# Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 7 (18): 2641-2645, 2007
ISSN 1812-5654


# The Effects of Bentonite on the Physic Chemical Characteristics of Sandy Soils in Algeria

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**Abstract:** In the objective to rehabilitate the degradation soils and improve the agricultural product, especially cereals and leguminous plants, in the sandy soils countries, we take an interest in the use of bentonite to ameliorate the physical and chemicals properties of these soils. To value the ecological advantage of this clay in these countries, it is proposed a study of increasing amount effect of bentonite on the physical and chemical characteristics on sandy soils. Results show that the texture of mixture tends from sandy soil under 2.5% of bentonite added to sandy silt soil under 7, 10 and 15% of bentonite. The EC increases with the amount bentonite mixture. pH does not fluctuate from one mixture to the another and tends to the alkalinity of soil; Total $CaCO_3$ raises when the bentonite is added in the mixture but active $CaCO_3$ decreases. The high bentonite amounts (10 and 15%) showed no effect on the total phosphorus. The mixture bentonite at 15% reduces the organic carbon and organic matter, whereas total nitrogen falls down when this mixture is enriched with bentonite. $Na^+$ and $Ca^{++}$ become higher when bentonite increases its amount; $K^+$ reduces in all treatments then this reduction affects $Mg^{++}$ only under high mixture bentonite (15%).

**Key words:** Bentonite, sandy soil, physical and chemical characteristics, rehabilitation

## INTRODUCTION

Algeria is among the Maghreb countries that is affected by climatic changes leading to an ecological mutation of ecosystems. The observations conclude that a degradation increasing of soils in a various zone known by their agricultural (Cheverry and Robert, 1998; Morsli *et al*., 2004) which led a loss of their fertility and productivity (Lhotsky, 1979; Tessier, 1994). This damage remains under the pressure for erosion (Demmak, 1981; Haddadj, 1997; Lal, 1998), salinity of soils (Postel, 1989; Oldeman *et al*., 1991; Belkhodja *et al*., 2000; Flowers, 2004), the agricultural over exploitation and a management of cultural technicals not more often adapted (Ambouta and Valentin, 1996). The sandy soils are very exposed to this degradation strongly marked by the drought agressivity (Le Houerou, 1993) which returns them in water deficit and poor fertilizing (Goa *et al*., 1998) on account of a weak capacity to keep back water, clay humus complex not existing, a high infiltration (Wierda and Veen, 1992) and a weak capacity of cationics exchange. So, the characterization of soils like a natural resource is one of important data, principally in the project of durable development of countries (Carter, 1993).

Soils of Mostaganem zones (North- West of Algeria), on 212, 000 ha of cultivated areas, cover 61% of sandy land (USDA, 1993) threatened by the degradation. The prevention against this natural phenomena requires various strategies to ameliorate these soils and rehabilitate their agricultural vocation for this purpose, if the organic improvements are often brought to satisfy to the fertilizing requirements of soils and plants, the requirements of mineral origin are little used.

Therefore, in the perspective to rehabilitate the sandy soils in the Mostaganem zone, the use of natural resources, such as bentonite, forms one of the eco physiological approaches to re- erect first the fertility of soils and later to recommend a companion crops system, as cereals-leguminous Various works brought that bentonite ameliorates the properties of sandy soils by increasing their wealth clay (Lhotsky, 1970; El Sherif, 1987; Benkhelifa, 1997) its adding to sand allow to the improvement of the physic chemical and hydrous characteristics on account of its high capacity to keep back the water and its strong exchange cationic capacity (Petr, 1985; Dejou, 1987) and to increase the agricultural yield (Kherroubi, 1992; Henni, 1994; Abdel Aleem *et al*., 2000).

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The aim of this study is to evaluate the physic chemical responses of the sandy soils to the increasing amount of bentonite in this first experimentation led with tomato plants later, the objective will be applied to this substrate in the cereals leguminous association cultivation. In this paper we present first results of texture mixture analysis then variations of pH, EC, total $CaCO_3$, active $CaCO_3$, phosphorus, organic carbon, organic matter, total nitrogen parameters in each treatment in the second step we propose a study in the exchangeable cations capacity as $Ca^{++}$, $Mg^{++}$, $Na^{+}$, $K^{+}$, in the sandy bentonite mixture soils.

