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RESEARCH PAPER

Development of a Color Chart for Determination of the Soil Organic Matter at Field Level

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ABSTRACT

Soil organic matter (SOM) plays pivotal roles in several soil ecosystem processes. It is very important to develop a rapid in-field and easy method for the farmers to measure soil organic matter at the field level. This experiment was carried out in the Department of Soil Science, Bangladesh Agricultural University (BAU), Mymensingh from September 2013 to March 2014 to develop a color chart for the rapid determination of soil organic matter at the field level in formulating efficient fertilizer recommendation for the farmers. Therefore, 47 soil samples were collected from different Agro Ecological Zones (AEZ) covering a sufficient range in texture, soil organic matter and pH for the development of the color chart. Furthermore, the developed color chart was validated by using a set of 16 newly collected soil samples. Thereafter, the organic matter content of the same set of soil was measured by the wet oxidation method, and the soils samples were subdivided into four groups based on the BARC (2005) classification of soil organic matter to compare with the soil organic matter measured by using newly developed color chart. The validation test showed that organic matter content as measured by color chart in 14 soil samples out of 16 matches well with the organic matter content measured by wet oxidation method representing an accuracy of 87.5%. However, further fine-tuning is necessary for the developed color chart with extensive validation using a large set of soil samples covering all AEZ, in wide ranges of soil types, management, and soil texture before recommendation to the farmers.

Key words: Color chart, soil organic matter, wet oxidation method, validation and soil texture.

Introduction

Soil organic matter (SOM) is any material produced originally by living organisms (plant or animal) that is returned to the soil and goes through the decomposition process. At any given time, it consists of a range of materials from the intact original tissues of plants and animals to the substantially decomposed mixture of materials known as humus. SOM consists of a variety of components. These include, in varying proportions and many intermediate stages, an active organic fraction including microorganisms (10–40 %), and resistant or stable organic matter (40–60 %), also referred to as humus (FAO, 2005). Forms and classification of soil organic matter have been described by Tate (1987) and Theng (1987). For practical purposes, organic matter may be divided into aboveground and belowground fractions. Aboveground organic matter comprises plant residues and animal residues; belowground organic matter consists of living soil fauna and microflora, partially decomposed plant and animal residues, and practical purposes humic substances. SOM is generally used to indicate the total of all organic components present in soil, including living organisms.

Physical, chemical, and biological processes occurring in soils are greatly influenced by soil organic carbon (SOC) content. SOM has been shown consistently to have a large influence on soil physical properties within each textural group (Haynes *et al*., 1991). The importance of SOM in restoration of soil fertility and development of good soil structure has been widely studied (Palm *et al*. 1997, 2001). SOM is widely distributed over the earth's surface occurring in almost all terrestrial and aquatic environments (Schnitzer, 1978). Estimates of SOC are often required for a wide variety of agricultural, environmental, and engineering applications. Both quantitative and semiquantitative methods are available for SOC determination (Schumacher, 2002). Although quantitative methods for SOC are more accurate than semiquantitative methods, they are also typically more expensive and time consuming (Abella and Zimmer, 2007), making them impractical for applications requiring rapid analysis of a large number of samples. For such applications and applications where spatial variability in SOC is more critical than measurement accuracy, semiquantitative methods provide an attractive alternative to quantitative methods. Semiquantitative techniques for determining SOC are frequently faster, less expensive, and more readily adaptable for usage in the field.

Several semiquantitative methods are available for laboratory and in-field estimation of SOC. These include soil color measurements (Fernandez *et al*., 1988), loss-on-ignition (Konen *et al*., 2002), remote sensing (Chen *et al*., 2005), and nondestructive or destructive spectroscopic techniques (McCarty *et al*., 2002; Bowman *et al*., 1991). Selecting an appropriate semiquantitative SOC method can be challenging because each method has different advantages and disadvantages. Semiquantitative methods vary in measurement accuracy, degree of site specificity, applicability for large-scale use, and environmental friendliness. Most of the methods to determine SOC content are constrained by the time or required equipment, thereby limiting their use in determining soil organic carbon at field level. Therefore, it is very important to develop a rapid in-field and easy method for the farmers to measure SOM. It is a pre-requisite to develop a color chart for the development for such field level soil organic matter determination method to avoid the use of equipment and make it easy for farmers use. Therefore, the objective of this research work is:

- To develop of a color chart for determining SOM at field level for farmer.
- To validate the develop color chart by using anonymous soil samples.

Materials and methods

This experiment was carried out in the Department of Soil Science, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh from September 2013 to March 2014 to develop a color chart for the rapid determination of soil organic matter at the field level in formulating efficient fertilizer recommendation for the farmers.

