieved soil samples. The laboratory analyses of soil were made after preparing all the thirty composite samples.

Table 1. Morphological description of different soil series

S. No	Soil series	General soil type	USDA taxonomy*	Location	Land type	Cropping pattern
01	Sonatala	Non-calcareous floodplain soil	Aeric Haplaquept	BAU farm, Mymensingh	Medium low land	Boro-F- T. Aman
				BAU farm, Mymensingh	Medium high land	Boro-F- T. Aman
				Village: Katlasen, Upazila and dist.: Mymensingh	Medium high land	Veg.-F-T. Aman
				Village: Mograpara, Upazila: Sonargoan, Dist.: Narayangonj	Medium low land	Rice-F-F
				Village: Mograpara, Upazila: Sonargoan, Dist.: Narayangonj	Medium low land	Rice-F-F
				Village: Ragendrapur, Upazila: Netrokona Sadar, Dist.: Netrokona	Medium high land	Rice-F-rice
02	Sherpur	Sandy soil	Aquic Eutrochrept	Village: Anondipur, Upazila and dist.: Mymensingh	High land	Veg-F-T. Aman
03	Ghatail	Non-calcareous floodplain soil	Aeric Haplaquept	Village: Katlasen, Upazila and dist.: Mymensingh	Low land	Rice-rice/F-rice
04	Balina	Non-calcareous floodplain soil	Mollic Haplaquept	Village: Batipar, Boror char, Upazila and dist.: Mymensingh	Very low land	Rice-F-F
05	Melandaha	Non-calcareous floodplain soil	Aeric Fluvaquent	Village: Sirta Nowapara, Upazila and dist.: Mymensingh	Medium high land	Rice-F-rice
06	Gorargaon	Non-calcareous floodplain soil	Typic Haplaquept	Bausia Bill, Bazitpur Char, Nilokhia, Mymensingh sadar Upazila and dist.: Mymensingh	Very low land	Rice-F-F
07	Silmondi	Non-calcareous floodplain soil	Aeric Haplaquept	Village: Katlasen, Upazila and dist.: Mymensingh	Medium low land	Boro -Aus/F-T. Aman
				RARS, Jamalpur Sadar, Dist.: Jamalpur	Medium high land	Rice/F-F-rice
				Village: Boro Nondura, Upazila: Netrkona Sadar, Dist.: Netrokona	Medium low land	Rice-F-rice
				Village: Mograpara, Upazila: Sonargoan, Dist.: Narayangonj	Medium low land	Rice-F-F
08	lshordi	Calcareous soil	Aeric Haplaquept	Upazila and dist.: Faridpur	Medium low land	Boro-F- T. Aman.
09	Raipur**	Non-calcareous floodplain soil	-	Village: Giarchar, Upazilla: Raipur, Dist.: Laxmipur	Medium low land	Boro-F- T. Aman
10	Dhamrai	Non-calcareous floodplain soil	Typic Haplaquept	Village: Sirta Nowapara, Upazila and Dist.: Mymensingh	Medium low land	Rice-F-F
11	Jamun	Sandy soil	Typic Haplaquept	Village: Vatgao, Upazilla: Kahrul. Dist.: Dinajpur	High land	Wheat/maize-F-T. Aman or Potato-Boro-F-T. Aman or Boro-F-T. Aman
12	Ranisankail	Sandy soil	Udic Ustochrept	Village: Vatgao, Upazila: Kahrul, Dist.: Dinajpur	High land	Potato-potato-maize
		Non-calcareous floodplain soil		Village: Sonahar, Upazilla: Debigonj, Dist.: Panchaghor	Medium high land	F-rice-rice or Potato-fallow/jute-T. Aman

