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IMPROVEMENT OF SANDY SOIL PROPERTIES BY USING CLAY MINERALS

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Abstract

Bentonite is a natural deposit consists of mainly of montmorillonite clay mineral. It is recognized as a very good material for improving sandy soil criteria particularly clay content which reflects on physical and chemical properties and consequently plant growth and crop production. Two locations have been selected to obtain bentonite clay: Luxor governorate (Esna District) and Aswan governorate (Wadi Abbad) as well as sandy samples from the same areas to carry the experimental work. The sandy samples were mixed with several rates of bentonite (0, 3,7,12 and 18%) and placed in plastic columns and irrigated with water at intervals for one year. Grain size analysis has been determined out besides cation exchange capacity (CEC). The obtained results proved that beneficial changes in soil texture from sandy to loamy sand due to application of 12 and 18% bentonite. CEC increased from 5.30 and 6.33 cmolc kg^{-1} in the control to 13.21 and 14.72 cmolc kg^{-1} in samples of Esna and Wadi Abbad, respectively. The examination of prepared thin section by polarized-microscope of the treated sandy soils with bentonite, shows clear changes in the fabric of the groundmass and the related distribution between coarse and fine components, from monic and enaulic to chitonic and partly gefuric. Distinct changes in the dominant voids from simple in the sandy samples to compound packing besides some coarse vughs and chambers in the treated samples with bentonite.
***Keywords*:** Bentonite, sandy soils, thin section, micro-morphology, CEC.

Introduction

To maintain and sustain soil productivity, we must take a special care of sandy soils that have unfavorable properties. These soils contain very low content of colloidal material, where water management is severe due to weak structure containing only large pores and loos nutrient is expected. Sandy soil is among the most extensive soil in the world, covering more than 900 million hectares (Driessen *et al.*, 2001), which are found in arid and semi-arid areas it has been identified as inherent sterile and deteriorating physical properties and with weak (Noble *et al.*, 2000). Thus, they are considered marginal for crop production. It is known that the sandy soil that have such properties have a large space in Egypt (Egypt, covering 80% of the sandy soil USDA, 1991) is damaged.

The only way to increase the low CEC of long-term sandy orbital soil and improve the characteristics is to apply high CEC materials such as clay minerals 2: 1 (bentonite). Bentonite is a rock that contains mainly on montmorillonite (clay mineral 2: 1), and it has been recognized membership smectite family in many countries is very good to improve the characteristics of benefactor of these sterile sandy soil (Benkhelifa *et al.*, 2008).

Bentonite clay is a metal 2: 1 with a plate octahedral one and two sheets of silica that form a layer. Carry net negative charge because of the broken links around the edges of silica and alumina units. This would give rise to unconvinced charges, which would be balanced by interchange cations (Bhattacharyya and Sen Gupta, 2008). In this, point Noble *et al.* (2005) appeared that the application of bentonite to the soil of low CEC, could achieve significant increases in bentonite simply because of the negative CEC of its charge permanent. In addition, as a factor to increase soil CEC, bentonite can improve nutrient retention and availability, thereby enhancing agricultural productivity and improve the fertilizers use efficiency.

It also has the ability to increase plant available water as a function of increasing porosity percentage (Soda *et al.*, 2006). On the other hand, confirmed Hosseini (2014) to play an important role in bentonite absorption of heavy metals, due to the characteristics of high density, berry color and play an important role in the adsorption of water clarification. Bentonite is a rock composed mostly of metal clay has been montmorillonite recognized as a very good material to improve the texture of the coarse soil in different parts of the world (Satje and Nelson, 2009; Yssad and Belkhodja, 2007). Therefore, Masazumi *et al.* (2016) added that bentonite at a rate of 4% to the sandy northeast of Thailand soil, to increase the water content of the soil.

In this way, Abd El-Hady and Ebtisam (2016), who found that the use of bentonite for sandy soils greatly reduces the evaporation accumulated during the three evaporation cycles, and decreases with increasing applied rates, except for the higher ratio (8%), which increases the accumulated evaporation under current conditions. The same authors (2012) confirmed that the use of rock sediment (bentonite) of sandy soil at different rates led to the improvement of the physio-chemical properties, especially soil moisture characteristics and the ability to exchange cations.