Soil and site description

In total, 47 soil samples were collected from different districts of Bangladesh to represent typical rice based cropping patterns covering a sufficient range in texture, SOM, pH, and type of management. Fifteen sub-soil samples from a whole field of each location were collected at a depth of 5 cm from the surface using an auger and these samples were bulked and left to dry in air. Prior to the physico-chemical analysis of the soil samples, the air dried soils were broken apart and crushed by hand to pass through a 2-mm sieve. Soil series of the collected soil samples were identified in most of the cases, taking the help from the expert personnel of Soil Resources Development Institute (SRDI). Names of the Soil series, soil type location and cropping system history of sampled farmers fields are briefly summarized in Table1.

Table: 1 Soil series name, soil type, cropping system history of sampled farmer’s fields

Soil ID	Location	Soil Series	Soil type	Cropping Pattern
01	BAU farm, Mymensingh	Sonatola-1	Aeric Haplaquepts	B-F-T.A
02	BAU farm, Mymensingh	Sonatola-2	Aeric Haplaquepts	B-F-T.A
03	Larairchar, chandpur	Faridgonj	Aeric Haplaquepts	B-F-T.A
04	Larairchar, chandpur	Noakhali	Arent	B-F-T.A
05	Giarchar, Laxmipur	Ramgoti	Aeric Fluvaquents	B-F-T.A
06	Anondipur, Mymensingh	Sherpur	Aquic Eutrochrepts	V-F-T.A
07	Katlasen, Mymensingh	Silmondi-1	Aeric Haplaquepts	B-A-T.A
08	Katlasen, Mymensingh	Sonatola-3	Aeric Haplaquepts	V-F-T.A
09	Katlasen, Mymensingh	Ghatail	Aeric Haplaquepts	R-R/F-R
10	Batipar, Mymensingh	Balina	Mollic Haplaquepts	R-F-F
11	Nowapara, Mymensingh	Melandoho	Aeric Fluvaquents	R-F-R
12	Modhupur, Mymensingh	Tarakanda	Typic Fluvaquents	F-F-R
13	Mograpara, Narayangonj	Sonatola-4	Aeric Haplaquepts	R-F-F
14	Bazitpur, Mymensingh	Gorargao	Typic Haplaquepts	R-F-F
15	Bhaluka, Mymensingh	Noadda-1	Ultic Ustochrepts	F-F-R
16	Panchagor sadar, Panchagor	Ruhia	Entic Haplumbrepts	W-F-T.A
17	Mograpara, Narayangonj	Sonatola-5	Aeric Haplaquepts	R-F-F
18	Nowapara, Mymensingh	Damrai	Typic Haplaquepts	R-F-F
19	Vatgao, Dinajpur	Jamun	Aeric Haplaquepts	M-F-T.A
20	Faridpur	Ishordi	Aeric Haplaquepts	B-F-T.A
21	Vatgao, Dinajpur	Ranisankail-1	Udic Ustochrepts	P-P-M
22	Panchagor sadar, Panchagor	Atowary	Typic Haplaquepts	W-F-T.A
23	Faridpur	Gopalpur	Aquic Eutrochrepts	B-F-T.A
24	Jamalpur sadar, Jamalpur	Silmondi-2	Aeric Haplaquepts	B-F-T.A
25	Ragendrapur, Netrokona	Sonatola-6	Aeric Haplaquepts	B-F-T.A
26	Arathinyamat, Rangpur	Gangachhara-1	Typic Haplaquepts	F-A-T.A
27	Sonahar, Ponchaghor	Ranisankail-2	Udic Ustochrepts	P-J-T.A

