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Development of analytical method for soil organic carbon, rapid, reliable, user-friendly and economical for remote areas

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Summary

Numerous standard methods are already exist for determining soil organic carbon and each method has its own advantages and disadvantages. In present study we tried to develop a "modified colour matching method" that is rapid, reliable, user-friendly, safe, time-efficient and economical for determinations of oxidizable organic carbon (OOC) in agricultural soils. Analysis of OOC of 136 numbers of soil samples were determined by 'Walkley and Black wet oxidation method' (Walkley and Black, 1934) and 'Modified colour matching method'. In the proposed method soil organic carbon is determined using 2.5 ml potassium dichromate solution with 2 ml (1.25:1) concentrated sulphuric acid. The data obtained by using the proposed method correlated strongly with the data obtained by wet oxidation Walkley and Black method. New modification safeguards the objectivity of results; since it gives the mean value of Z-test for two samples were 0.190 which is non-significant at 5% level of significance. The OOC value of a given soil sample determined by two methods did not differ largely. Maximum difference was 0.32 units and 2.9% of the total sample had no difference. In fact, 45.6, 27.2, 18.4, 3.7 and 2.2% of total sample showed the differences of 0.01-0.05, 0.06- 0.10, 0.11-0.15, 0.16-0.20 and >0.2 units, respectively. This method not only reduces the cost but it can be sufficed at remote places where soil testing laboratory are not available so, it can be easily accommodated in soil testing kit.

Key words : Oxidizable organic carbon, Colour matching method, Soil testing kit, Cost efficient

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Introduction

Soil testing is an indispensable tool for crop production in different soils. The nutrient status of soil is an important criterion to judge the production potential. This study demonstrates the benefits of using 'colour matching methods' for rapid, reliable and accurate soil organic carbon (SOC) determination in agricultural soils (Tamang, 2007). In developing nation like India most of the farmers are indiscriminately using fertilizers without knowing the soil test values. Subsequently, numerous problems have been arises in agricultural soils, *i.e.* nutrients built up like phosphorus and potassium in soils (Hubert Tunney *et al.,* 2003 and Sen, 2001), deficiency of some elements like sulfur (Basak *et al.,*2002), soil acidification, decrease in organic matter content' (Chatterjee *et al.*, 2006), incidence of soil borne diseases, soil pollution etc. in addition to declining yield with high cost of production. The SOC participates in many biological, chemical and physical soil properties. For this reason the SOC is one of basic parameters of soil fertility and it also influences non-production soil functions. The soil organic carbon currently is a key indicator of soil quality. Being the fundamental parameter of soil, it directly or partially influenced many soil characters. Now its quick estimation can also give us general idea about nitrogen status by C:N ratio. Hence, it is befall essential to provided with soil testing services for all farmers. Large country like India has shortfall of soil testing services to all the farmers, as because it is highly expensive. But, indubitable, the crop production without soil testing is alarming. So, in such situation an attempt may be taken to provide soil testing services by soil testing kits in areas where soil testing laboratories are not available.

In the proposed method soil organic carbon is determined using 2.5 ml one normal potassium dichromate solution as an oxidizing agent for 1 g of dry soil (1:2.5). The data obtained using the proposed method correlated strongly with the data obtained by Walkley and Black (1934) titration methods. Now, to make a soil testing kit of high quality a colour matching method for determination of soil organic carbon (Basak and Das, 2003) was further modified for its economical aspect, rapid, reliable, user-friendly, safe and time-efficient was essential. This study aimed at evaluating the analytical procedures used in the determination of organic carbon and their advantages in remote areas. Thus, in the present study this method was compared with standard method of Walkey and Black (Piper, 2005 and Jackson, 2014) that is followed in the all soil testing laboratories.

