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Relative Suitability Evaluation of Two Methods of Particle-Size Analysis for Selected Soils of Sudan Savanna of Nigeria

B. A. Lawal, B. R. Singh, G. A. Babaji, P. A. Tsado

***Abstract*—**The two widely used methods base on the sedimentation principle (Bouyoucos hydrometer and International pipette) for particle-size analysis were comparatively evaluated on soils collected from various locations in Sudan savanna of Nigeria particularly from Sokoto and Zamfara States. The hydrometer method under-estimated the silt and over-estimated the clay content. Also, the hydrometer reading proved difficult and tended to submerge when floated for clay reading in the suspension of very sandy soils (900g kg^{-1} sand). Furthermore, the results from the two methods were validated by subjecting the data to USDA soil textural triangle to determine their textural class names. The outcome was that 91.67 % of the experimental soils retained the same textural class names irrespective of the method. Thus, Bouyoucos hydrometer method may conveniently find a place in routine work in view of its simplicity, rapidity, and strong correlation with the pipette method.

***Keywords*—**Hydrometer and pipette methods, particle-size analysis, sedimentation.

I. Introduction

An ideal soil in good condition for plant growth is reported to have a volume composition of about 50 % solid and 50 % pore space. The solid phase is made up of the mineral and organic matter while the pore space is filled partly with air and water [1]. The mineral fractions that is, sand, silt and clay also referred to as soil separates determine the texture of a soil.

Rapid population growth in Nigeria necessitates the expansion of farmlands / intensification of cropping practices to meet the food requirement, hence, the need for regular taking of the inventory of soil resources to generate information for effective soil management. Information on particle size distribution in any soil is essential since soil texture, according to [2], influences to a large extent several components of soil fertility such as the amount of nutrient reserves and their proportion to the available nutrient fraction. Texture also influences aeration, pore space distribution, water-holding capacity and drainage characteristics.

On the other hand, the soil organic matter (SOM) which in most arable soils, accounts for between 1% and 6% of the soil's dry weight greatly influences nearly all soil properties and uses [1]. However, from a practical agricultural standpoint, SOM is important for two main reasons, (i) serving as a revolving nutrient fund and (ii) as an agent to improve soil structure, maintain tilt, and minimize erosion [3]. The later is important to this study because it was reported that SOM increases as the clay content increases thereby, increasing the potential for aggregate formation [3]. The influence of SOM in the cementation of the soil separates is usually destroyed by treating the soil sample with a strong oxidizing agent such as H_2O_2 [4], [5] to enhance complete dispersion of the soil separates [6].

Texture of a soil may be determined in the field by feel method in which the soil is rubbed between the fingers and the thumb and an estimate of the amount of the various soil separates present is made based on the degree to which the characteristic properties of each are expressed [7]. The feel method of textural estimation requires skill and experience of the scientist. The laboratory methods which are based on the principle of differential sedimentation rate of different soil separates are more accurate. Two widely used and accepted as standard methods base on the sedimentation principle are Bouyoucos hydrometer and International pipette. The pipette method is more refined and accurate and is often used as the standard to which other methods are compared. On the other hand, the Bouyoucos hydrometer method is somewhat less accurate than the pipette method, but it is easier to use [8], [9] while the pipette method was considered to be time-consuming and labour-intensive [10].

The objective of the study was to relatively evaluate the suitability of the two methods of particle-size analysis, i.e. the Bouyoucos hydrometer and pipette methods, also, to find out whether the Bouyoucos hydrometer method is suitable for use on soils collected from Sudan savanna agroecological zone of Nigeria. Furthermore, the effect of H_2O_2 pre-treatment was evaluated on the experimental soils presumed to be low in SOM and to find out whether such treatment is necessary.

II. Materials and Methods

A. Sample Collection

Soil samples were collected from 12 locations in Sokoto and Zamfara States lying between longitudes 10^o 50' N and 13° 58' N and latitudes 4° 08' E and 7^o 13' E. From each sampling site, soil samples were collected along diagonal transects from 0-30cm depths and bulked to form a composite

B.A. Lawal is with the Department of Soil Science, Federal University of Technology, Minna, Nigeria (Phone: +2348036207353; e-mail: lawalba63@ futminna.edu.ng).

B.R. Singh was with Department of Crop Production, Abubakar Tafawa Balewa University, Bauchi, Nigeria.