28	Koichor, Bogra	Amnura	Aeric Albaquepts	P-M-T.A
29	Dhobadanga, Nilfamari	Gangachhara-2	Typic Haplaquepts	B-F-T.A
30	Koroitola, Mymensingh	Pritompasha	Typic Haplaquepts	F-F-T.A
31	Bristol, Kishoregonj	Sulla	Typic Haplaquepts	B-F-F
32	Netrokona sadar, Netrokona	Silmondi-3	Aeric Haplaquepts	B-F-T.A
33	Mograpara, Narayangonj	Silmondi-4	Aeric Haplaquepts	B-F-F
34	BADC farm, Tangail	Noadda-2	Ultic Ustochrepts	B-F-T.A
35	BADC farm, Tangail	Kalma	Aeric Albaquepts	B-F-T.A
36	Borbila, Mymensingh	Karail	CumulicHumaquepts	B-F-F
37	Netrokona sadar, Netrokona	Sonatola-7	Aeric Haplaquepts	V-V-T.A
38	Jamalpur pauroshava,	Jamalpur	Aeric Haplaquepts	R-F-R
39	Jamalpur pauroshava	Silmondi	Aeric Haplaquepts	R-F-R
40	Kendua, Jamalpur	Sonatala	Aeric Haplaquepts	M-R-R
41	Meshta, Jamalpur	Ghatail	Aeric Haplaquepts	P/M-R-R
42	Hamidpur, Jamalpur	Tejgaon	Aquic Ustochrepts	W-J-R
43	Chandra, Jamalpur	Chandra	Ultic-Albaquepts	R-F-R
44	Sahabajpur, Jamalpur	Khilgaon	Typic Haplaquepts	R-R-R
45	Sahabajpur, Jamalpur	Kalma	Aeric Haplaquepts	R-R-R
46	Lakshmirchar, Jamalpur	Brahmaputra alluvium	Typic Fluvaquents	V-V-F
47	Lakshmirchar, Jamalpur	Sherpur	Aquic Eutrochrepts	V-V-F

B=Boro, F = Fallow, T. A= T.Aman, V = Vegetable, A=Aus, R= Rice, W = Wheat, M=Maize, P = Potato, J = Jute

Soil Analysis

Mechanical Analysis

Mechanical analysis was done by hydrometer method (Buoyiucos, 1926) and the textural class was determined following "Marshall's Triangular Coordinates" using United States Department of Agriculture (USDA, 1993) system. Texture was expressed as percentage (%) of sand, silt and clay.

Soil pH

The pH-KCl was determined with the help of a glass electrode pH meter (Jackson, 1962) for all the collected soil samples. To determine the pH-KCl, 10 g of air-dried and sieved (<2 mm) soil was weighed in a 50 ml glass vase, 25 ml 1 M KCl was added and the suspension was well-mixed with the aid of a glass bar. After waiting for 10 min, the suspension was mixed again. Afterwards, pH-KCl was measured with a pH-electrode. The pH-H_2O was also determined following the same procedure while 25 ml water was added instead of 25 ml 1 M KCl. General soil properties of selected soils were given in Table 2.

Table 2 Physical and chemical properties of sampled soil series (Source: Kader *et al*., 2013)

SL No.	Soil series name	Soil Particles (%) Sand	Silt	Clay	USDA Soil Textural Class	pH
1	Sonatola-1	4±0	76±3	20±3	Silt Loam	5.99
2	Sonatola-2	13±1	73 ±1	14±3	Silt Loam	5.85
3	Faridgonj	14±0	79±1	7±1	Silt Loam	6.1
4	Noakhali	9±1	79±1	12±0	Silt Loam	6.63
5	Ramgoti	6±1	73±1	21±0	Silt Loam	6.29
6	Sherpur	49±0	40±0	11±0	Loam	5.49
7	Silmondi-1	14±1	59±1	27±3	Silty Clay Loam	6.1
8	Sonatola-3	15±0	66±3	19±3	Silt Loam	5.87
9	Ghatail	9±0	41±1	50±1	Silt Clay	5.9
10	Balina	17±3	48±0	35±3	Silty Clay Loam	5.95
11	Melandoho	21±1	63±1	16±0	Silt Loam	5.54
12	Tarakanda	78±0	14±0	8±0	Sandy Loam	5.66
13	Sonatola-4	7±4	61±1	32±6	Silty Clay Loam	6.2
14	Gorargao	18±3	39±1	43±4	Clay	5.95
15	Noadda-1	10±0	46±0	44±0	Silty Clay	5.49
16	Ruhia	62±0	27±1	11±1	SandyLoam	5.73
17	Sonatola-5	5±1	60±0	35±1	Silty Clay Loam	6.4
18	Damrai	15±0	60±0	25±0	Silt Loam	5.47
19	Jamun	31±0	56±0	13±0	Silt Loam	5.55
20	Ishordi	11±3	50±3	39±6	Silty Clay Loam	6.92
21	Ranisankail-1	60±1	25±1	15±3	SandyLoam	5.74
22	Atowary	41±0	37±1	22±1	Loam	5.85
23	Gopalpur	5±0	88±0	7±0	Silt	6.1
24	Silmondi-2	6±0	61±1	33±1	Silty Clay Loam	5.93
25	Sonatola-6	18±1	60±0	22±1	Silt Loam	5.75
26	Gangachhara-1	27±0	60±0	13±0	Silt Loam	5.77
27	Ranisankail-2	71±0	19±1	10±1	SandyLoam	5.8
28	Amnura	19±0	65±1	16±1	Silt Loam	5.88

