Int. Agrophysics, 2000, 14, 269-272

EFFECTS OF SOIL MANAGEMENT ON THE DISPERSIBILITY OF CLAY IN A SANDY SOIL

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Accepted April 10, 2000

A b s t r a c t. The dispersion of clay in soil can lead to a number of agricultural and environmental problems. The purpose of the experiments reported here was to investigate the effects of soil organic matter content on the dispersibility of clay. Soil samples were collected from a long-term field experiment on a sandy soil (4% clay) in which different crop rotations and different fertilization practices had led to a range of soil organic matter contents. Clay dispersibility was measured with a turbidimetric technique. This showed clearly that increasing contents of organic matter in the soil result in reductions in clay dispersibility.

K e y w o r d s: clay, dispersion, fertilization, organic carbon content, turbidity, stability

INTRODUCTION

When soils which are stable come into contact with water, the clay remains flocculated in larger compound particles. In unstable soils, on the other hand, the clay particles repel and disperse in water and the clay becomes potentially mobile in the soil and in the wider environment. Problems associated with dispersed clay include: soil crusting and associated poor crop emergence, collapse of the soil structure and associated aeration problems, reduced infiltration of water with associated increased risk of run-off, flooding and soil erosion. Nutrients, especially phosphorus, are often transported with clay particles in run-off water towards reservoirs and other water storages and these can subsequently contribute to algal 'blooms' and other environmental risks.

It is well-known that organic matter contributes to various aspects of soil stability [2]. However, most of the published measurements are results from the wet-sieving of soil aggregates, and there are very few data on the effects on clay dispersion from sandy soils. An additional problem is the wide range of experimental techniques which have been used. This makes comparison of the results from different researchers or laboratories almost impossible.

The amount of clay which disperses when a soil sample is placed in water depends on two main factors. Firstly, there is the amount of mechanical energy which is applied to the system, and secondly, there is the sodicity of the clay fraction. The clay which disperses when no energy is applied is often called 'spontaneously dispersible clay'. The clay which disperses when only small energy is applied is called 'readily-dispersible clay'. The clay which disperses when very high energy is applied is called 'the total clay'. When sodium ions are adsorbed on the surfaces of the clay particles, the particles tend to repel in and disperse in water. Other cations, especially calcium, cause the clay particles to combine together into groupings (or floccules) which are stable in water. The proportion of sodium ions adsorbed onto the surfaces of the clay particles is called the Exchangeable Sodium Percentage (or ESP). When the ESP is larger than about 15 %, the soil is described as 'sodic', and is highly prone to clay dispersion and instability problems. A high ESP makes the soil more susceptible to damage by mechanical energy inputs [3]. This is in contrast with a high content of organic matter, which makes soil less susceptible to mechanical damage [4].

The purpose of this research was to investigate some effects of soil management on the content of readily-dispersible clay in a sandy soil, with the aim of identifying the management practices which potentially can mitigate these problems.

MATERIALS AND METHODS

The experimental site, soil and climate

Soil samples were collected from the IUNG experiment station at Grabów about 20 km west of Puławy. The centre of the experimental plots, as determined by GPS is at 51^o 20′ 58" N, 21^o 39′ 51" E, altitude 165 m. The site is located on the Radom Plateau which is part of a greater physiographic unit called the Southern Mazovian Upland. The soil at the site is classified as Stagnogleyic Luvisols and contains 71 % sand, 25 % silt and 4 % clay. This puts it on the boundary between loamy sand and sandy loam according to the USDA classification system.

The mineralogy of the clay fraction was investigated using X-ray diffraction. This showed quartz to be dominant but with chlorite and mica also present. The total carbon and total nitrogen contents of the soil were measured with a Carlo Erba autoanalyser. Carbonate carbon was negligible.

The climate at the site is temperate with a mean annual rainfall of about 560 mm and a mean annual temperature of 7.8 ^{o}C (Table1).

The field experiment

The field experiment, which has been running for about 20 years, comprises two 4-year crop rotations (high and low organic matter inputs) with different levels of organic fertilization (manure), and inorganic fertilization. Rotation A has the lower organic matter inputs and comprises: potatoes, winter wheat, spring barley, and maize. Rotation B has the higher organic matter inputs and comprises: potatoes, winter wheat + mustard, spring barley + clover, and red clover + grass. For the purposes of this experiment, only the extreme treatments were sampled: (0 and 80 t ha^{-1} manure once every 4 years in the potato phase of the rotation) x (0 and 135 kg N ha^{-1} yr^{-1}) for each of the crop rotations A and B.

Soil sampling

Six replicate samples were collected from each of the four replicate plots of each treatment. Three of these were bulked to make composite samples for chemical and mineralogical analysis. To ensure that the composite samples were representative, they were prepared and sub-divided by repeated mixing and 'coning and quartering'. The remaining three samples were kept in essentially undisturbed form in their cylinders and were allowed to air-dry until they were needed for measurements of clay dispersibility.

T a b l e 1. Mean climatic data for the site (years 1981-1990)

	Month												Year
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
precipitation (mm)	26	21	32	31	64	83	69	56	57	30	44	46	total 558 mm
mean air temperature (°C)	-2.8	-2.3	2.2	7.7	14.0	16.0	17.8	17.4	13.1	8.6	2.4	-0.3	mean 7.8 °C

Clay dispersion measurements

The method for determining the content of dispersible clay in the soil samples was rather similar to that described by Kay and Dexter [1], and by Watts *et al.* [5], but modified so that sandy soils could be studied.