G.A. Babaji, a Professor of Soil Physics, is with Department of Crop Production, Abubakar Tafawa Balewa University, Bauchi, Nigeria.

P.A. Tsado is with the Department of Soil Science, Federal University of Technology, Minna, Nigeria.

sample for each site. The samples were taken to the laboratory, air-dried, gently crushed to break the clods and passed through a 2-mm sieve to separate the fine-earth materials from coarse fragments.

The particle-size analysis was performed by both hydrometer and pipette methods as described in [6]. In the process, the pre-treatment of samples with H_2O_2 was carried out in order to destroy the cementing materials such as organic matter to enhance complete dispersion of the sand, silt and clay. Values obtained for sand, silt and clay were used to determine the textural class names using the USDA soil Textural Triangle. Where necessary, the data were subjected to the paired t-test to ascertain the statistical level of significance.

III. Results and Discussion

A. Effect of H_2O_2 Treatment on Particle-size Distribution

The data for pre-analysis (without or with H_2O_2) treatment to find out if such an exercise is necessary for the soils investigated which are poor in SOM and predominant in sand are presented in Table I. The overall effect of H_2O_2 treatment yielded significantly ($P<0.05$) higher amount of clay than the no treatment. Although statistically non-significant, the proportion of sand separate in majority of the untreated soils was more than in the treated ones. Furthermore, the increase in the amount of clay fraction was at the expense of that of sand fraction. Evidently, some clay particles in the form of micro-aggregates went along with the sand separate when the H_2O_2 pre-treatment was omitted. The clay aggregation may be attributed partly to the binding effect of SOM in the experimental soils or may be due to the cementation effect of calcium carbonate [4], [5] since studies have shown that soils of the Sudan savanna are low in organic matter [11], [12].

Furthermore, the effect of H_2O_2 pre-treatment which yielded significantly ($P<0.05$) higher amount of clay than the no treatment also translated to differences in textural names of soils from Dabagi Prison Farm, UDUS Commercial Farm (Dabagi) and Tunga Maiburtu (Table I). The implication was that performing particle-size analysis without H_2O_2 pre-treatment on the experimental soils may give wrong information because of poor dispersion of soil separates. Thus, the suggestions of [13] and [6] that the H_2O_2 pre-treatment is not necessary for sandy soils due to their low organic matter content should be interpreted with caution with respect to the experimental soils evaluated. The result probably implies that the aggregation of separates may partly be due to the binding effects of SOM and partly to the cementation effect of calcium carbonate [4], [5]. On the basis of finding from this study, it may, therefore, be concluded that the H_2O_2 pre-treatment is necessary for soils of Sudan savanna of Nigeria even if they are poor in SOM.

TABLE I
EFFECT OF H_2O_2 TREATMENT ON PARTICLE-SIZE DISTRIBUTION (HYDROMETER METHOD)

Soil from	Without H_2O_2 treatment				With H_2O_2 treatment			
	←			g kg^{-1}			→	
	Sand	**Silt**	**Clay**	***TC**	**Sand**	**Silt**	**Clay**	***TC**
Bakura	850	70	80	LS	840	50	110	LS
Dabagi Prison Farm	880	80	40	S	770	80	150	SL
UDUS Commercial Farm	870	80	50	LS	700	120	180	SL
Dange	910	40	50	S	895	20	85	S
Karkara Matuzgi	800	80	120	SL	780	80	140	SL
Kwanar Kalgo	800	40	70	LS	870	40	90	LS
Rini	510	240	250	SCL	510	240	250	SCL
Tunga Maiburtu	450	230	320	SCL	410	240	350	CL
Yabawa	800	80	120	SL	790	80	130	SL
UDUS Teaching and Research Farm:								
Hydromorphic (Fadama)	850	80	70	LS	850	80	70	LS
Upland (Dryland) –Flat	900	60	40	S	900	60	40	S
Upland (Dryland) -Depression	890	20	90	LS	880	20	100	LS

*TC = textural class (USDA), CL = clay loam, LS = loamy sand, SL = sandy loam, S = sand