29	Gangachhara-2	42±1	48±0	10±1	Loam	6.02
30	Pritompasha	17±0	48±0	35±0	Silty Clay Loam	5.67
31	Sulla	10±1	31±1	59±3	Clay	5.59
32	Silmondi-3	28±1	52±0	20±1	Silt Loam	5.78
33	Silmondi-4	16±0	68±0	16±0	Silt Loam	6.5
34	Noadda-2	24±0	50±0	26±0	Silt Loam	5.68
35	Kalma	10±0	60±0	30±0	Silty Clay Loam	6.13
36	Karail	20±0	48±0	32±0	Silty Clay Loam	5.75
37	Sonatola-7	29±0	62±3	9±3	Silt Loam	5.8
38	Jamalpur	13.6	64	22.4	Silt Loam	5.18
39	Silmondi	19.6	58	22.4	Silt Loam	5.06
40	Sonatala	27.6	64	8.4	Silt Loam	5.03
41	Ghatail	19.6	68	12.4	Silt Loam	4.58
42	Tejgaon	33.6	38	28.4	Loam	4.18
43	Chandra	21.6	64	14.4	Silt Loam	4.43
44	Khilgaon	21.6	64	14.4	Silt Loam	4.23
45	Kalma	19.6	64	16.4	Silt Loam	4.55
46	Brahmaputra	21.6	68	10.4	Silt Loam	4.63
47	Sherpur	45.6	44	10.4	Loam	4.73

nd= not determined

Organic matter

Organic matter was estimated by wet oxidation method as outlined by Black (1965) and the organic matter content was calculated by multiplying the percent carbon with the Van Bemmelen factor; 1.73 (Piper, 1950)

Total nitrogen

Total nitrogen of soil was determined by micro-Kjeldahl method where soil was digested with 3 ml concentration H_2O_2, 3 ml concentration H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4$, $5H_2O$ Selenium powder at the ratio of 10:1:0.1) Nitrogen in the digest was estimated by distillation with 40% NaOH followed by titration of distillate trapped in H_3BO_3 with 0.01N H_2SO_4 (Page *et. al.*, 1989).

Extractant and dilution ratio:

Soil organic matter of the sampled 47 soils and validated 16 soils were extracted by using NaOH+ Pyrophosphate + HCl extracts with a soil dilution ratio of 1:50 (Sabila, 2013). It was observed that the NaOH+ Pyrophosphate + HCl extracts are a colored solution and these colors are easily visible or detectable by the naked eye. More interestingly, it was found that the intensity of the color of soil extract increased with the increase of soil organic matter content.

Development of color chart

For the development of color chart, 0.25 mol L^{-1} NaOH + 0.1 mol L^{-1} $Na_4P_2O_7$. 10 H_2O (pyrophosphate) followed by 1 mol L^{-1} HCl extractant was used following Schnitzer (1982). An amount of 1g of air-dried soil was weighed into a 50-ml polypropylene centrifuge tube followed by the addition of 50 ml extractant solution for the ratio of 1:50 and shaken by hand for 15 to 20s at 1 min intervals for 5 min. The extracts were filtrated through 0.45 µm polycarbonate syringe filters. The soil extract was categorized into four groups by visual observation. Afterwards, the soils were sub-grouped into four groups based on the BARC (2005) classification of soil organic matter. According to this classification, soil containing <1, 1-1.7, 1.8-3.5 and >3.5% organic matter were classified as very low, low, medium and high organic matter content soil. The extracts were then also classified to the above mentioned four groups based on the visual observation of the extract color. Then, a color chart was developed based on the variations in intensity of color of the soil extracts. A colored chart was prepared for comparison and determination of extracted SOC. This color chart consists of 4 distinguish color panel that corresponds to <1 (very low), 1-1.7 (low), 1.8-3.5 (medium), and >3.5 % (high) soil organic matter.

Soil samples for validation

In total, 16 soil samples were collected from different places of Bangladesh to represent typical rice based cropping pattern covering a sufficient range in texture, soil organic matter, pH, and type of management. Fifteen sub soil samples from a whole field of each location were collected by means of an auger and these samples were bulked and left to dry in air. Prior to the physico-chemical analysis of the soil samples, the air dried soils were broken apart and crushed by hand to pass through a 2-mm sieve. Names of the soil type location and cropping system history of sampled farmers fields are briefly summarized in Table 3.