About 5 g of air-dry soil was shaken with 125 ml of distilled water in a standardized way. The suspension was allowed to stand for 18 h for the larger particles to sediment leaving only colloidal (mostly clay) particles in suspension. 30 ml of suspension was taken from the centre of each sample with a pipette and was transferred to a glass turbidity cell.

The turbidity was measured with a Hach 2100 AN ratio turbidimeter. A schematic diagram of this apparatus is shown in Fig. 1. It is important to realize that the measurement is of the proportion of light which is scattered by the sample. It is therefore independent of sample colour, and is linearly proportional to the concentration of colloids in suspension. The results were measured as NTU (Nephelometric Turbidity Units) and were normalized by dividing by the mass of the sample to give NTU/g. Calibration has shown that 1 NTU represents 1 ppm of clay, approximately.

The results were analysed with MINITAB® statistical software.

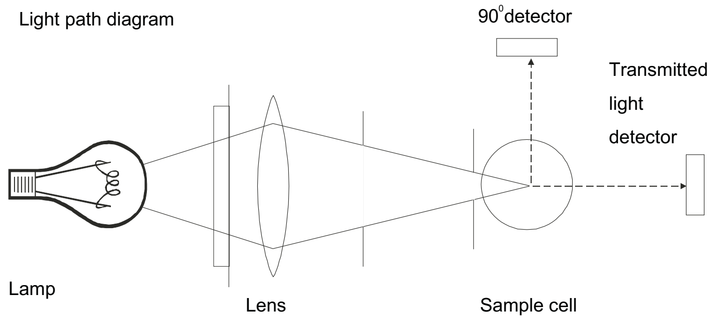

Fig. 1. Schematic diagram showing the principle of operation of the ratio turbidimeter.

RESULTS AND DISCUSSION

The different management practices had produced a range of organic carbon contents in the soil ranging from 0.65 % in Rotation A with zero inputs to 0.81% in Rotation B with maximum inputs. The mean C/N ratio was found to be 13.3 with no significant effects of treatment.

The results which are plotted in Fig. 2 show a clear negative correlation between the amount of dispersible clay, y, and the organic carbon content of the soil, x:

$$y = 5.97 - 5.11x, \ r^2 = 0.89, \ p = 0.001$$
$$(\pm 0.60) \ (\pm 0.81) \qquad (1)$$

where y is in NTU/g and x is % organic carbon content. Therefore, the treatment with the highest organic carbon content has about 33 % less dispersible clay than the treatment with the lowest organic carbon content.

Extrapolation of Eq. (1) to y = 0 shows that the amount of dispersible clay is predicted to be

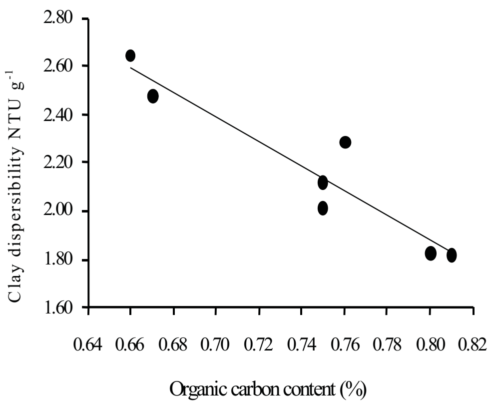

Fig. 2. Plot of the normalized amount of readily- dispersible clay (in NTU g^{-1}) against the organic carbon content (%) of the soil.

zero for organic carbon contents greater than x = 1.17 %. However, we cannot be sure that this extrapolation is very accurate. Also, it would not be easy to attain such a high organic carbon content in a sandy soil which is used for agricultural production. This is due in part to the effects of mechanical energy inputs to soil during tillage increasing microbial activity and hence loss of carbon to the atmosphere by respiration of carbon dioxide.

CONCLUSIONS

The sandy soil at Grabów, in spite of its coarse texture, suffers from many of the problems mentioned in the introduction. In particular, crusting and run-off occur with this soil. Such sandy soils are also often prone to wind erosion when in a loose, non-cemented state.

The different crop rotations and fertilization treatments, applied over a period of 20 years, have produced a range of levels of organic matter content in the sandy soil at Grabów.

A strong negative correlation was found between clay dispersibility and the organic carbon content of the soil.

It should be noted that clay dispersion occurs in water and therefore that the results in this paper are relevant only to wet or submerged soil. The results cannot be used to comment on the likely effects on the risks of wind erosion.

It can be concluded that the selection of soil management practices with appropriate crop rotations and fertilization regimes can maintain high levels of soil organic carbon and thereby reduce the amount of dispersible clay in the soil. Such practices can be expected to minimize the adverse agricultural and environmental problems which are mentioned in the introduction.

ACKNOWLEDGEMENTS

The authors would like to thank Dr. F. Bartoli and his colleagues at the Centre de Pdologie Biologique, CNRS, Nancy, France for their help with the characterisation of the soils and organic matter. They would also like to thank Doc. dr hab. Cz. Maćkowiak (IUNG, Puławy) for permission to sample the experiments at Grabów.

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