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Improving Sandy Soil by Using Natural Soil Amendments in the Form of Nanoparticles

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ABSTRACT

There is an emerging importance for improving the productivity of sandy soils, and enhancing the efficiency of nutrient use, especially with the newly reclaimed soils in Egypt. Nanotechnology plays a vital role in various fields, and is currently beginning to develop in soil improvement as well. Nanotechnology is the science that deals with particles less than 100 nanometers in length. Due to its nano size, it is ready to react with additives very effectively. Due to its nanoscale size, soil behavior also shows different characteristics. Nano-sized particles have a high surface area when compared to non-nano particles. By using these nano-sized particles in soil amendment, the reaction becomes more effective. The main objective of this study is to make a comparison between the traditional methods of adding Tafla as natural soil amendments and the new method of adding Nano-clay (Nano Tafla) on some physical properties of sandy soils, corn (*Zea mays* L.) as a test crop. Experiments were conducted in containers to study the effect of adding nano Tafla at two different rate of 0.025%, 0.05% and raw Tafla at two different rate of 0.25%, 0.5 compared control. The data indicated that the addition of nano Tafla and crude Tafla resulted in an increase in total porosity (TP); Available water (AW), water holding capacity (WHC), pressure characteristics and germination percentage, while hydraulic conductivity and bulk density (Bd) values decreased and calcium carbonate values were not affected compared to the control treatment.

Keywords: Compaction properties, Nano Tafla, raw Tafla**,** Germination percentage (%) and and Characteristics of sandy soils**.**

1. Introduction

There is no doubt that the ratio between soil resources and the growing population is one of the most serious problems in Egypt. Therefore, agricultural expansion in the desert by adding about 4.3 million acres becomes one of the main goals of Egypt, in order to meet the food security requirements of this massive population increase (Abel-Hamid *et al.,* 2016). Sandy soil is considered infertile due to its low clay, organic matter, nutrients and water content. Tafla was contains clay in different proportions ranging from 45-75%. It also differs in the quality of the dominant clay mineral. It may be rich in bentonite or kaolinite. General Tafla is characterized by its effective surface activity and high cationic exchange capacity.

Bentonite consists mostly of the clay mineral (montmorillonite). Bentonite is used to control swelling and catalytic response (absorption and heat) (Suranjana *et al.,* 2020). It improves sandy soil better, as the exchange capacity of cations, organic carbon, macronutrients and micronutrients is improved (Czaban and Siebielec, 2013; Czaban *et al.,* 2013). 2014; Semalulu *et al.,* 2017). Bell *et al.* (2015) found that bentonite increases the CEC of soil. Application of bentonite to sandy soil reduced water loss during deep percolation, prevented nutrient leaching, and improved water properties and water holding capacity (Abd El-Hady and Eldardiry, 2016). Bentonite is used around the world to reduce water loss. High quality bentonite should mainly contain montmorillonite (Brigatti *et al.,* 2016).

In Egypt, out of one million kilometers of total geographical area, arid and semi-arid areas occupy more than a third of the area. Sandy soil represents a major problem for crop production due

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to poor physical and chemical environment, especially in irrigated areas. The idea of nanotechnology was first proposed by Richard Feynman in 1959, (Feynman, 1960). After that, this technology developed in all branches of science.

The main strategy of nanotechnology in geotechnical engineering is to improve soil properties through the application of nanomaterials. The presence of only a small amount of nanomaterial in soil can significantly affect the physical and chemical behavior of soil due to the very high surface area of nanomaterials, surface charges, and their morphological characteristics. Zhang (2007) studied the effect of natural nanoparticles on the engineering properties of soil. It was found that the presence of only a small amount of nanoparticles in soil has a significant impact on the chemical behavior of the soil and the engineering properties of the soil. It was also concluded that soils containing nanoparticles with nanoscale intraparticle voids typically showed higher fluid–plastic limits, and the presence of fibrous nanoparticles enhanced the soil shear strength. Ghazi *et al.* (2011) conducted a study on the plasticity and strength properties of fine soil and its mixture with nanomaterial. They report the results of a series of Atterberg limits and unconfined compressive strength tests. The results showed that adding modified montmorillonite nanoclay to the soil increases the fluid limit and plasticity index and significantly improves the unconfined compressive strength of the soil. “Nanotechnology is the art and science of manipulating matter on the nanoscale.” Design, characterization, production, and application of the structure, device, and system by controlling shape and size. At the nanoscale (British Standards Institution, 2005).