Table 3 Soil type, cropping system history of sampled farmer's fields

Soil ID	Location	Soil type	Cropping Pattern
01	Dhanbari, Tangail	Ultic Ustochrepts	B-F-M
02	BAU farm, Mymensingh	Aeric Haplaquepts	O-F-T.A
03	Kalihati, Tangail	Ultic Ustochrepts	B-F-M
04	BAU farm, Mymensingh	Aeric Haplaquepts	B-F-T.A
05	BAU farm, Mymensingh	Aeric Haplaquepts	B-F-T.A
06	BAU farm, Mymensingh	Aeric Haplaquepts	B-F-T.A
07	Dhanbari, Tangail	Ultic Ustochrepts	B-F-M
08	BAU farm, Mymensingh	Aeric Haplaquepts	W-F-T.A
09	Rangpur, BINA	Typic Haplaquepts	F-A-T.A
10	BAU farm, Mymensingh	Aeric Haplaquepts	O-F-T.A

11	BAU farm, Mymensingh	Aeric Haplaquepts	C-F-T.A
12	BAU farm, Mymensingh	Aeric Haplaquepts	C-F-T.A
13	Kalihati, Tangail	Ultic Ustochrepts	B-F-T.A
14	BAU farm, Mymensingh	Aeric Haplaquepts	B-F-T.A
15	BAU farm, Mymensingh	Aeric Haplaquepts	W-F-T.A
16	BAU farm, Mymensingh	Aeric Haplaquepts	P-F-T.A

B=Boro, F = Fallow, O=Onion, T.A= T.Aman, M=Mustard, W=Wheat, C=Carrot, P = Potato

Validation of the method for unknown soil

The developed colored chart was validated by using a set of 16 newly collected soil samples. First, the soil organic matter of the newly collected soil samples was extracted with NaOH+ Pyrophosphate + HCl extracts with a soil dilution ratio of 1:50 by using 0.5 g soil sample. Then the color of the soil extracts were compared with the newly developed color chart and categorized into either very low or low or medium or high organic matter content soil. The developed color chart consists of 4 distinguished color panels that correspond to <1 (very low) 1-1.7 (low), 1.8-3.5 (medium) and >3.5 % (high) organic matter as classified by BARC (2005) (Figure 4.2). Each color panel was again subdivided into 4 color panel to makes it easily comparable with soil extract by naked eye at farmers field.

Statistical Analysis

Data are presented as mean values ± standard deviations. Mean values were compared by performing one way analysis of variance (ANOVA), followed by Dunkan's Multiple Range Test (DMRT). The software used for statistical analyses was SPSS, Version 20. Color chart was developed by using a specialized photographic software named Adobe Photoshop, Version CS6.

Results

Soil Organic Matter and Nitrogen Content

Soil Organic Matter (SOM)

The %soil organic matter content of the soil series were shown in Table 4.1. The %SOM content of the studied soils showed a wide variation. The highest SOM value of 6.05 was found in Karail series and the lowest of 0.67 was found in Tarakanda series. The SOM content of the majority of studied soil series lies around 2% with an average value of 2.37±1.12%. Higher %soil organic matter content was found in those soils which were collected from low lying areas and having finer texture.

Nitrogen content

The % total N of the soil series were shown in Table 4. Likewise SOM content, % total N content of the studied soils also showed a wide variation. The highest % total N value of 0.317 was found in Gorargao series and the lowest of 0.036 was found in Gangachhara-2 soil series. The average % total N content of the studied soil series was 0.135±0.061%. Likewise total organic matter content, higher total N content was also found in those soils which were collected from low lying areas. Soils having higher clay content also showed higher total N content. In contrast, soil samples collected from high land and sandy areas showed lower total N content.

Table 4 Soil organic matter and nitrogen content of the sampled soil series

SL No.	Soil series name	Total N (%)	Soil organic matter (%)
1	Sonatola-1	0.206	3.67
2	Sonatola-2	0.169	2.80
3	Faridgonj	0.120	1.97
4	Noakhali	0.164	2.82
5	Ramgoti	0.155	2.55
6	Sherpur	0.091	1.60
7	Silmondi-1	0.162	2.83
8	Sonatola-3	0.099	1.62
9	Ghatail	0.224	3.64
10	Balina	0.193	2.62
11	Melandoho	0.093	1.40
12	Tarakanda	0.041	0.67
13	Sonatola-4	0.197	3.00
14	Gorargao	0.317	5.25
15	Noadda-1	0.101	1.57
16	Ruhia	0.161	3.17
17	Sonatola-5	nd	4.97
18	Damrai	0.185	2.92
19	Jamun	0.102	1.76
20	Ishordi	0.220	3.98
21	Ranisankail-1	0.076	1.92
22	Atowary	0.189	3.19
23	Gopalpur	0.088	1.31
24	Silmondi-2	0.133	2.13
25	Sonatola-6	0.127	2.08
26	Gangachhara-1	0.096	1.71
27	Ranisankail-2	0.069	1.11
28	Amnura	0.150	2.12