Resource and Research Methods

Laboratory trials for development of "modified colour matching method" was conducted during 2010 to 2011 at department of Agriculture Chemistry and Soil Science, Bidhan Chandra Krishi Viswavidalaya, Mohanpur, West Bengal. One hundred thirty six (136) numbers of composite soil samples were collected from plough layer (0 – 15 cm depth) from different locations in Terai zone of West Bengal. These soil samples were properly labeled and brought to the laboratory. All the visible plant and animal residues were removed from soil samples and then dried thoroughly in shade, pulverized and sieved through 0.5 mm mesh sieve. The SOC was determined by two methods, namely, 'Walkley and Black method' (Walkley and Black, 1934) and 'color matching method' (Basak and Das, 2003). The difference of soil OOC values of each soil sample obtained by two methods was studied. For all methods three replicates were used.

On the basis of soil testing results obtained by methods that are used in soil testing laboratories in India, the soils were group into different categories that are followed in West Bengal (Bhattacharyya, 1998 and Ali, 2005) as follows:

Table A: Rating of oxidizable organic carbon in laboratory methods

Oxidizable organic carbon (%)	Rating
Above 0.75	High
0.50 – 0.75	Medium
Below 0.50	Low

Methodology used:

Walkley and Black method (Walkley and Black, 1934):

The soil sample is pass through a 0.5 mm mesh sieve, was placed in a 500 ml Erlenmeyer flask. Ten milliliters of one normal potassium dichromate ($K_2Cr_2O_7$) and 20 ml of concentrated sulfuric acid (H_2SO_4) were added to the soil while stirring it to ensure good mixing of the soil with the reagents. After a 30-min rest 200 ml of distilled water, 10 ml of concentrated H_3PO_4 and 1 ml of diphenylamine were added. The excess dichromate that was not reduced in the reaction was determined by volumetric titration using ammonium ferrous sulfate [$Fe(NH_4)_2 (SO_4)_2 6H_2O$)] (Mohr's salt).

Table B : Rating of oxidizable organic carbon value in color matching methods

Colour developed	% Oxidizable organic carbon	Rating
Yellow crimson	0.001-0.300	Low
Yellow crimson with tinge of light green	0.302-0.400	Low
Yellow crimson with tinge of deep green	0.407-0.500	Low
Greenish crimson	0.505-0.600	Medium
Deep greenish crimson	0.603-0.700	Medium
Mixture of deep viridian green and deep hookers green	0.705-0.800	Tends toward high
Deep viridian green	0.803-1.00	High

Methodology developed (Modified):

Colour matching method:

Composite soil samples were collected from plough layer (0 – 15 cm depth), subsequently plant and animal residues were removed and then the samples are sieved through 0.5 mm sieve. Developed method is as follows: In a graduated test tube 1 g of soil sample is added. Two and half ml (2.5 ml) of one normal potassium dichromate ($K_2Cr_2O_7$) solution is added to the tube. Two ml of concentrated sulfuric acid (H_2SO_4) were also added to the soil than. Stir gently for good mixing of the soil with the reagents.The tube was kept standing for 15 minutes to complete the oxidation process. The colour of the supernatant liquid is compared with chart to find out the nearest matched value.

Statistical analysis:

Statistical analysis was performed using the R 3.5.0 statistics computing software (*https://www.r-project.org/*).

Research Findings and Discussion

We tried to establish easy, time efficient, less economical and user friendly method for determination of oxidizable organic carbon. The newly developed method for determination of oxidizable organic carbon is user-friendly, safe, time-efficient and economical is evidently reflects in result. The result of colour matching method is compared with the internationally standard Walkley and Black method (Basak, 2006). Organic carbon values of a given soil sample determined by two methods did not differ largely. The OOC content varied from 0.32 to 1.45% in this region which is almost diverse range for SOC value. Maximum difference found was 0.2 unit for all the sample analyzed by two methods. This results also corroborated the earlier findings obtained by Ghosh *et al*. (2002); Basak and Das (2003) and Kumari and Basak (2006). Out of the total sample analyzed 26, 70 and 40 number of samples fall under the category of low, medium and high, respectively (Table