Nanotechnology is developing as the sixth revolutionary technology of the current era. It is considered an emerging scientific field that is widely subjected to many scientific fields and is supposed to play the major role in the field of agriculture and food science in the coming era, but so far, there are no scientific studies on its application in agriculture all over the world (Mousavi and Rezaei, 2011 and Abobatta, 2018) They found that nanotechnology is a new key to developing agricultural production through implementing nutrient efficiency and improving plant protection practices. Nanotechnology may have real solutions to various agricultural problems such as crop varieties Improved plant protection, disease detection and plant growth monitoring (El-Nagar and Sary 2021). It was found that the preparation of nano-bentonite from raw bentonite was explained. Nano bentonite contains an abundance of montmorillonite compared to raw bentonite. The surface area of nanobentonite increased compared to that of raw bentonite. The addition of nano-bentonite also improved the soil’s water properties, such as: available water and water retention capacity (El-Nagar and Sary, 2021.) It was found that the pore size by different methods was larger in nano-bentonite of raw bentonite, which indicates the high chemical activity of nano-bentonite. There is a relationship between increased surface area and absorption of elements. When the surface area increases, there is an increase in the absorption of elements. This is due to the increased number of absorption sites. Therefore, nano bentonite is a good adsorbent.

The purpose of this study is to compare the effects of the new technique of adding Nano-clay (Nano Tafla) on specific physical parameters of sandy soils with traditional methods of adding Tafla as natural soil amendments, corn (*Zea mays* L.) as a test crop.

2. Materials and Methods

2.1. Preparation of nanoparticles

Nanoparticles are usually prepared in a bottom-up and top-down manner. The top-down method starts with bulk materials (top) that are subsequently reduced into nanostructures (bottom) by physical, chemical and mechanical processes, e.g., mechanical ball milling, milling etc.

Nanoparticles are prepared by planetary ball milling. Through scanning electron microscopy (SEM), the particle sizes of ground clay were calculated in the range of 40.54 - 81.08 nm and that of ground clay in the range of 25.97 - 77.92 nm (Figure 1 and Figure 2). After the ball milling process, the particle size was reduced compared to the raw additives.

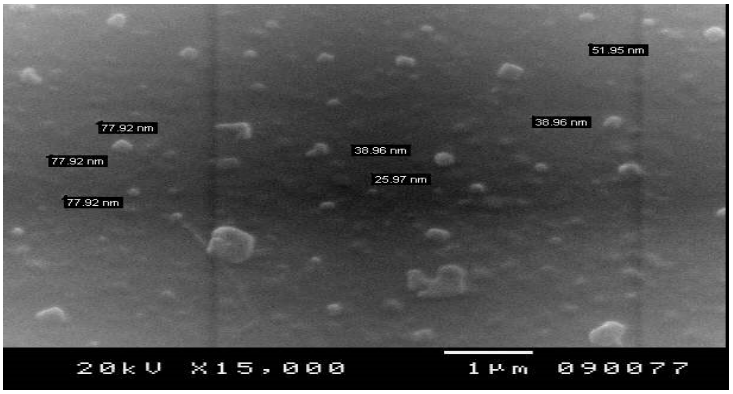

Fig. 1: SEM micrograph of Nano- Tafla

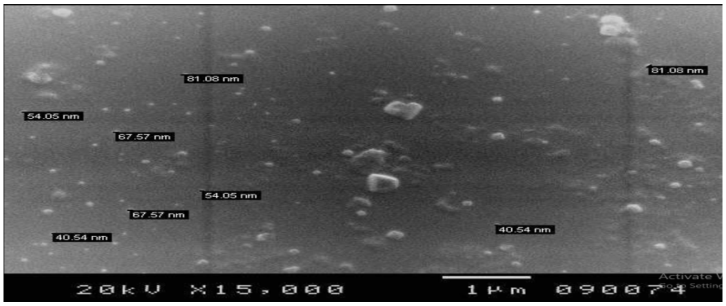

Fig. 2: SEM micrograph of Nano- Tafla

Tafla is taken and addition to mix with soil at rate 0.025 and 0.05% from nano Tafla and 0.25 and 0.5% less than 15mm from conventional Tafla (Where the raw Tafla was grinded to a size less than 15mm.) Surface area and pore volume analysis of nanotafla.