## MATERIALS AND METHODS

Substratum; it concerns clay, bentonite, taken from mine of Mzila (near Mostaganem) with characteristics (Table 1) according to Kherroubi (1992).This clay, under natural granulous state is strongly pulverized with an electrical pulverized to obtain a fine powder before using it with sand. Sand, taken from seaside, is first strained and leached with fresh water several times, then strongly with hydrochloric acid for excluding salts, finally leached several times with distilled for eliminate chloride. After drying, sand (5000 g/pot) is mixed with bentonite at 2.5% (125 g/pot), 7% (350 g), 10% (500 g) and 15% (750 g). In each pot, bentonite and sand are homogenized. The experiments are led in the Agricultural Research Center of Mostaganem University from September 2000 to September 2001(including all analysis).

In each pot, one young plant of tomato (var Marmande Claudia) is cultivated until three months old during their growth, plants are irrigated at 30% of the field capacity according to the mixture soil and received the nutrient solution: Nitrogen (11%), Phosphorus (15%) and Potassium (15%) (Table 1).

For analysis of the physic chemical compounds, five samples of mixture soil by each pot are taken carefully around root zone in each pot the experimental pots are arranged according to the method of randomized blocs with five repetition.

**Analytical methods used:**

- Texture of mixture is determinated with International sedimentation method by using sodium hexametaphosphate as dispersing,
- pH: with a pH meter from aqueous extract of each mixture sand bentonite sample diluted at 1/2.5. pH KCI are determinated.
- EC: (electrical conductivity mmhos/cm) with conduct meter from extract at 1/5.
- Exchange cations capacity (ECC in meq 100 $g^{-1}$ of sample bentonite sand mixture):

Table 1: Physic chemical characteristics of bentonite of Mzila (Mostaganem) according to Kherroubi (1992)

| Fraction (texture) | Clay* | Fine silt | Coarse silt | Fine sand | Coarse sand |
|---|---|---|---|---|---|
| | 83.75% | 5.31% | 3.38% | 1.74% | 1.79% |
| Elemental oxides | $Al_2O_3$ | $SiO_2$ | CaO | MgO | $Fe_2O_3$ |
| | 18.2% | 59.35% | 1.95% | 0.95% | 0.43% |

*Principally in montmorillonite

$Ca^{++}$, $Mg^{++}$, $Na^{+}$, $K^{+}$ are extracted by ammonium acetate and determinate by Atomic Absorption Spectrophotometer,

- Total nitrogen (%) with Kjeldhal method,
- Calcareous complete (%) with Bernard calcimeter apparatus,
- Calcareous active (%) with Drouineau Galet method,
- Phosphorus complete (%) with Aubert method,
- Organic carbon and matter (OM in%) with Anne method.

## RESULTS AND DISCUSSION

**Variations of texture according to the treatment of bentonite:** Data shown Table 2 show that clay content in control is present only at 1.27%; under 2.5% of bentonite mixture, rate of clay does not vary. When substrate is enriched from 7% of bentonite, the rate of clay increases significantly in the mixture with regard to control. For example, the rate of clay is multiply by 4 when bentonite is added to sand at 15%.

The fine silt develops their rates with increasing bentonite amount values of these rates fluctuate significantly under all treatments compared to control, but no effect of the bentonite treatment at all rate on the of fine silt appears. On the contrary, the coarse silt appeared to decrease due to the increase of bentonite present. Under 2.5% of mixture, the rate of coarse silt reduces without effect, but when bentonite amount changes to 7%, the reduction of coarse silt is significantly lower (3.98% against 10.47% in control).

The presence of sand is more important whatever the treatment with bentonite with regard to other fractions of texture. Nevertheless, one must notice that rates of fine sand are near but they all the same remain significantly high compared to control. On the contrary, the coarse sand falls down from 7% of bentonite treatment.

**pH and EC values as affected by bentonite treatments:** In all conditions, data of Table 3 show that pH water does not fluctuate enough values reduce the alkalinity of mixture soils, on the other hand, pH KCI falls down with regard to value unregistered for pH water and adjusts around the average value (7.99).

The EC presents 0.37 ds $m^{-1}$ in control, this parameter evolves progressively with the increasing of the bentonite

Table 2: Textural class of the sand bentonite mixtures

| Texture | Control | 2.50% | 7% | 10% | 15% | M±σ |
|---|---|---|---|---|---|---|
| Clay | 1.27 | 1.88NS | 2.94S | 3.36S | 5.11S | 2.91±1.48 |
| Fine silt | 2.90 | 5.14NS | 7.96S | 7.67S | 7.98S | 6.33±2.25 |
| Coarse silt | 10.47 | 6.05S* | 3.98S* | 4.06S* | 5.12S* | 5.93±2.67 |
| Fine sand | 30.93 | 32.74S | 34.07S | 33.98S | 32.90S | 32.92±1.27 |
| Coarse sand | 54.43 | 54.19NS | 51.11S* | 50.93S* | 48.89S* | 51.91±2.36 |