13	Ruhea	Black terai soil	Entic Haplumbrept	Upazila: Panchagor Sadar, Dist.: Panchagor	High land	Wheat/ sugarcane oilseed/ groundnut-F- T. Aman
14	Karail	Non-calcareous floodplain soil	Cumulic Hamaquept	Village: Borbila, Upazila: Fulbaria, Dist.: Mymensingh	Medium low land	Boro -Fallow-Fallow
15	Tarakanda	Non-calcareous floodplain soil	Typic Fluvaquent	Village: Modhupur, Upazila: Fulphur, Dist.: Mymensingh	Medium high land	F-F-rice
16	Atwari	Black terai soil	Typic Haplumbrept	Upazila: Panchagor Sadar, Dist.: Panchagor	High land	Wheat-Fallow-T. Aman
17	Gangachara	Non-calcareous floodplain soil	Typic Haplaquept	Village: Arathinyamat, Upazila: Gongachora, Dist.: Rangpur	High land	Fallow-Aus-T. Aman
18	Pirgachha	Sandy Soil	Udic Ustocherpt	Village: Dhobadanga, Upazila and dist.: Nilphamari	Medium high land	Boro-F- T. Aman
19	Sulla	Non-calcareous floodplain soil	Typic Haplaquept	Village: Boroitola, Upazila: Karimgonj, Dist.: Kishoregonj	Very low land	Boro-F-F
20	Birampur**	Non-calcareous floodplain soil	-	Village: Larairchar, Upazila: Faridgonj, Dist.: Chandpur	Medium high land	Boro-F- T. Aman; occasionally potato or mustard before boro
21	Gopalpur	Calcareous soil	Aquic Eutrocherpt	Upazila and dist.: Faridpur	Medium high land	Boro-F- T. Aman

Note: *After Zijevelt (1980); **Series name not confirmed; F means fallow, dist. means district and veg. means vegetables, USDA means United States Department of Agriculture.

2.4. Analysis of Soil Samples

Following the standard procedure outlined below, the various soil parameters, including particle size distribution, soil texture, particle density, pH, organic matter, total nitrogen, available phosphorus, exchangeable potassium, and available sulphur were examined to assess the fertility status.

2.4.1. Particle Size Distribution

The Hydrometer method was used to determine particle size distribution (Bouyoucos, 1927). The percentage of sand, silt and clay was calculated by the following formula:

$$\% \text{ (Silt + Clay)} = \frac{\text{Corrected hydrometer reading after 40 seconds}}{\text{Dry weight of soil}} \times 100$$

$$\% \text{ Clay} = \frac{\text{Corrected hydrometer reading after 2hours}}{\text{Dry weight of soil}} \times 100$$

% Sand = 100 - % (Silt + Clay)

% Silt = % (Silt + Clay) - % Clay

2.4.2. Soil Texture

Following the United States Department of Agriculture (USDA) approach, the findings of sand, silt and clay of the collected soils were plotted on a triangular diagram (Marshal, 1947) to identify the textural classes.

2.4.3. Particle density

The volumetric flask method was used to determine particle density (Black, 1965). The following formula was used to determine the particle density:

$$\text{Particle density (PD)} = \frac{Ws}{Vs} \text{ g/cm}^3$$

Where,

Ws= Weight of the soil in "g"

V_S = Volume of soil solid in "cm^3".

2.4.4. Soil pH

The pH of the soil was measured using a glass electrode pH meter (Jackson, 1988). The ratio of soil and water was 1:2.5.

2.4.5. Organic Matter

Wet oxidation method was used to determine the organic carbon in the soil samples (Nelson & Sommers, 1982) and the usual Van Bemmelen factor of 1.73 was used to calculate the organic matter.

2.4.6. Total Nitrogen

Micro-kjeldahl digestion was used to calculate the total nitrogen content of the soil. The soil samples were digested using a catalyst mixture (K_2SO_4: Cu SO_4. $5H_2O$: Se =10:1:0.l) and 30% H_2O_2 and conc. H_2SO_4. The digest was distilled with help of 40% NaOH. Then titrating the distillate trapped in H_3BO_3 with 0.01 N H_2SO_4, it was possible to estimate the amount of N present in the mixture (Bremner & Mulvaney, 1982).

2.4.7. Available phosphorus

A 0.5 M $NaHCO_3$ solution with a pH of 8.5 was used to determine the soil's available phosphorus (Olsen, Cole, Watanabe, & Dean, 1954). The amount of phosphorus in the extract was then determined colorimetrically by producing a blue hue with $SnCl_2$ using a spectrophotometer at 660 nm wavelength.

2.4.8. Exchangeable Potassium

Ammonium acetate extraction technique was used to calculate exchangeable potassium (Peterson, 2002). 1N NH_4OAc solution was used to extract soil samples. The amount of exchangeable potassium in the extract was determined using a flame photometer and a standard curve made from potassium standard solutions of various concentrations.

2.4.9. Available Sulphur

The amount of available sulphur was determined using the calcium chloride (0.15%) extraction method (Williams & Steinbergs, 1959). Then the available sulphur content in the extract was estimated turbidimetrically with a spectrophotometer at 420 nm wavelength.

2.5. Statistical Analysis

The mean, range and standard error of the soil data were calculated following the methods of descriptive statistics.