Generally, calcium bentonite can hold a weight of 1 to 5 times in water only and is used in horticulture, because it is more stable (Wahab *et al.*, 2010), who added that the calcium bentonite stores water and release it much easier than other types of mud. Clay bentonite contains an area of hundreds to thousands of surface area more than sand particles and thus improves nutrients retain-ability to soil and helps to provide a better home of microorganisms in the soil (Croker, 2004). Also, bentonite is associated with organic carbon and plant fertility, Janusz *et al.* (2013) concluded that the soil with bentonite additives contain much higher than the total organic carbon and nitrogen from the soil control amounts. Moreover, compared to soil control, organic matter in soil containing $12 kg/m^2$ of bentonite contains larger amounts of humic. The addition of bentonite to sandy soils to enhance the isolation of C and N in the soil, as a result of global warming mitigation, has been taken into contemplation recently (Churchman and Chittleborough, 2013). Churchman *et al.* (2012) reported that the addition of mud (including bentonite) of sandy soil degraded boosted the growth of plants in this soil. Increasing plant growth contributes to carbon sequestration intensively, by further incorporation of higher levels of plant waste into the soil. In addition, both Pleasureja and Peltodja (2007) observed an increase in the organic carbon content of the enriched sand by 2.5 and 10 % of bentonite after a year.

Recently, Nur *et al.* (2016) used sodium bentonite with laterite soil and reported that the physical properties of the tested soil properties can interact with the distinctive properties of sodium bentonite. Therefore, the best ratio of sodium bentonite mixture to laterite soil can be determined.The results of this study give positive results due to the potential of sodium bentonite to improve laterite soil particles. Janusz and Barbara (2017) reported that the addition of bentonite (bentonite containing carbonate) to soil of very poor acidic sandy soil significantly slowed down the gradual reduction of the CFU of these bacteria. A number of *Azotobacter chroococcum* introduced into the soil

The aim of this study is to evaluate the effects of additives bentonite on the physical and chemical properties of the soil and the study of micro-morphological changes in the sandy soil through the examination of thin sections of the soil under the polarized microscope.

Material and Methods

Activity (1): Effect of bentonite clay and application rate on the textural soils and Cation exchange capacity (CEC). The bentonite used in this study comes from two different locations N° 1 Esna district (El–Luxor governorate, Latitude: 25°17′36″ N, Longitude: 32°33′14″ E, Egypt) and location N°2 Wadi Abbad (Aswan governorate, Latitude: 24°05′26″ N, Longitude: 32°53′57″ E, Egypt) representing two sandy soils profiles were sampled from the same locations. Bentonite added to the soil was in a powdered form with the size of particles < 0.71 mm after drying at 400ºC. Bentonite was applied to soils at rates of 0, 3, 7, 12 and 18 g/kg, which, assuming a bulk density of 1 mg/m^3 and an incorporation depth of 10 cm, are equivalent to field rates of 3, 7, 12 and 18t/ha. The mixture of bentonite and soil put in plastic columns (60 cm length and 20 cm in diameter). Distilled water added equal to reach the maximum water holding capacity for each treatment. The soil was re-irrigated weekly for a year. Samples of the mixtures in each column were analyzed for particle size distribution, EC (paste), pH (1:2.5) and CEC using standard methods Black *et al.* (1982). Calcium carbonate was determined after (Soil Survey Staff, 1993).

Activity (2): For micro-morphological observation four samples were prepared for thin sections (2 control and 2 with 18 % bentonite application. Normal (2x2 cm) thin section were prepared according to the general procedure elaborated by Stoops (1976) using a mixture of plastic material diluted by styrene and accelerated by catalyze. The impregnation was done under vacuum. The hardened material was cut, ground, polished and mounted on a petro-graphic slide. The thin section were examined by polarized microscope (Zeiss) and described according to terminology by Stoops (1978) and Bullock *et al.* (1984).

Results and Discussion

The analytical data recording bentonite clay from two sites (Esna and Wadi Abbad) in Table 1.

Both deposits have high clay content of 89.46% and 88.12%, respectively. Carbonates are very low and slightly saline (EC 3.32 and 2.88 dSm^{-1}) and CEC values. The increase in their values corresponds to the increase in the clay content (mostly from the fine clay, the dominant predominant clay mineral).