Statistical significant test of student (LSD at 5%), S = Significantly upper with regard to control (sand without bentonite), NS = No effect of bentonite S* = Significantly inferior

Table 3: pH water and KCl) and electrical conductivity (mmhos $cm^{-1}$) determinate under treatment of bentonite

| Parameters | Control | 2.5% | 7% | 10% | 15% |
|---|---|---|---|---|---|
| pH water | 8.13±0.290 | 8.17±0.040 | 8.21±0.010 | 8.23±0.010 | 8.28±0.006 |
| pH KCl | 7.99±0.009 | 8.00±0.006 | 8.00±0.006 | 7.99±0.005 | 7.99±0.005 |
| EC (mmohs $cm^{-1}$) | 0.37±0.020 | 0.55±0.020 | 0.81±0.010 | 0.90±0.010 | 1.07±0.020 |

Table 4: Chemical compounds (%) in mixture soil according to bentonite amount calcareous

| Chemical compounds | Control | 2.5% | 7% | 10% | 15% | M±σ |
|---|---|---|---|---|---|---|
| A | 30.47±0.66 | 32.00±0.8S | 32.98±0.48S | 33.81±0.61S | 32.91±0.58S | 32.43±1.13 |
| B | 10.33±0.22 | 10.49±0.17NS | 10.47±0.18NS | 10.68±0.2NS | 10.83±0.12NS | 10.56±1.17 |
| C | 0.20±0.08 | 0.22±0.06NS | 0.40±0.01S | 0.25±0.01NS | 0.27±0.01NS | 0.26±0.07 |
| D | 0.40±0.02 | 0.47±0.03NS | 0.55±0.04S | 0.6.±0.04S | 0.46±0.03NS | 0.49±0.07 |
| E | 0.06 | 0.05NS | 0.03 | 0.04* | 0.04* | 0.04±0.01 |
| F | 0.69±0.09 | 0.82±0.06S | 0.95±0.07S | 1.03±0.07S | 0.79±0.05NS | 0.85±0.12 |

A = Total calcium carbonate, B = Active calcium carbonate, C = Total phosphorus, D = Organic carbon, E = Total nitrogen, F = Organic matter, NS: Non Significant, S: Significantly upper with regard to control, *: Significantly inferior

Table 5: Exchangeable cations capacity (ECC in meq.100 $g^{-1}$ of mixture soil) according to the bentonite amount

| Ions | Control | 2.50% | 7% | 10% | 15% | m±σ |
|---|---|---|---|---|---|---|
| $Na^+$ | 0.43 | 1.79NS | 3.30S | 3.59S | 5.56S | 2.93±1.93 |
| $Ca^{++}$ | 4.10 | 4.73NS | 8.40S | 10.20S | 13.80S | 8.24±4.00 |
| $K^+$ | 4.76 | 4.27NS | 3.11S* | 2.70S* | 1.64S* | 3.29±1.24 |
| $Mg^{++}$ | 1.60 | 3.30NS | 5.80S | 6.60S | 8.3S | 5.12±2.66 |
| SAR* | 0.29 | 1.11 | 1.55 | 1.54 | 2.10 | 1.31±0.67 |

*Sodium adsorption ratio, NS: Significant, S: Significantly uper with regard to control, S*: Significantly inferior

amount. EC estimated in 15% mixture of bentonite sand increases about three fold compared to EC in control (1.07 against 0.37 mmhos $cm^{-1}$).

**Chemical compounds:** Results of Table 4 indicate that total calcium carbonate increases in all mixture soils, but under 15% of bentonite treatment, it should be observed that this compound expresses an reduction even if its value remains significantly upper than control. Active calcium carbonate does not vary in all treatments and their rates end to the average value (10.56%).

The rate of total phosphorus is important only in soil mixture at 2.5% of bentonite; in the following treatments, bentonite does not appear to affect it.

Organic carbon increases significantly in soils enriched with 7 and 10% of bentonite, when it is added 15% carbon falls until a same rate obtained in control. Total nitrogen is important in control and mixture sand bentonite at 2.5%; its rate changes by reducing significantly at 7% of bentonite then increases sensibly under the others treatments. The rate of organic matter becomes higher until 10% of bentonite in the mixture; on the contrary, the treatment at 15% causes a reduction of it not significant with regard to control (0.79 for 0.69%).