29	Gangachhara-2	0.036	0.72
30	Pritompasha	0.138	2.27
31	Sulla	0.239	2.97
32	Silmondi-3	0.124	1.84
33	Silmondi-4	0.140	2.25
34	Noadda-2	0.113	1.81
35	Kalma	0.149	2.48
36	Karail	0.274	6.05
37	Sonatola-7	0.076	1.40
38	Jamalpur	0.094	1.81
39	Silmondi	0.103	1.98
40	Sonatala	0.077	1.46
41	Ghatail	0.103	1.97
42	Tejgaon	0.067	1.30
43	Chandra	0.132	2.58
44	Khilgaon	0.141	2.73
45	Kalma	0.148	2.99
46	Brahmaputra alluvium	0.053	0.90
47	Sherpur	0.066	1.22

nd= not determined

Extraction of soil organic matter content

The sampled 47 soils were subdivided into four groups based on the BARC (2005) classification of soil organic matter to develop a color chart. According to this classification, soil containing <1, 1-1.7, 1.8-3.5 and >3.5% organic matter were classified as very low, low, medium and high organic matter content soil.

Sub-division of soil extract based on organic matter content

The sub-division of soil extract based on organic matter content as per BARC (2005) classification of soil organic matter is shown in Table 5. Soils of Brahmautra alluvium, Gangachhara-2 and Tarakanda series were fallen in very low (<1%) organic matter content. Soils of Sherpur, Sonatola-3, Melandoho, Noadda-1, Jamun, Gopalpur, Ranisankail-2, Sonatola-7, Sonatola and Tejgaon series were fallen in low (1-1.7%) organic matter content. Soils of Sonatola-1, Ghatail, Gorargoa, Sonatola-5, Ishordi and Karail series were fallen in high (>3.5%) organic matter content. Rest of the 28 soil series were fallen in medium organic matter content soil. The extracts were classified into the above mentioned four groups based on the visual observation of the extract color.

Table 5 Sub-division of soil extract based on soil organic matter content

Very low (< 1%)	Low (1-1.7%)	Medium (1.8-3.5%)	High (>3.5%)
Brahmaputra alluvium	Sherpur	Sonatola-2	Sonatola-1
Gangachhara-2	Sonatola-3	Faridgonj	Ghatail
Tarakanda	Melandoho	Noakhali	Gorargao
	Noadda-1	Ramgoti	Sonatola-5
	Jamun	Silmondi-1	Ishordi
	Gopalpur	Balina	Karail
	Ranisankail-2	Sonatola-4	
	Sonatola-7	Ruhia	
	Sonatala	Damrai	
	Tejgaon	Ranisankail-1	
		Atowary	
		Silmondi-2	
		Sonatola-6	
		Gangachhara-1	
		Amnura	
		Pritompasha	
		Sulla	
		Silmondi-3	
		Silmondi-4	
		Noadda-2	
		Kalma	
		Jamalpur	
		Silmondi	
		Ghatail	
		Chandra	
		Khilgaon	
		Kalma	

Sherpur

Development of Color Chart

As the intensity of the color of soil extract increased with the increase of soil organic matter content, therefore, a color chart was developed based on the variations in intensity of color of the soil extracts. For this purpose, 2- 4 soil extracts were selected from previously subdivided each group having a color gradient from the lowest intensity to the highest intensity. Then photograph was taken for each group of soil extract with a high resolution camera (Figure 1). Then a color chart was developed from this photograph by using a specialized photographic software named Adobe Photoshop, Version CS6. The developed color chart consists of 4 distinguish color panel that corresponds to <1 (very low) 1-1.7 (low), 1.8-3.5 (medium) and >3.5 % (high) organic matter as classified by BARC (2005) (Figure 2). Each color panel was again subdivided into 4 color panel to makes it easily comparable with soil extract by naked eye at farmers field

