Importance of Microorganisms for Soil Aggregation

Jean-Luc Chotte

1 Introduction

Martin et al. (1955, quoted by Allison 1968) defined an aggregate as a “naturally occurring cluster or group of soil particles in which the forces holding the particles together are much stronger than the forces between adjacent aggregates”. Brewer (1964) considered an aggregate as having an identifiable morphological boundary which distinguishes it from its neighbors. There have been many major papers describing the ways in which these aggregates are formed. These models describe the mechanisms that form and stabilize aggregates: the orientation of the mineral particles, the attractions between these particles, the interactions between these particles and the soil microorganisms and the production of aggregating agents by these microorganisms (Emerson 1959; Harris et al. 1963; Dexter 1988 cited by Oades and Waters 1991).

In general, these papers support a hierarchic model for the aggregation process. Oades and Waters (1991) tested this model on three types of soil (Mollisol, Alfisol, Oxisol). In soils (Mollisol, Alfisol) where organic matter plays a role in the stabilization of aggregates greater than 250 µm, the hierarchic model was confirmed. However, in Oxisols, the role of iron oxides in cementing mineral particles minimizes the importance of the hierarchic model in aggregation. Nevertheless, it is evident that most papers describing the formation and stabilization of aggregates and the determining factors controlling the process have been strongly influenced by the hierarchic model of aggregation.

The most important strategies proposed for maintaining and improving soil fertility are those which target the physical properties of the soil. The abundance and stability of the aggregates are critical for several soil functions.

- Plant growth (Hamblin 1985; Letey 1985),
- Resistance to erosion (Le Bissonnais and Arrouays 1997; Barthès and Roose 2002)

1Laboratoire d’Ecologie Microbienne des Sols, UR Ibis R083, Centre ISRA-IRD Bel Air, BP 1386 Dakar, Sénégal, e-mail: Jean-Luc.Chotte@ird.sn, Tel: +221-8493308, Fax: +221-8321675

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– Soil organic matter turnover (Feller and Beare 1997; Chotte et al. 1998; Puget et al. 2000; Six et al. 2001),

– The abundance, activity and diversity of organisms, both mesofauna (Quénehervé and Chotte 1996) and microflora (Elliott 1986; Gupta and Germida 1988; Kabir et al. 1994; Chotte et al. 2002).

Consequently, it is still very important to determine the factors controlling the processes of formation and stabilization of aggregates. The importance of soil microorganisms for soil aggregation has been regularly reviewed (Griffiths 1965; Lynch and Bragg 1985; Robert and Chenu 1992; Oades 1993). This paper summarizes the literature and reports new findings.

2 Evidence of the Role of Soil Microorganisms

Many methods have been used to characterize the particle structure of a soil (reviewed by Diaz-Zorita et al. 2002). There is no agreed standard method. The most commonly used methods, however, use a sieving process to separate the soil particles physically. The sieving may be carried out on a soil sample maintained at its natural humidity level, on a soil sample rewetted by capillary action, on a soil sample immersed in water or on a soil sample dried and then rewetted. In these methods, the air trapped in the pores by the water and rapid wetting exerts a force on the solid mass, causing it to disperse. If the soil is rewetted slowly, the air can escape and so there is less force than when the soil is rewetted rapidly. It should be noted that some authors recommend more vigorous methods, such as using agitator beads, which are particularly useful for studying microaggregates in 2:1 clay soils (e.g., Vertisols; Jocteur Monrozier et al. 1991). There are a number of papers in the literature which show the effect of increasingly vigorous dispersion on the destruction of macroaggregates (> 250 µm; Cambardella and Elliott 1986; Elliott 1986; Bossuyt et al. 2001). Therefore, the method used for separating the aggregates must be specified when describing the role of soil microorganisms in aggregation.

In a recent paper, Bossuyt et al. (2001) have observed that the formation of macroaggregates (> 2000 µm) in an incubated soil with the addition of organic residues in the presence of a fungicide is significantly less than in the same soil without the fungicide. On the other hand, introducing a bactericide did not cause a reduction in the quantity of macroaggregates with respect to the control soil. This observation confirms the results in other papers and shows the role of fungi in the stabilization of aggregates (Tisdall and Oades 1982; Lynch and Bragg 1985; Miller and Jastrow 1990; Beare et al. 1997; Tisdall et al. 1997; Jastrow et al. 1998). In a laboratory