Table 1: Mean difference of total sample under different rating category

Rating value	Total number of samples	Oxidizable organic C (mean value)		
		Walkley black method % C	Colour matching method % C	Difference in method
Low	26	0.43	0.41	0.02
Medium	70	0.61	0.62	0.01
High	40	0.94	0.92	0.02
Mean	136	0.66	0.65	0.01

Table 2: Difference of soil OOC values determined by two methods

Differences of OOC values	Number of samples	% of total samples
0	4	2.9
0.01 – 0.05	62	45.6
0.06 – 0.10	37	27.2
0.11 – 0.15	25	18.4
0.16– 0.2	5	3.7
> 0.2	3	2.2
Total	136	100

1). This table represents the whole range of SOC values which is essential for agricultural practices. Undoubtedly, the mean difference by both the analytical methods under different categories *i.e*. low, medium and high SOC is 0.02, 0.10 and 0.02 units, producing overall mean difference 0.01 is negligible. That signifies the analytical advantages of modified methods in all conditions of soil organic carbon status, which gives us similar value as per the other laboratory methods.

The differences in OCC values analyzed by both method were categorized into six classes from zero (0) unit to more than 0.2 units (Table 4). It seems 2.9% of total sample had no difference in OOC determined by the this two methods. Maximum samples 45.6% fall under the category differences of 0.01 – 0.05 unit values. Again, out of the total samples 27.2, 18.4, 3.7 and 2.2% showed the differences of 0.06 – 0.10, 0.11 – 0.15, 0.16 – 0.20 and >0.2 units, respectively **(**Fig. 1). In point of fact a difference of 0.20 unit or less can not largely change the crop growth and yield. Thus, for agricultural practices such as, organic matter status, selection of fertilizers particularly nitrogen following the normal C: N ratio and their application methods the modified colour matching method is reliable (Basak and Das, 2003) and can be used in areas where soil testing laboratories are not available (Devdas *et al.*, 2013). Similar work on soil testing towards sustainable agriculture and land management on farmer beliefs and attitudes was also done by Singh *et al*. (2013). This method can be accommodated in soil testing kits in very cheap amount. Usually this method is followed in soil testing kit. Das (1998) had also developed the colour matching method for determination of oxidizable organic carbon of a soil and later, its efficiency was validated by Sen (2001).

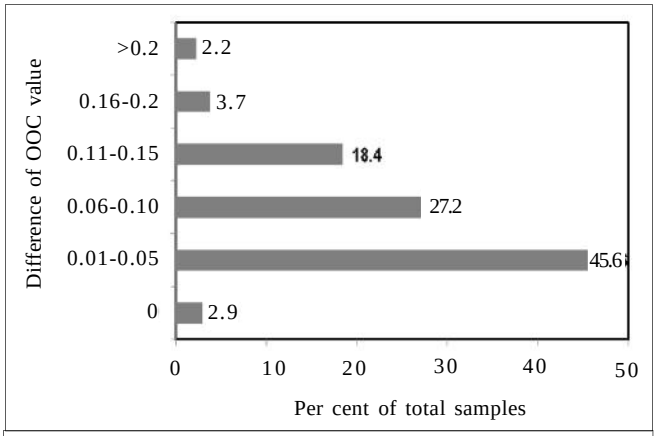

Fig. 1: Frequency distribution of OC values determined by two methods

We assess OOC by the colour matching method and the Walkley and Black method. The colour matching method is compared with Walkley and Black method which is internationally adapted in laboratories for determining OOC. Indeed there was suitable variation of OCC values within the soil samples analyzed from 0.32 to 1.45% which almost signifies all category of organic carbon status *i.e*. low, medium and high (Bhattacharyya, 1998 and Ali, 2005). It seems maximum number of soil sample *i.e*. sixty two analyzed by both methods had relative difference of 0.01-0.05 units (Fig. 2). Among the all sample analyzed only three (3) numbers of samples had more than 0.2 unit difference which is around 2 % of total samples. Two per cent of samples is negligible in terms of manual method were no modern instrument is used (Mitra,1999).