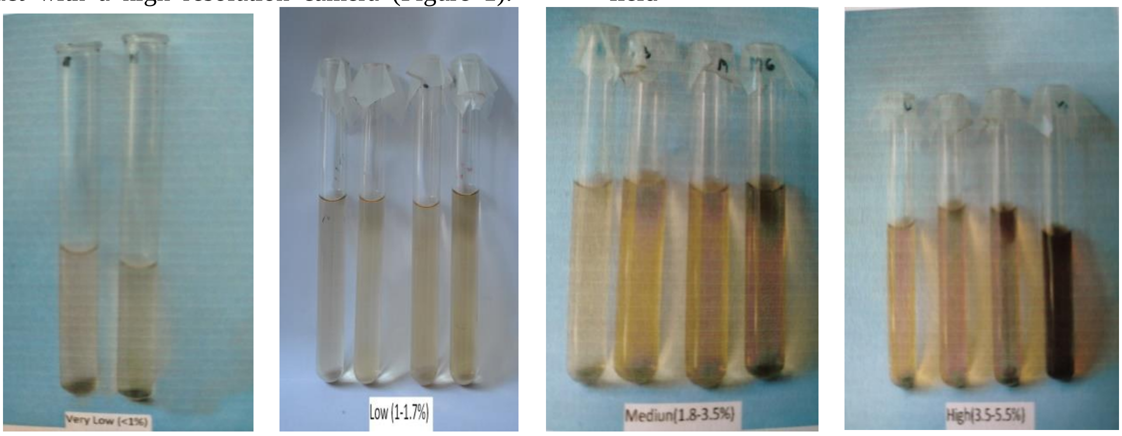

Fig. 1 Four sub-groups of soil extracts based on BARC (2005)

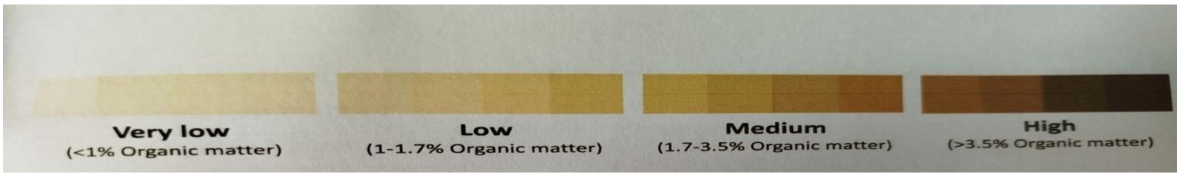

Fig. 2 Developed color chart

Validation of Color Chart

Five soil samples (2, 6, 10, 11 and12) out of 16 were fallen in very low (<1%) organic matter content. Another five soil samples (5, 7, 8, 9 and16) were fallen in low (1-1.7%) organic matter content. Rest of the six soil samples (1, 3, 4, 13, 14 and15) were fallen in medium organic matter content soil.

Thereafter, the organic matter content of the same set soil was measured by wet oxidation method and the soils samples were subdivided into four groups based on the BARC (2005) classification of soil organic matter to compare with the soil organic matter measured by using newly developed color chart. The soil samples have a wide range in organic matter content varied from 0.38-3.23% (Table 6). Fourteen, out of 16 soil samples match well with the organic matter content measured by both the wet oxidation and colorimetric methods. In colorimetric method, only there is an overestimation of organic matter content for soil sample no 4 (Graded medium instead of low) and underestimation of organic matter content for soil sample no 7 (Graded low instead of medium) (Table 6). Primary validation test showed that organic matter content as measured by color chart matches well with the organic matter content measured by wet oxidation method representing an accuracy of 87.5%.

Table 6 Comparison of organic matter results measured by colorimetric method with wet oxidation method

Sample no	Organic Matter content			Comments
	Wet oxidation method		Colorimetric method	
	Absolute OM value (%)	OM grade as per BARC	OM grade as per BARC	
1	3.2	Medium	Medium	
2	0.99	Very low	Very low	
3	1.93	Medium	Medium	
4	1.24	Low	Medium	
5	1.72	Low	Low	
6	0.90	Very low	Very low	
7	1.93	Medium	Low	
8	1.17	Low	Low	
9	1.10	Low	Low	Borderline
10	0.38	Very low	Very low	

11	0.69	Very low	Very low
12	0.76	Very low	Very low
13	1.79	Medium	Medium
14	3.23	Medium	Medium
15	3.16	Medium	Medium
16	1.51	Low	Low

Very low= <1% OM, Low=1-1.7% OM, Medium=1.8-3.5% OM and High=>3.5% OM

Discussions

The soil set (47 soil samples) used in this study for developing the method covered a wide range in organic matter content from 0.67 to 6.05%, a sufficient range in texture from sandy loam to clay, a wide variation in pH from 4.1 to 6.9 and a wide variation in land type from high land to very low land. The textural classes of the studied soils were mostly silt loam. This indicates that the soil set was a typical paddy soil of Bangladesh.