Field observations and results obtained in the table (2) concerning the characteristics of the selected profiles of Esna and Wadi Abbad, reveal that this sandy soil, non-saline, low carbonate content with a weak cation exchange capacity. Accordingly, they are classified as subgroup level as Typic Torripsamment.

Table 1 : Particle size distribution and some chemical properties of bentonite clay

Bentonite Property	Esna	Wadi Abbad
Coarse sand% 2000:200u	2.31	3.11
Fine sand% 200:20u	1.99	1.45
Silt% 20-2u	6.24	7.32
Clay% > 2u	89.46	88.12

Bentonite property	Esna	Wadi Abbad
pH 1:5	7.81	7.65
EC dSm^{-1}	3.23	2.88
CEC Cmolkg^{-1}	80.12	78.45
$CaCO_3$%	2.35	1.46

Table 2 : Some physical and chemical properties of the soil samples

Soil Property	Esna	Wadi Abbad
Coarse sand% 2000:200u	6.05	6.02
Fine sand% 200:20u	85.12	87.16
Silt% 20-2u	6.92	5.71
Clay% > 2u	1.91	1.11

Soil Property	Esna	Wadi Abbad
Texture	Sand	Sand
pH 1:5	8.23	8.11
EC dSm^{-1}	2.12	1.45
CEC Cmolkg^{-1}	7.23	6.15
$CaCO_3$%	1.35	1.14

Table 3 shows the changes in the exchange capacity of the soil and textural soil after mixing bentonite soil at different rates after one year.

Table 3 : Textural soil and cation exchange capacity after mixing with bentonite after one year

Localion	Bentonite rate %	Particle size distribution %					C.E.C
		C. sand	F. sand	Silt	Clay	Texture	Cmol kg^{-1}
Esna	0	6.05	85.12	6.92	1.91	Sand	6.33
	3	5.10	84.97	7.61	2.32	Sand	7.24
	7	4.25	84.09	8.13	3.53	Sand	9.13
	12	3.11	81.92	9.52	5.45	L. S	11.34
	18	2.02	76.61	13.13	8.24	L. S	15.72
Wadi Abbd	0	6.02	87.16	5.71	1.11	Sand	5.43
	3	5.44	85.82	6.82	1.92	Sand	6.23
	7	4.13	85.22	7.32	3.33	Sand	7.89
	12	3.03	82.59	9.24	5.14	L. S	10.13
	18	2.16	77.46	12.50	7.88	L.S	13.21

*L.S. Loamy sand

Analytical data shows that bentonite application increased clay content in soil. The increase in clay content after 3 and 7% of bentonite is very limited while rates 12 and 18% are the best bentonite ratios to be added to sandy soils increase clay content. When the utilization rate of 18 t / ha, has increased clay content from 1.91 to 8.24% in the soil of Esna and 1.11 to 7.88% in the soil of the Wadi Abad soil (Figure 1).

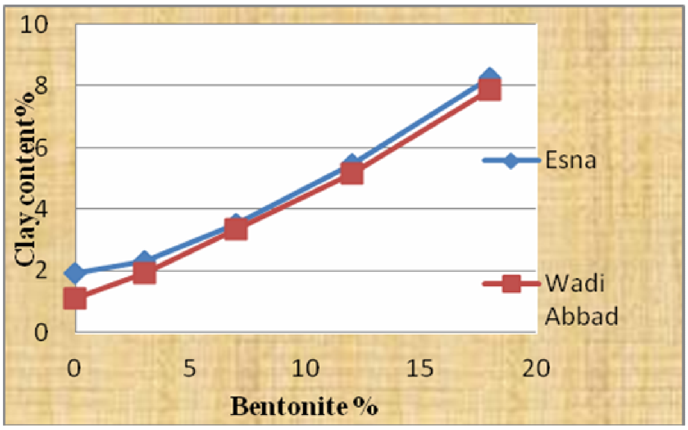

Fig. 1 : Relationship between bentonite percent and clay content.