B. Relative Suitability of the Hydrometer and Pipette Methods

The relative proportion of sand, silt and clay separates due to the Bouyoucos hydrometer and pipette methods are presented in Table II. The amount of sand recovered by both methods were not significantly different ($P>0.05$). The Bouyoucos hydrometer method yielded significantly less amount of silt ($P<0.01$) and more of clay ($P<0.05$) than pipette method. This may be explained on the basis of depth and time required for reading/sampling in the two methods. The pipette method requires sampling from a depth of 10 cm from the surface of the suspension in the sedimentation cylinder irrespective of soil type and suspension concentration. Since sand settles faster than silt and silt in turn settles faster than clay, one can assume that in about six hours, the time that was required for clay reading under the experimental conditions, little or no silt would be left within the sampling depth. The sample withdrawn would contain only clay fraction. Contrarily, there is no depth specification in the hydrometer method. The hydrometer is simply floated and the depth to which its bottom can go depends upon the concentration of the suspension. It was observed that in some soils particularly very sandy ones, the base of hydrometer touched the settled silt near the bottom of the cylinder and brought some of it back to suspension which was read as clay. In other words, what was recorded as clay in hydrometer method, in fact, contained some silt as well.

As for the time required for reading/sampling, it takes two hours irrespective of the suspension temperature to read for clay in the Bouyoucos hydrometer method. The time required for sampling in the pipette method is much longer and is temperature-dependent. Since not all the silt (especially fine silt) would settle within two hours in the Bouyoucos hydrometer method (even though a correction is applied for temperature deviation from 19.5^{o}C), the unsettled silt would be considered as clay fraction during the analysis. Such a situation would not arise in the pipette method where the time involved is long enough for virtually complete settling of the silt materials.

TABLE II
PARTICLE-SIZE DISTRIBUTION AS ESTIMATED BY THE HYDROMETER AND PIPETTE METHODS

Soil from	**Hydrometer Method** (g kg^{-1})				**Pipette Method** (g kg^{-1})			
	Sand	**Silt**	**Clay**	***TC**	**Sand**	**Silt**	**Clay**	***TC**
Bakura	840	50	110	LS	835	60	105	LS
Dabagi Prison Farm	770	80	150	SL	770	150	80	SL
UDUS Commercial Farm, Dabagi	700	120	180	SL	730	150	120	SL
Dange	895	20	85	S	885	50	65	S
Karkara Matuzgi	780	80	140	SL	790	100	110	SL
Kwanar Kalgo	870	40	90	LS	870	50	80	LS
Rini	510	240	250	SCL	520	250	230	SCL
Tunga Maiburtu	410	240	350	CL	420	300	280	CL
Yabawa	790	80	130	SL	800	100	100	LS
UDUS Teaching and Research Farm:								
Hydromorphic (Fadama)	850	80	70	LS	830	100	70	LS
Upland (Dryland) – Flat	900	60	40	S	910	60	30	S
Upland (Dryland) - Depression	880	20	100	LS	870	50	80	LS

*TC = textural class (USDA), CL = clay loam, LS = loamy sand, SL = sandy loam, S = sand

Although, [9] reported that the Bouyoucos hydrometer method was less accurate than the pipette method, it was only in the experimental soil sample from Yabawa that both methods evaluated differed in textural names (Table II). That is, 11 out of the 12 experimental soils which translated to 91.67 % gave the same textural names when the results of the two of methods used were compared. On the basis of findings from this study, since the Bouyoucos hydrometer method correlated with the pipette method in term of accuracy as much as 93 %, it became difficult to infer that the former method is inferior to the later method. This work agreed with the views of [10] which considered the pipette method to be time-consuming and labour-intensive when it comes to performing particle-size analysis on soils of the Sudan savanna of Nigeria.

IV. CONCLUSION

The pre-treatment with H_2O_2 was found necessary for the experimental soils even though many soils of the Sudan savanna were reported to have low SOM content. The Bouyoucos hydrometer method under-estimated the silt and over-estimated the clay fraction in the experimental soils as compared to the pipette method. In the case of very sandy soils having 900g kg^{-1} sand, and very low amounts of silt and clay in suspension, the hydrometer tended to submerge completely when floated in the suspension for clay which made the reading difficult. Hence, this finding suggest the need to further investigate the accuracy and applicability of the Bouyoucos hydrometer method on such soils containing 900g kg^{-1} sand and above. In view of the high correlation between the two methods, it may be safely stated that the Bouyoucos hydrometer will satisfactorily find a place in routine work in view of its simplicity and rapidity in performing the particle-size analysis on a wide variety of soils, more so that 91.67% of the experimental soils retained the same textural names relative to those from the pipette method.

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