The impact of soil water content and water temperature on wet aggregate stability. What answer do you want?

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Abstract

Wet aggregate stability determined by immersion wet sieving is commonly used as a measure of the stability of soil aggregates. Over the years different researchers have used a variety of methods with a wide range of sieve sizes, amplitudes, cycles, sieving times and pre-drying methods. The most common drying measurement prior to sieving is air drying but the soil water content after drying is generally not stated and often not determined. This water content can vary depending on soil texture, clay mineralogy and the air temperature at drying. This experiment studied the impact of soil water content following drying at different temperatures prior to wet sieving, and on the temperature of the sieving water, on the mean weight diameter (MWD) results obtained for three different soil types. The drying temperature affected the resulting soil water content particularly for the high clay soils and this also influenced the MWD results, with the lower drying temperature and higher soil water content resulting in a greater MWD in the soils with higher clay contents. The soil with the highest clay content and predominantly montmorillinite clay mineralogy had a MWD following drying at 15^{o}C more than five times greater than its MWD after drying at 25^{o}C. The results for the sandy loam soil were not significantly different as there was little difference in the soil water content across the range of drying temperatures. The temperature of the sieving water also significantly affected the MWD results for all soils with different soil types being affected differently. This is likely to be because of the different solubilities of binding agents within the soils. MWD results can vary significantly unless drying temperatures and the temperature of the water during sieving are standardized. The choice of conditions can significantly bias results.

Key Words

Wet sieving, Soil drying temperature, water sieving temperature.

Introduction

Maintenance of a high aggregate stability in soils is desirable for sustainable land use as it is essential for the preservation of agricultural production, minimizing soil erosion and degradation and reducing environmental pollution (Amezketa 1999). Aggregation of soil particles will result in conditions that are favorable for plant growth and soil microbial and faunal activity (Whitbread 1995), while good soil structure is the most important soil characteristic for sustaining agricultural productivity and retaining environmental quality (Amezketa 1999). Wet aggregate stability determined by immersion wet sieving has been used by numerous researchers over many years as a measure of the stability of soil aggregates (Yoder 1936; Zotarelli *et al.* 2005; Blair *et al.* 2006a, b; N’Dayegamiye 2006; Goverts *et al.* 2007; Wagner *et al.* 2007; Dimoyiannis 2009). The mean weight diameter (MWD) is commonly used to express aggregate stability as it determines the size distribution of aggregates and is essentially a measure of macro-aggregate stability as the aggregates that remained on each sieve must be stable to the wetting and sieving processes (Amezketa 1999).

The measurement of wet aggregate stability by immersion wet sieving has been characterized by the variability in methods used with a wide range of sieve sizes, amplitudes, cycles, sieving time and pre drying methods. The soil is commonly air dried prior to measurement but the moisture content of the soils prior to sieving is generally not stated and often not determined, but it is likely that it can have a large influence on the results obtained. This can be of particular relevance when determining the seasonal aggregate stability of soils or when comparing aggregate stability over time, where the temperature in the drying area may vary widely. The temperature of the water used for the sieving process may also vary and it is possible for this to also effect results obtained. This experiment was carried out to determine the effect of soil water content over a range of soil drying temperatures and water temperature used for sieving on the aggregate stability of three different soil types.

Methods

Soils

Three contrasting soils that had been collected for other experiments were used for this trial. They were a Red Clay (RC) (Chromic Vertisol; FAO 1990) soil (Blair *et al.* 2006b), a Black Earth (BE) (Pellic Vertisol; FAO 1990) soil (Blair *et al.* 2006b) and a Sandy Loam (SL) (Chromic Luvisol; FAO 1990) soil (Blair 2000). The Red Clay soil contained 320 g/kg sand, 220 g/kg silt and 460 g/kg clay, while the Black Earth soil had 290 g/kg sand, 170 g/kg silt and 540 g/kg clay and the Sandy Loam contained 570 g/kg sand, 240 g/kg silt and 180 g/kg clay (International system). The clay minerals in the Red Clay consisted of predominantly quartz and kaolinite, with some illite and a small amount of montmorillonite. By contrast the Black Earth contained predominantly montmorillonite with small amounts of quartz, kaolinite and illite. The clay mineralogy of the Sandy Loam was predominantly kaolinite, quartz and illite with a small amount of halloysite.

Soil water content wet sieving experiment

The three different soils were wet by misting to 75% of their field capacity and then incubated in the laboratory in sealed plastic bags for seven days to ensure moisture equilibrium was reached. Each soil was then divided into six sub-samples and gently broken down using fingers before each sub-sample was dried in fan forced incubators at six different temperatures, 15°C, 20°C, 25°C, 30°C, 35°C and 40°C to simulate air-drying at different temperatures. Following drying, the soil samples were broken down to pass through a 4 mm sieve. To achieve this, the soil was gently rolled on a board that had 4 mm high ridges on the sides to maintain a gap between the board and the roller. This prevented total disruption of the sample and ensured that each soil sample received a similar energy input. Soil water content was determined for each sub-sample at each drying temperature. Three replicates of each soil from each drying temperature were then wet sieved as per the method below.