Surface area and pore volume of raw tafla, and nanotafla was shown in Table (1). According to multi-point BET methods, BET single-point methods, the surface area of nano-tafla greater than the increase in surface area, there is an increase in absorption of elements. This is due to the increased number of absorption sites. Therefore, Nano Tafla is a good absorbent material.

Table 1: Surface area and pore volume for both raw and nano tafla.

Parameters	Raw Tafla	Nano Tafla
Single point BET surface area	m2/g36.307	99.950 m^2/g
Multipoint BET surface area	40.112m^2/g	110.43 m^2/g
Total pore volume	0.0257cc/g	cc/g0.0708

A pot experiment was conducted in the greenhouse of the Soil Department Improvement and conservation Soil, Water and Environment Research Institute, ARC, Giza, Egypt. during 2022-2023. The sandy soil of the experiment was collected from at El-Ismailia Research Station to evaluate the effectiveness of the manufactured nanotafla and study the relative performance with the conventional nano-tafla on some physical properties of sandy soils and with corn (*Zea mays* L.) as a test crop. The primary soil was analyzed for its physical properties in Tables (2 and 3).

Table 2: Particle size distribution (%) for the study soil sector.

Particle size distribution (%)				**Soil texture class**	**$CaCO_3$ (%)**
Coarse sand	**Fine sand**	**Silt**	**Clay**		
60.3	27.2	11.1	1.4	sandy	3.9

Table 3: Chemical analysis of the initial studied soil profile

pH	Ec (dS\m)	Sp	Anions(meq.\L)			Cations(meq.\L)			
			HCO_3	CL	SO_4	Ca	Mg	Na	K
7.6	5.8	20	4.66	28.72	29.32	26.5	19.8	14.16	2.24

The two sources, namely the nano-gel and the traditional clay, were evaluated at two levels of each one compared with control. While the tafla's sample was taken from, Al-Sagha Palace in Fayoum Governorate and its mechanical and chemical analysis is shown in Table No. (4).

Table 4: Mechanical and chemical analysis of Qasr El- Sagha Tafla.

Qasr EL-Sagha	Analysis
Clay%	75
Silt %	10
Fine sand %	7.0
Coarse sand %	3.0
Calcium carbonate %	5.0
Organic matter %	0.48
Gypsum %	1.0
Concentration of salts(ds/m)	8.0
Cation Exchange Capacity(meq.\100g)	44
Chlorides	39.4
Sulfates	22.8
Adsorbent sodium%)(SAR	35

2.2. Treatments:

The experiment included five Treatments as follows:

T1: Control.
T2: Nano Tafla at rate 0.025%.
T3: Nano Tafla at rate 0.05%.
T4: Conventional Tafla (raw Tafla) (<15mm) at rate 0.25%.
T5: Conventional Tafla (raw Tafla) (<15mm) at rate 0.5%.

2.3. Corn Experiment

A Pot experiment was conducted in a pot filled with 5 kg of soil and treated by raw Tafla and nano Tafla then were mixed well. Ten grains of corn (*Zea mays* L.) were planted per each pot, then the germination percentage was determined. the treatments were arranged in Randomize Complete Block Design (RCBD) with three replicates.

2.4. Germination Parameters

2.4.1. Germination percentage (GP)

The germination percentage was determined according to Scot *et al.,* (1984).

GP = Seeds germinated/total seeds x 100

2.5. Statistical Analysis

The data were analyzed statistically by analysis of variance (ANOVA) using Cohort computer program according to the method mentioned by Gomez and Gomez, (1984). Mean separation procedure was performed using LSD, at a 0.05 and 0.01 level of significance.

3. Results and Discussion

3.1. Influence of Nano Tafla and Non - Nano Tafla on:

3.1.1. Moisture content and available water in the soil used

Knowledge of moisture retention characteristic of the soil is very helpful because it does not only give the total amount of water held by the soil, but also give its pattern of release. This information is important for the proper planning of irrigation regimes particularly in arid and semi-arid zones, where the amount of water is very limited (Oweis and Hachum, 2006). Data presented in Table (5) showed that the effect of different additives soil Nano Tafla and Non - Nano Tafla treatments on the properties of the sandy soil. The data revealed that Moisture content and available water were increased with applied any each of them comparing with the control. The efficiency of the studied treatments on increasing available water, values could be arranged in the following order: T3> T2> T5> T4> T1. These results may be attributed to the total roughness of the nano-tafla is lower than that of the raw tafla, which indicates that the hydrophilic properties of the nano- tafla are more than that of the raw tafla. Moisture retention of sandysoil, which treated with Nano Tafla, was much higher than that with adding Nano Tafla, so both total prosityfield capacity and wilting point were increased with increasing application rate of Nano Tafla and Non - Nano Tafla but values of Non - Nano Tafla less than Nano Tafla.