The soil extractant and soil dilution ratio were selected from a previous intensive study by Sabila (2013) where three extractants namely NaOH, NaOH + EDTA and NaOH + Pyrophosphate + HCl were tested with soil dilution ratio of 1: 50, 1: 100 and 1: 200 to select a suitable extractant and soil: extractant ratio for extracting organic matter from soil that produced a color solution. From that study it was observed that NaOH + Pyrophosphate + HCl solution was found as the best extracting solution at 1: 50 dilution. It was also observed that the NaOH+ Pyrophosphate + HCl extracts are a colored solution and these colors are easily visible or detectable by naked eye. More interestingly, it was found that the intensity of the color increased with the increase of soil organic matter content. Therefore, the selection of NaOH+ Pyrophosphate + HCl as soil extractant with soil dilution ratio of 1:50 for developing color chart was based on a strong scientific basis and well justified.

The newly developed color chart consists of 4 distinguish color panel that corresponds to <1 (very low), 1-1.7 (low), 1.8-3.5 (medium) and >3.5 % (high) organic matter as classified by BARC (2005). As the method is developed for Bangladeshi farmers and Bangladesh Agricultural Research Council (BARC) is the apex body for agricultural research, therefore, the classification of soil based on organic matter content by them (BARC) was adapted. It will make the method easy and user friendly as the result can be easily incorporated with other documents or other use. For an example, the organic matter result as determined by this method will easily match with the Fertilizer Recommendation Guide as developed and updated by BARC in a regular interval. It is assumed that farmers will use this method for the determination of the fertility level of their fields by determining the central indicator of soil fertility. This will be finally used for the formulation of fertilizer recommendation. Moritsuka *et al*. (2019) expressed that soil organic matter affected soil color parameters which conformity with the findings of the present study.

The developed color chart and the colorimetric method seem very promising from the preliminary validation test. The accuracy of soil organic matter determination at field level by 87.5% is quite good. Estimation of SOC through spectroscopic measurements and imaging of soil color at field level for cheaper and accurate predictions of SOC (Gholizadeh *et al*., 2020; Costa *et al*., 2020; Ferrando Jorge *et al*., 2021; Taneja *et al*., 2021). The present study was conducted for determining the SOM using color chart at field level for cheaper method and the accuracy level found 87.5% that is also good.

However, it needs further validation by using a large soil set covering different agro ecological region, wide range in land type and soil texture and organic matter content to find out the pro and cons of this method. Further fine-tuning of the color chart could be possible if needed to increase the accuracy of the measurement or to accommodate other type of soils. Further research also necessary to settled the practical aspects of this method for using the method at farmer's level. For an example, it is necessary to reduce the amount of soil from 0.5 gram to reduce the use of soil extractant. It will reduce the cost of measurement. If the method is further fine-tuned with an extensive validation using a large set of soil samples covering all AEZ, wide range in soil type, management and soil texture, it would be a very popular and low cost method for the rapid determination of soil organic matter at field level for efficient fertilizer recommendation to the farmers of Bangladesh as well as the rice growing South East and East Asia.

Conclusion

An attempt was made to search a suitable color chart for the development of a low cost method for the rapid determination of soil organic matter in formulating efficient fertilizer recommendation for the farmers at field level. This investigation was carried out in the Department of Soil Science, BAU, Mymensingh from September 2013 to March 2014. Soil organic matter of the sampled 47 soils was extracted by using NaOH+ Pyrophosphate + HCl extracts with a soil dilution and observed that the NaOH+ Pyrophosphate + HCl extracts are a colored solution and these colors are easily visible or detectable by naked eye. More interestingly, it was found that the intensity of the color of soil extract increased with the increase of soil organic matter content. Therefore, the sampled 47 soils were subdivided into four groups based on the BARC (2005) classification of soil organic matter to develop a color chart. Then photograph was taken for each group of soil extract with a high resolution camera. Then a color chart was developed from this photograph by using a specialized photographic software named Adobe Photoshop. Furthermore, the developed colored chart was validated by using a set of 16 newly collected soil samples. Thereafter, the organic matter content of the same set soil was measured by wet oxidation method and the soils samples were subdivided into four groups based on the BARC (2005) classification of soil organic matter to compare with the soil organic matter measured by using newly developed color chart. The validation test showed that organic matter content as measured by color chart in 14 soil samples out of 16 matches well with the organic matter content measured by wet oxidation method representing an accuracy of 87.5%.

However, further fine-tuning is necessary of the developed color chart with an extensive validation using a large set of soil samples covering all AEZ, wide range in soil type, management and soil texture before recommendation to the farmers.

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