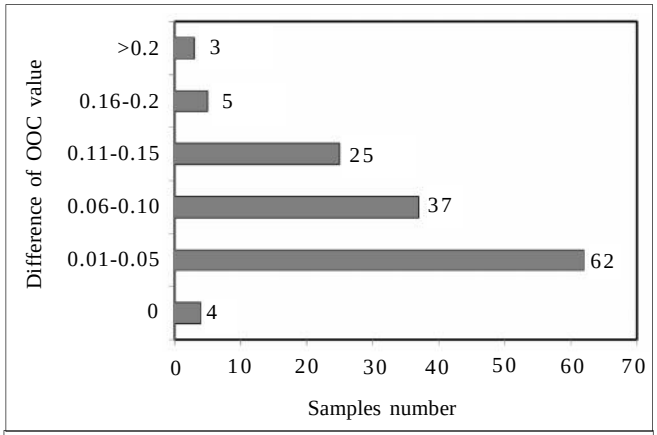

Fig. 2: Number of samples falls under different unit values determined by two methods

Thereafter the two methods namely colour matching method and Walkley-Black method are tested by using Z-test (Table 3). The value of Z-Statistics (0.190) is found to be non-significant at 5% level of significance which indicates that two methods for estimation of OCC are same which gives similar output values.

This method is not much complicated for analysis with less chemical and materials required as compare to the laboratory methods. The man power requires is less than a half for analysis of same samples (Table 3). Moreover, one trained person can analyzed nearly 70-80 samples per day as compare to laboratory methods where 30-35 samples per day can be completed with well-trained persons like Scientist, Research Scholar and Laboratory Assistant etc. It's very much justified that

Table 3 : Two sample Z-test for method comparison

	Walkley black method % C		Color matching method % C
Mean	0.673		0.668
Known variance	0.047		0.047
Observations	136		136
z value		0.190	
p value		0.850	

Table 4: Comparative cost analysis of testing soil organic carbon Method 1: (n=136)

Particular	Rate	Walkley and Black		Modified color matching method	
		Quantity (g/litre)	Amount (Rs.)	Quantity	Amount (Rs.)
Chemicals					
Potassium di-chromate GR	622 / 500 g	66.69 g	82.97	16.67	20.74
Sulphuric acid GR 98%	850 / 2.5 l	2.720 l	924.80	272.00	92.48
Ortho-phosphoric acid 88%	1600 /2.5 l	1.360 l	870.40	-	-
Diphenylamine for synthesis	592/250 g	0.68 g	1.61	-	-
Ferrous ammonium sulphate Pure	245/ kg	523.08 g	128.15	-	-
Man power					
Technical	280 / MD	4.5 MD	1260.00	2 MD	560.00
Non-technical	229 / MD	4.5 MD	1030.50	2 MD	458.00
Total cost			4298.43		1131.22
Cost / unit sample			31.60		8.32

MD= Mandays

method is rapid, user-friendly and less time accounting as compare to other laboratory methods.

Economics:

Walkley and Black method is an internationally adopted method for analysis of soil organic carbon. Economic analysis of the both method clearly revealed that a 'modified colour matching method' had significant edge over Walkley and Black method in terms of cost estimated (380 %) for testing soil organic carbon (Table 3). It was also investigated from result of the modified color matching method that the variation in result is negligible (Table 3) over the standard Walkley and Black method. Hence, it is justifiable that modified method had economic advantages and it's applicability in farmer's field. Therefore, the new innovative method would be a scientific ready reckoner for rapid, reliable, user-friendly, safe, time-efficient and economical for estimation of OCC.

Conclusion:

It was concluded from the experiment that modified color matching method is rapid, reliable, user-friendly, safe, time-efficient and economical (325%) for determinations of oxidizable organic carbon (OOC) in agricultural soils. Indeed, this method gives the same result for OCC analysis as internationally adopted Walkley-Black method produce (using Z-test). Thus, for agricultural practices, to know the organic matter status this modified colour matching method is reliable, can be accommodated in soil testing kits and used in areas where soil testing laboratories are not available.

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