**Variations of exchangeable cations determinated in mixture soils according to bentonite amount:** Table 5 show that $Na^+$ and $Ca^{++}$ are rising significantly in mixture form 7% of treatment bentonite; for example, under 15% of treatment bentonite, the amounts are multiply by 13 and by about 3.2 respectively for $Na^+$ and $Ca^{++}$ compared to control. For $K^+$, their amounts decrease significantly with the increasing of the bentonite amount in the mixture but the treatment at 25% bentonite does not change the amount of this cation with regard to control (4.27 for 4.76 meq 100 $g^{-1}$ of mixture soil).

$Mg^{++}$ does not varies with control in the mixture at 2.5% of bentonite; the effect of bentonite expresses it self by significant increasing amount of $Mg^{++}$ until 10% of mixture then this cations falls down rapidly (1.64% meq 100 $g^{-1}$ of mixture soil) under treatment at 15% of bentonite.

## CONCLUSIONS

The main results obtained in this study conclude that the physical characteristic varies according to texture and the mixture of soil. Clay rate analyzed increases with the bentonite amount which is without effect on the fine silt, but the coarse silt reduces with the increasing of bentonite in the mixture, rate of fine sand decreases under high bentonite amount (15%) while the one of coarse sand begins to fall down from 7% of bentonite mixture.

The chemical characteristics varies with the parameter analyzed and the mixture of middle. pH does not fluctuate from one mixture to the another and tends to the alkalinity of soil; the EC increases with the amount bentonite mixture. Total $CaCO_3$ raises when the bentonite is added in the mixture but active $CaCO_3$ decreases. The high bentonite amounts (10 and 15%) showed no effect on the total phosphorus. The mixture bentonite at 15% reduces the organic carbon and organic matter, whereas total nitrogen falls down the mixture is enriched with bentonite. For the exchangeable cations, $Na^+$ and $Ca^{++}$ become higher when bentonite increases its amount; $K^+$ reduces in all treatments then this reduction affects $Mg^{++}$ only under high mixture bentonite (15%).

Obtained data conclude to a variability of physic chemical parameters according to the proportion of bentonite added to sandy soils. Results show that the texture of mixture tends from sandy soil under 2.5% of bentonite added to sandy silt soil under 7, 10 and 15% of bentonite according to the triangle of texture (USDA, 1993), on the contrary according to Henin (1969), the mixture soil is sandy silt until 10% of bentonite added then becomes sandy silty clay under 15% of bentonite. The adding of bentonite to sandy soils can have an effect upon the porosity, particularly the micro porosity, that increase when the amount of clay becomes important in the mixture (Lhotsky, 1970). El Sherif (1987) shows that the porosity increases until 45% when bentonite is mixed at 10% to sand. These result traduce the change from the macroporosity to the microporosity of the mixture soil favorable to the capacity of soil ked back water (Benkhelifa, 1997). On the other hand, Tessier (1994) have come to the conclusion that it exists the correlation between the retention capacity of soil in water and the amount of clay and fine silt. The texture of soil plays a part in the migration of salts; Cherbury (1991) notes that silt sandy soils are vulnerable because the rapidity of ascending of salts is more important. Our results show that the mixture soils until 10% of bentonite are sandy silt and under 15% of bentonie become sandy silt clay according the classification of Henin (1969). The relation of cations, particularly $Na^+$, $Ca^{++}$ and $Mg^{++}$, leads to the calculation of SAR (Sodium Adsorption Ratio) in each mixture soil; results indicate that this ratio is around 0.29 in control, raises to 1.54 for the sandy silt soil (10% of bentonite) then increases to 2.10 for the sandy silt clay mixture (15% of bentonite). Carrow and Duncan (1998) report $Na^+$ can produce adverse effects on soil structure even when the SAR is near 5 due in part to type and content of clay. These authors note that clay type montmorillonite, vermiculite, illite and mica-derived clays is more sensitive to $Na^+$ than other clay. In present case, the bentonite used in the experimentation is a clay type Montmorillonite (Kherroubi, 1992). We observe in present results that $Na^+$ and $Ca^{++}$ cations increase with the bentonite amount respectively from 0.43 and 4.1% in control to 5.56 and 13.8% in sandy silt clay soil (15% of bentonite mixture). SAR determinated in all treatments is more below 5 then while $Mg^{++}$ reduce strongly under 15% of bentonite. The risk of it is not well reasoned, will be able to become a constraint particularly as source of the accumulation of salts in the root zones. The resistance of cereals and leguminous in association cultivation under combined effects of bentonite salinity will be nearest objective of present research.

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