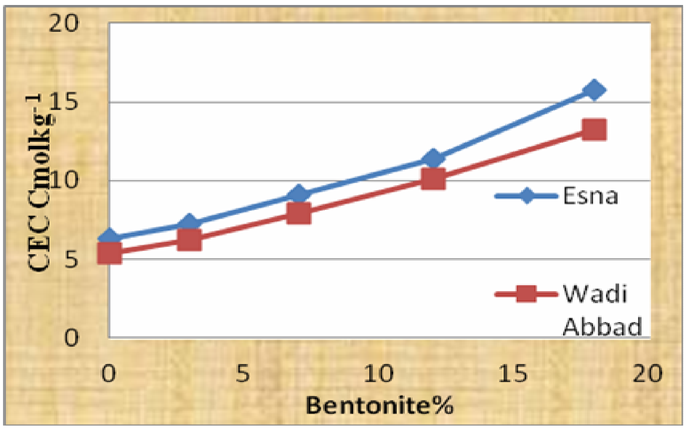

Fig.1: Relationship between bentonite percent and cation exchange capacity.

Useful changes are made in the structural layer of soil that has changed from sandy soils to loamy sand with 12 and 18% bentonite after a year. These results are in agreement with that obtained by Suzuki et al. (2007) who reported that the addition of bentonite in the upper layer of 20 cm of sandy soil significantly increased each of silt and clay content in this layer.

In Egypt, Hanna *et al.* (1979a) virgin sandy soils were improved of Tahrir Governorate by adding Khafrei shale that modified the texture, structure and cation exchange capacity of this soil. In this point Hassan and Abdel Wahab (2013) mentioned that enhancement of the structural layer of soil from sand to loamy sand has been increased with fine particles when using bentonite and zeolite as soil conditioners in sandy soils.

The ability of the cation exchange of capacity, all types of bentonite increased effectively soil CEC. In both Esna and Wadi Abbad soil, the change in CEC condensation was associated with soil with the addition of bentonite. It is clear that the addition of bentonite increased the cation exchange capacity, especially at the rate of 18% (15.72 and 13.21 Cmolkg^{-1}). These results are very important because increasing of CEC values lead to increased absorption capacity and surface area. The obtained results agreed with those obtained by (Noble *et al.*, 2005; Czaban *et al.*, 2013) they stated that the use of bentonite in low CEC soil, bentonite can achieve significant increases in CEC simply as a result of its permanent negative charge.

Figure (1) shows the relationship between bentonite rates and clay content. The increase in clay content due to the increase in bentonite is very clear. Whereas, Figure (2) illustrated the effect of bentonite application from zero to 18 % and cation exchange capacity. In both Esna and Wadi Abbad soils, the change in soil CEC was positively associated with increase of bentonite addition. In Esna soil, the minimum rate of bentonite 3% was a corresponding mean increase in CEC of 7.24 Cmolkg^{-1}. At the highest rate of bentonite application (18%), CEC was raised from 6.33 Cmolkg^{-1} in the control to a mean of 15.72 Cmolkg^{-1} The same trend was attained with Wadi Abbad soil. Also, figures indicated that the favorable rate of bentonite may be used is 18%.

The examination of the thin sections of treated sandy samples with 18 % bentonite from the two sites (Esna and Wadi Abbad) and the untreated samples (control) indicates some micro-morphological variation. The groundmass which is dominated by coarse grains of mostly quartz in the original soil samples (Photo 1, 3), a considerable parts became covered with the fine plates of bentonite clay in the treated samples. A clear change in the type of voids, although it is not natural peds but mixed and kept in columns. The dominant voids are mainly single and compound packing voids besides some large irregular vughs in the untreated samples (Photos 1 and 2).