3. RESULTS AND DISCUSSION

Particle size distribution, soil texture, particle density, soil pH, organic matter, total nitrogen, available phosphorus, exchangeable potassium, and available sulphur were some of the parameters analyzed to determine the fertility status of the collected soils. The possible packages for sustainable agriculture were created for the study region based on the information regarding soil fertility status. The results obtained from the present study are given and discussed below.

3.1. Particle Size Distribution

The particle size distribution of the soils of the study area is given in Table 2. The percentages of sand, silt, and clay in the collected soil series varied widely. To determine the relative proportions of sand, silt, and clay in the soils as well as the textural classes, a mechanical examination of the soils was carried out. The results showed that the percent contents of sand, silt and clay ranged from 2.0 to 65.8, 16.0 to 89.8 and 7.2 to 39.0, respectively.

3.2. Soil Texture

The majority of the research area's soils had a silt loam texture Table 2. The higher agricultural qualities of silt loam are a result of its lessened inclination to become loose and open (Weir, 1949). Silt loam soil is excellent for seed germination, easy to keep in the right tilt, has a high water holding capacity, and is permeable to roots. This soil might be highly productive if cared for properly.

3.3. Particle Density

It was discovered that only a small range, between 1.79 and 2.50 g cm^{-3}, was occupied by the particle density of soil samples Table 2. The Gangachara and Sherpur series had the highest particle density values due to low organic matter concentration, whereas the Karail series had the lowest values due to high organic matter content.

3.4. Soil pH

Nearly all of the major soil groups in the research area had acidic soil pH, with the exception of Sonatala-2, Sonatala-5, Silmandi-4, Gopalpur, Raipur, and Ishordi, which had soil pH levels higher than 6.5 (Table 3). Soil acidity is caused by a number of mechanisms over time, including the leaching of N fertilizers, crop removal of basic cations (Ca^{2+}, Mg^{2+} and K^{+}), breakdown of organic wastes, and H^{+} produced by Al^{3+}. The availability and solubility of vital plant nutrients are regulated by soil pH (Prasad & Power, 1997). Soil pH has to be better understood in terms of its nature and control.

Table 2. Particle size distribution, textural classes and particle density of the collected soils.

Soil series	Particle size distribution			Textural class	Particle density (g cm^{-3})
	Sand (%)	Silt (%)	Clay (%)		
Sonatala-1	4.4	77.2	18.4	Silt loam	2.19
Sonatala-2	12.7	73.3	14.0	Silt loam	2.36
Sonatala-3	14.8	72.0	13.2	Silt loam	2.43
Sonatala-4	4.8	74.0	21.2	Silt loam	2.07
Sonatala-5	5.8	78.0	16.2	Silt loam	2.04
Sonatala-6	19.4	65.0	15.6	Silt loam	2.43
Silmandi-1	10.0	66.8	23.2	Silt loam	2.33
Silmandi-2	13.4	58.0	28.6	Silty clay loam	2.08
Silmandi-3	21.8	71.0	7.2	Silt loam	2.17
Simandi-4	11.8	81.0	7.2	Silt	2.08
Ghatail	20.8	43.0	36.2	Clay loam	2.15
Melandaha	47.8	39.0	13.2	Loam	2.27
Dhamrai	27.8	57.0	15.2	Silt loam	2.21
Balina	24.8	64.0	11.2	Silt loam	2.14
Gorargaon	18.8	49.0	32.2	Silty clay loam	1.97
Karail	10.8	50.2	39.0	Silty clay loam	1.79
Sulla	4.7	69.3	26.0	Silt loam	2.09
Sherpur	48.0	42.8	9.2	Loam	2.50
Tarakanda	59.8	30.0	10.2	Sandy loam	2.24
Jamun	44.8	46.0	9.2	Loam	2.33
Ranisankail-1	65.8	23.0	11.2	Sandy loam	2.47
Ranisankail-2	76.4	16.0	7.6	Loamy sand	2.36
Gangachara	32.4	56.0	11.6	Silt loam	2.50
Pirgachha	52.4	40.0	7.6	Loam	2.26
Ruhea	65.8	23.0	11.2	Sandy loam	2.29
Atwari	57.8	30.0	12.2	Sandy loam	2.36
Gopalpur	26.4	66.0	7.6	Silt loam	2.46
Ishordi	19.8	64.0	16.2	Silt loam	2.16
Raipur	4.0	78.8	17.2	Silt loam	2.44
Birampur	2.0	89.8	8.2	Silt	2.45
Range	2.0 to 65.8	16.0 to 89.8	7.2 to 39.0	-	1.79 to 2.50
SE (±)	2.02	1.79	1.12	-	0.051