Water sieving temperature experiment

Soil that had been prepared as for the soil water content experiment and dried at 25°C was used for this experiment. The soil was wet sieved, as per the method below, in water at five different temperatures 15°C, 20°C, 25°C, 29°C and 36°C. The water was equilibrated for each temperature in an incubator for 48 hours prior to sieving and three replicates of each soil were sieved at each water temperature. Water temperature was measured immediately prior to commencing sieving.

Wet sieving

A modification of the Yoder wet sieving procedure (Whitbread 1996) was used to determine wet aggregate stability. A set of five 100 mm diameter sieves of 2000, 1000, 500, 250, 125 µm size screens was used. A further 125 µm sieve was used for a lid. The 30 g sample of the soil (<4 mm) was placed onto the top sieve and immersed in distilled water at approximately 25°C (or as stated for the water temperature experiment) for 30 sec before being sieved for 10 min through an amplitude of 17 mm at 34 cycles/min. Following sieving, the sieves were drained and the soil dried at 40°C for 24 h prior to weighing. Soil weights for soil dried at less than 40°C were corrected for water content before calculations were made. Mean weight diameter (MWD) was calculated for each soil by the formula:

$$\text{MWD} = \sum_{i=1}^{n} x_i w_i$$

where x_i is the mean diameter of any particular size range of aggregates separated by sieving, and w_i is the weight of aggregates in that size range as a fraction of the total dry weight of soil used.

Results

Soil water content wet sieving experiment

The Black Earth soil had the widest range in soil water content for the different drying temperatures while the Sandy Loam soil showed the lowest range (Table 1). The water contents of the three different soils at each drying temperature are shown in Table 1. The relative MWD was calculated by dividing the MWD at any given drying temperature by the MWD result for the 25°C drying temperature for each individual soil. This was then converted to a percentage. There was no significant difference between any of the MWD's for the Sandy Loam soil, while for the Red Clay soil, the MWD at the water content when dried at 15°C was significantly different from all other water contents (Table 1). However the Black Earth soil showed a wide range in MWD over the different water contents, with significant differences between drying at 15°C, 20°C and 25°C but no difference between the MWD results for the three lowest water contents following drying at the three higher temperatures (Table 1). When calculating the MWD following wet sieving it is necessary to correct the soil weights to the moisture content of the drying temperature used to dry the samples following wet sieving, particularly for soils with high clay contents. For the Black Earth soil dried at 15°C the MWD for the corrected (for drying at 40°C) and uncorrected value ranged from 1.437 mm to 1.327 mm, respectively, while after drying at 20°C it ranged from 0.536 mm to 0.512 mm, respectively.

Table 1. The soil water content (WC) (%) and the relative mean weight diameter (Rel. MWD) expressed as a percentage of that at 25°C for each soil at each drying temperature.

	Sandy Loam		Red Clay		Black Earth	
Drying Temp. (°C)	WC (%)	Rel. MWD	WC (%)	Rel. MWD	WC (%)	Rel. MWD
15	1.8	106a[1]	6.1	111a	14.6	566a
20	1.7	98a	5.5	102b	9.4	206b
25	1.3	100a	3.5	100b	5.7	100c
30	1.3	101a	2.3	99b	5.0	79d
35	1.1	101a	2.0	98b	4.7	78d
40	1.0	100a	2.0	94b	4.2	66d

[1] Numbers in the same column followed by the same letter are not significantly different according to Duncan's MRT.

Water sieving temperature experiment

The relative MWD was calculated by dividing the MWD at any given water temperature by the MWD result for the 25°C water temperature for each individual soil. This was then converted to a percentage. The only significant difference for the Sandy Loam soil was for the water temperature at 36°C which was significantly lower than all other temperatures (Table 2). The Red Clay soil showed a significant difference in relative MWD between 15°C, 20°C and 25°C but there was no difference between the results for the three highest water temperatures (Table 2). For the Black Earth soil, a significant difference was shown between the relative MWD for the two lower water temperatures and the three higher water temperatures while the relative MWD at 25°C water temperature was significantly higher than that at a water temperature of 36°C (Table 2).

Table 2. Relative mean weight diameter (MWD) expressed as a percentage of that at 25°C for the different water temperatures used for wet sieving for the three different soil types.

Soil	15°C	20°C	25°C	29°C	36°C
Sandy Loam	103a[1]	101a	100a	101a	89b
Red Clay	124a	112b	100c	99c	98c
Black Earth	110a	111a	100b	98bc	91c

[1] Numbers in the same row followed by the same letter are not significantly different according to Duncan's MRT.

Conclusion

When comparing different soil samples for aggregate stability using the immersion wet sieving method it is essential that soils are dried at the same temperature. This is particularly necessary when collecting soil samples at different times of the year when temperatures in drying areas may vary significantly. It should also be ensured that corrections for soil water content are made when the drying temperature of the soil sample differs from the drying temperature of the sieved samples. The high clay content soils exhibited the greatest differences under these conditions. The clay types are also likely to be influencing the results with the soil containing predominantly montmorillonite clay showing the greatest differences.

When determining aggregate stability using the immersion wet sieving method, water temperature should be monitored as differences in water temperature can significantly influence the results obtained. Different soil types are affected in different ways and this is likely to be influenced by the solubility of the various binding agents found in the different soil types. The MWD results can vary significantly unless soil drying temperatures and the temperature of the sieving water are standardized. The choice of conditions used can significantly bias the results.

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