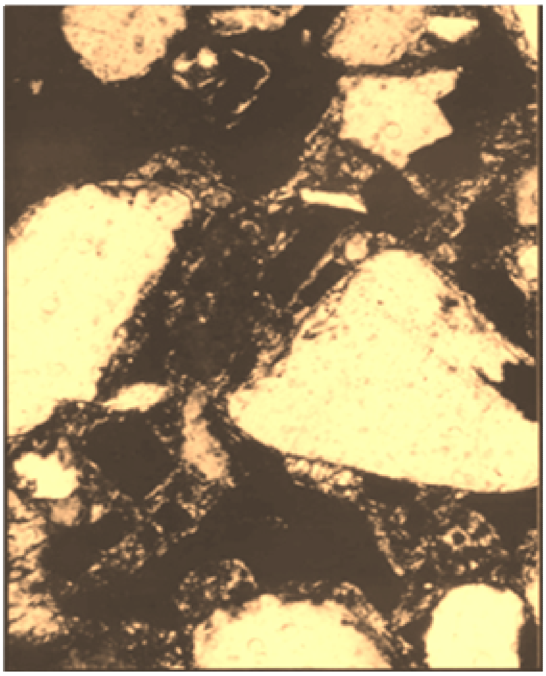

Photo 1 : Esna sandy Soil untreated.X40

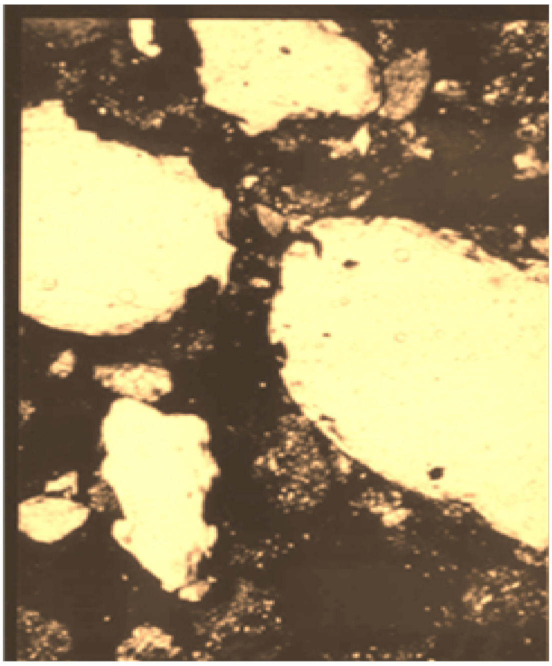

Photo 2 : Wadi Abaad sandy Soil untreated. X40

In case of addition of bentonite and after a year of irrigation it is observed that many smooth channels, vughs and vesicles besides the compound packing voids (photo 3 and 4). In particular distinct changes in the dominant voids from simple in the sandy samples to compound packing besides some coarse vughs and chambers in the treated samples with bentonite clay. The related distribution (C/F related distribution) changed from monic and enaulic to chitonic and locally gefuric.