Note: SE (±) means standard error

3.5. Organic Matter

Based on its concentration in the soil, the organic matter contents in the collected soil series were categorized from very low to high (Anon, 1997). The collected soils had an organic matter level ranging from 0.60 to 3.65% (Table 3). It might be due to extensive cultivation and agricultural residue removal from the land. Organic matter aids in controlling soil pH, which has a significant impact on the availability of nutrients (Prasad & Power, 1997). A soil should have at least 4% organic matter in order to be productive (Gregorich, Monreal, Ellert, Angers, & Carter, 1993). However, the organic matter status in some soils of the study area was less than 1.5%, and even less than 1% (Anon, 1997). The lack of organic matter has a negative impact on soil tilth, soil water retention, soil erosion, infiltration of air and water, and the fate of pesticides applied to soils (Gregorich et al., 1993) which impacts environmental health and crop output.

3.6. Total Nitrogen

The total nitrogen content of all the collected soil series ranged from 0.04 to 0.19% Table 3). The soil series from Karail and Pirgachha had the highest and lowest total nitrogen contents, respectively. The total nitrogen contents of the collected soil series' except Karail were extremely low to low (Anon, 1997). This is a result of N losses as well as poor organic matter composition. Leaching, surface runoff, denitrification, and ammonia volatilization are some of the common ways that nitrogen is lost, all of which pollute the environment. Therefore, a full dose of N fertilizer should be administered in two separate applications to meet the N requirements of each crop in the cropping pattern and to reduce nitrogen losses as well as environmental pollution in the study area.

3.7. Available Phosphorus

The available phosphorus content of the soils in the research area ranged from 2.82 to 22.18 ppm (Table 3), falling between a very low and medium level (Anon, 1997). In acid soils with Fe (Fe^{3+}) and Al (Al^{3+}) where pH declines below 5.5 (Tisdale & Nelson, 1975) phosphorus forms less soluble compounds (Prasad & Power, 1997). The average amount of phosphorus in Bangladeshi soil solution is 0.05 ppm, but there are large variations between soils. The amount of phosphorus in soil that is organically bound ranges from absolutely insignificant to 1000 ppm (Anon, 1997). The phosphorus availability decreases in the winter due to the cold weather while increasing in the summer (Anon, 2002). When the entire dose of phosphorus is applied for the winter crop, this helps to reduce phosphorus application in the second and third crops of the cropping pattern by up to 30–60% (Anon, 2002).

3.8. Exchangeable Potassium

The exchangeable potassium content in the collected soil series was primarily low to medium level (Anon, 1997) and ranged from 0.09 to 0.26 meq/ 100g soil (Table 3). Balina, Gorargaon, and Silmandi-4 soil series were determined to have the highest and lowest exchangeable potassium contents, respectively. The majority of the potassium in Bangladeshi soils is adsorbed on clay and humus particles in high land soils, preventing it from being extensively leached. About 25-35% of the total potassium can be reduced in the subsequent crops after potato, tobacco, sugarcane, vegetables, and spices are grown with high doses of potassium fertilizers (Anon, 2002).

3.9. Available Sulphur

The contents of available sulphur of the collected soil series were extremely low to medium level (Anon, 1997) and ranged from 2.90 to 20.30 ppm (Table 3). The soil series from Sulla and Sherpur had the highest and lowest available sulphur contents, respectively. The sulphur shortage is typically found in soils with low levels of organic matter and moderately to severely acidic soil reactions. Sulphur is abundant in organic matter, and in most soils, organic sulfate makes up roughly 90% of the total sulfate in the soil (Anon, 1997). In general, the soil response in the research area was acidic with little organic matter present. As a result, sulphur deficit exists in some regions (Anon, 1997). Sulphur deficiency could be the cause of chlorosis in plants. Grain crops hardly ever experienced the effects of sulphur deficiency. However, crops that commonly love sulphur, such as crucifers, oil seeds, and legumes, are susceptible to sulphur deficiency. Soil in the research region should be advised sulphur-containing fertilizer to prevent deficiency.

Table 3. Soil pH, organic matter, total nitrogen, available phosphorus, exchangeable potassium and available sulphur of the collected soils.

Series	Soil pH	Organic matter (%)	Total nitrogen (%)	Avail. phosphorus (ppm)	Ex. potassium (meq/100g soil)	Avail. sulphur (ppm)
Sonatala-1	6.24	2.18	0.13	5.46	0.12	15.4
Sonatala-2	6.60	1.71	0.10	3.54	0.11	8.00
Sonatala-3	6.35	0.98	0.05	21.78	0.11	17.5
Sonatala-4	7.03	2.29	0.11	7.80	0.19	6.40
Sonatala-5	6.61	1.65	0.12	20.78	0.17	15.5
Sonatala-6	5.57	1.36	0.09	5.28	0.13	5.20
Silmandi-1	6.24	1.90	0.09	11.34	0.11	6.20
Silmandi-2	5.68	1.39	0.10	7.62	0.25	15.00
Silmandi-3	5.70	1.11	0.08	10.26	0.13	7.90
Silmandi-4	7.10	1.63	0.10	15.34	0.09	9.50
Ghatail	6.20	2.43	0.12	7.38	0.18	10.70
Melandaha	5.15	1.81	0.09	6.50	0.23	5.10
Dhamrai	5.17	2.24	0.18	18.26	0.24	11.50
Balina	5.51	2.59	0.15	8.40	0.26	20.10
Gorargaon	5.55	3.53	0.18	9.18	0.26	11.90
Karail	5.54	3.65	0.19	6.14	0.21	15.00
Sulla	5.22	2.0	0.14	10.02	0.12	20.30
Sherpur	5.12	1.16	0.06	9.40	0.25	2.90
Tarakanda	5.52	0.91	0.05	6.48	0.14	6.40
Jamun	5.22	1.21	0.08	22.18	0.18	5.90
Ranisankail-1	5.28	1.25	0.07	10.00	0.18	12.00
Ranisankail-2	5.42	0.79	0.05	12.00	0.20	15.20
Gangachara	5.56	1.05	0.08	9.36	0.20	11.20
Pirgachha	6.10	0.60	0.04	11.94	0.20	17.50
Ruhia	5.54	2.60	0.13	11.24	0.13	11.40
Atwary	5.29	1.70	0.10	15.84	0.19	7.20
Gopalpur	7.58	2.04	0.15	4.80	0.24	13.80
Ishordi	7.86	2.58	0.12	8.40	0.24	18.70
Birampur	5.85	1.57	0.10	2.94	0.10	15.70
Raipur	6.61	1.87	0.10	2.82	0.14	16.40
Range	5.12 to 7.86	0.60 to 3.65	0.04 to 0.19	2.82 to 22.18	0.09 to 0.26	2.90 to 20.30
SE (±)	0.181	0.072	0.005	0.62	0.032	0.81

Note: SE (±) means standard error, avail. means available and Ex. means exchangeable.

3.10 Sustainable Agricultural Packages

The present study was conducted in order to create possible sustainable agricultural packages in the study area based on the soil fertility level. Sustainable agriculture primarily focuses on boosting soil productivity and minimizing the negative consequences of agricultural activities on the climate, soil, water, environment, and public health. The study area has very low to medium soil fertility levels. As a result, it is essential to apply fertilizer in a balanced and integrated manner to both improve soil fertility and lower environmental contamination. Due to low levels of organic matter, the soil samples had very low to low total nitrogen concentrations. These soils have low to medium levels of potassium, extremely low to moderate levels of available phosphorus and sulphur, and very low to moderate levels of available sulphur. In Bangladesh, fertilizer is applied in an extremely unbalanced manner, which has led to exhausted, deteriorated, and polluted soil. Crop leftovers are the primary source of soil organic matter in the collected soils. The sorts of crops grown, the amounts of root and shoot biomass, the style of residue management, etc. all affect the soil's organic matter content. Growing green manuring crops during fallow periods is advised whenever possible, and choosing high residue crops for crop rotation is also advised to boost the amount of organic matter in the soil. Fertilizers containing nitrogen have minimal to no after effects. However, fertilizers containing phosphorus and sulphur have significant after effects that are useful to succeeding crops. Therefore, balanced fertilizer recommendations based on cropping patterns and location are suitable for the research area. In addition to these, the best management strategies for preserving or enhancing agricultural output and a healthy environment in the research area include soil testing, crop rotation, crop-based fertilizer recommendations, and integrated pest management. These procedures can guarantee optimum crop growth and development, sufficient yields, and reduce harmful environmental consequences on the research area.