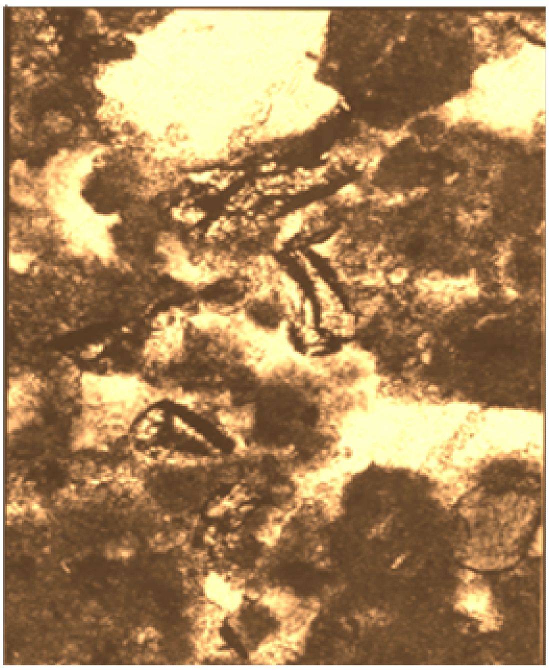

Photo 3 : Esna sandy Soil treated.X40

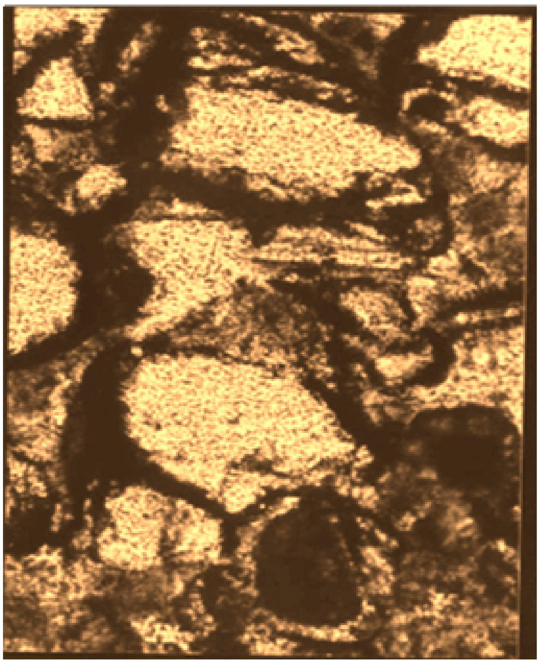

Photo 4 : Wadi Abbad sandy Soil treated.X40

With respect to the role of bentonite in improving textural soil, one can notice that large voids in all samples were improved as a result of adding bentonite in rate 18% comparing with untreated soil.

In coarse textured soil, the bentonite clay can be precipitated and grow in the wide vughs (photo5). Another way for pattern of bentonite, for the pores and vughs are mainly of fine-size, the bentonite clay cannot reach coarse size and remain in fine fractions. Bentonite can coating the coarse sand particle or fills the voids and vughs (photo 6). Voids: dominant large vughs and chambers.

Bentonite contains fine and colloidal particles, these particles play an important role in clogging macro pores and change pore size distribution towards fine pores that a key role in retained water (Hassan and Abdel Wahab, 2013). On the other hand, enrichment of sandy soils with bentonite increases their porosity and alters pore-size distribution

(Satje and Nelson 2009). Lhotský *et al.* (1970) reported an increase in pore ratio <0.3, 0.3-3, and 3-30 µm and a decrease in pores of 30-300 µm after soil adjustment with bentonite, which increase water capillary rise (Lazányi, 2005). Therefore, the addition of bentonite to sandy soils has improved the soil texture and therefore plant relationships in soil water. Improvement of soil texture and hence plant relationships with soil water.

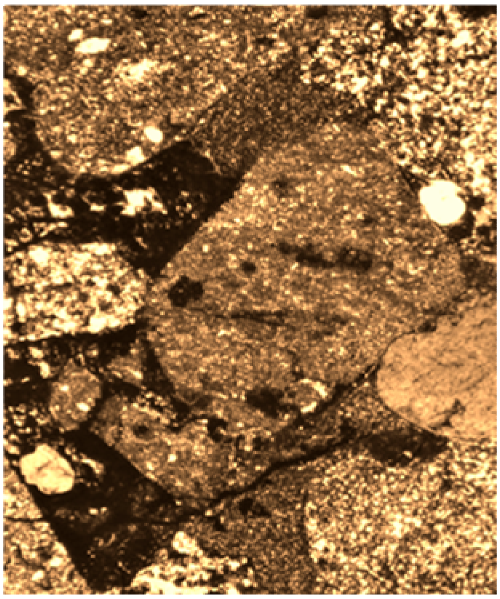

Photo 5 : Bentonite fills the voids and vughs.X60

Photo 6 : Bentonite coating the particles sand. X60

Conclusion

The main objective of this research work was to throw the light on one of the most promising aspect for reclamation of sandy soils through improving their physical and chemical conditions and consequently their agricultural production. Application of bentonite (dominated by montmorillonite) characterized by high surface area, great both water retention and CEC is a very beneficial material to combine the very lose sand particles into small aggregate. Application of bentonite to sandy soils has a clear impact on the CEC particularly at a highest rates (18%), which increase water holding capacity and the plant nutrients and hence plant growth will increase and agricultural production.

Application rate 18% gives a clear vision about the changes in the micromorphology of sandy soil. The coarse grains of sand became cover with plates of bentonite and act as adhesion to combine several particles. The fabric of the treated samples and the related distribution between coarse and fine fractions changed from monic and enaulic to what can be described chitonic and gefuric. The dominant voids improved by bentonite addition.

From economical and practical view, reclamation sandy soil by application of bentonite has many advantages over many other materials. Bentonite is stable, hardly disintegrated over the time, therefore it last in the soil and no need to repeat application every year. It is a natural deposit in many bentonite locations and low cost, besides it does not has any impurities or pollution impact on the environment.

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