4. CONCLUSION

The fertility status of the research area appeared to be very low to medium, necessitating careful management in order to preserve soil fertility for increasing crop yield. Unquestionably, soil tests are important and ought to be prioritized as the finest management and decision making tool for sustainable agriculture which enhance food security. Hence, balance fertilizer requirements as learned through soil testing can be applied in order to increase the yield of different crops in the cropping pattern for enhancing food security of the research area.

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REFERENCES

Al-Zubaidi, A., Yanni, S., & Bashour, I. (2008). Potassium status in some Lebanese soils. *Lebanese Science Journal, 9*(1), 81-97.

Anon. (1997). *Fertilizer recommendation guide.* Dhaka, Bangladesh: Bangladesh Agricultural Research Council, Farm Gate.

Anon. (2002). *Land and soil utilization guide of Dimla Sub-District.* Bangladesh: Soil Resource Development Institute.

Black, C. A. (1965). Methods of soil analysis. Part I, American society of agronomy. In (pp. 1572). Wisconsin, USA: Madison.

Bouyoucos, G. J. (1927). The hydrometer as a new method for the mechanical analysis of soils. *Soil science, 23*(5), 343-354. https://doi.org/10.1097/00010694-192705000-00002

Bremner, J. M., & Mulvaney, C. S. (1982). Nitrogen-total. In: A.L. Page, R.H. Miller and D.R. Keeney (Eds.), Methods of soil analysis Part II. In (pp. 595-624). USA: American Society of Agronomy, Inc.

Foth, H. D., & Ellis, B. G. (1997). Soil fertility. In (pp. 290). USA: Lewis CRC Press, LLC.

Gregorich, E. G., Monreal, C. M., Ellert, B. H., Angers, D. A., & Carter, M. A. (1993). *Evaluating changes in soil organic matter. In: Acton D.F. (Ed.), A program to assess and monitor soil quality in Canada.* Ottawa: Agriculture Canada.

Jackson, M. L. (1988). Soil chemical analysis. In (pp. 45-82). London. UK: Constable and Co. Ltd.

Marschner, H. (2011). *Marschner's mineral nutrition of higher plants.* London, UK: Academic Press.

Marshal, T. J. (1947). Mechanical composition of soils in relation to field description of texture. Common Wealth of Australia, Council for Scientific and Industrial Research, Melbourne, Australia. *Bulletin, 224*, 20.

Nelson, D. W., & Sommers, L. E. (1982). Total carbon, organic carbon and organic matter. In: A.L. Page, R.H. Miller and D.R. Keeny (Eds.), Methods of Soil Analysis, Part II. In (2nd ed., pp. 539-580). Wiscosin: American Society of Agronomy and Soil Science Society of America.

Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular. In (Vol. 939, pp. 19). Washington, DC: US Department of Agriculture.

Parnes, R. (2013). *Soil fertility: A guide to organic and inorganic soil amendments.* Retrieved from http://creativecommons.org/licenses/bynd/3.0

Peterson, L. (2002). Analytical methods: Soil, water, plant material and fertilizer. In (pp. 45-47). Dhaka: Soil Resources Management and Analytical Services, Soil Resource Development Institute.

Prasad, R., & Power, J. F. (1997). *Soil fertility management for sustainable agriculture.* New York: CRC, Lewis Publishers, Boca Raton

Tisdale, S. L., & Nelson, W. L. (1975). Soil and fertilizer phosphorus, chapter 6, soil fertility and fertilizers. In (3rd ed., pp. 189-242). New York: Macmillan Publishing Company Inc.

Tyler, G., & Olsson, T. (2001). Concentrations of 60 elements in the soil solution as related to the soil acidity. *European Journal of Soil Science, 52*(1), 151-165. https://doi.org/10.1046/j.1365-2389.2001.t01-1-00360.x

Velayutham, M., & Bhattacharyya, T. (2000). *Soil resource management. Natural resource management for agricultural production in India. In: J.S.P. Yadav and G.B. Singh (Eds.).* Paper presented at the International Conference on Managing Natural Resources for Sustainable Agriculture.

Weir, W. W. (1949). *Soil science, its principles and practices.* Philadelphia, Pa. USA: J.B. Lippincott Co.

Williams, C., & Steinbergs, A. (1959). Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. *Australian Journal of Agricultural Research, 10*(3), 340-352. https://doi.org/10.1071/ar9590340

Zijevelt, N. F. W. (1980). Soil correlation tables for Bangladesh. In (pp. 64). Farmgate, Dhaka: FAO-UNDP Soil Survey Interpretation Project, Soil Resources Development Institute.