Table 5: Moisture content at different applied suction and available water (A.W., volume %) under different rates of application of Nano Tafla and Tafla.

Treatments	**Moisture content at different applied suction (atm)**				**A.W (Vol %)**
	0.001	**0.1**	**0.33**	**15**	
T1	35.43d	2.96e	2.43c	1.41d	1.55e
T2	56.42ab	11.58a	7.63b	5.34bc	6.24b
T3	58.65a	14.23b	8.86a	6.73a	7.5a
T4	52.5c	8.5d	7.43b	4.88c	3.62d
T5	54.01bc	9.47c	7.7b	5.45b	4.02c
LSD 0.05	3.83	0.93	0.69	0.47	0.22

T1: Control, **T2**: 0.025% Nano, **T3**: 0.05% Nano, **T4**: 0.25% <0.15, **T5:** 0.5% <0.15

Because increasing the moisture retained in sandy soil is important, the available moisture, which is the most important, was calculated as the difference between the moisture content at field capacity (0.10 bar) and the moisture content at the wilting point (5 bar) and is presented in Table (3). The data reveal that the moisture content at field capacity (0.10 bar) increase with increasing application rate of any of the two Tafla. On the other hand, increasing the application rate increase the moisture content at W.P. but the rate of increase in filed capacity is higher than the rate of the increase in wilting point. Consequently, the available moisture content increase with increasing the application rate of any of the two Tafla the rate of increase in A.W. under nano Tafla. treatment was higher than that under raw Tafla. Treatment this difference is due to the total roughness of nano Tafla is lower than that of the raw Tafla, which indicates that the properties of the nano-tafla are more hydrophilic than that of the raw tafla. Similar results have been reported by (El-Nagar and Sary, 2021). This is because nano-tafla enables the formation of highly swollen, gel-like, hydrophilic forms by adding water. It diffuses in water with the help of polarity property, which creates a more viscous liquid and reduces filtration by reducing permeability (Shakib *et al.,* 2016 & Mohamadian *et al.,* 2018). It accumulates in the gaps between the larger particles, leading to prevention of the flow in the matrix (Wilson, 2012).

3.1.2. Pore size distribution

The inherent properties of sandy soil are low water retention and rapid water movement. Therefore, any attempt to improve sandy soils must focus on redistribution of pores, i.e. increasing water retention in the pores and reducing Q.D.P whereas the mean values are shown in Table (6) The data reveal that fine capillary pores (<0.19μ) and water holding pores (8.62-0.19μ) were increased whereas quickly drainable pores (<28.8μ) were decreased with increasing the application rates of any of nano Tafla or raw Tafla. This effect reaches it maximum at higher application rate in T3. This result is in favor of improving sandy soil, i.e. increasing its moisture retention and reducing water movement in it.

Adding any of two Tafla leads to a change in pore size distribution due to total roughness of the nano-tafla is lower than that of the raw tafla, which indicates that the properties of the nano-tafla are more hydrophilic than that of the raw tafla. Which leads to an increase in fine capillary pores at the expense of fast-draining pores, thus increasing the moisture retained in sandy soil. The increase in available water (AW) and water holding capacity (WHC) was higher when nano-tafla was added, and this is due to the fact that nano-tafla was hydrophilic. This is because it had a large surface area and large pore volume, which resulted in high chemical activity. It was probably because of the many functional groups that provided more active adsorption sites and high adsorption efficiency as well, so nano-bentonite (which is part of the tafla components) is considered a good adsorbent (Ghounam *et al.,* 2016; Sirait and Manalu, 2018).

Table 6: Pore size distribution (μ) under the different rates of application from Nano Tafla and Tafla.

Treatments	**QDP** **0.001-0.1 >28.8** (μ)	**SDP** **01-0.33** **28.8-8.6** (μ)	**WHP** **0.33-15** **8.6-0.19** (μ)	**FCP** **>15 <0.19** (μ)
T1	44.94a	0.53d	0.82d	1.01e
T2	34.84d	4.15b	2.19b	5.14b
T3	31.42e	5.27a	2.73a	6.73a
T4	40b	1.07c	1.55c	4.08d
T5	37.48c	1.37c	2.25b	4.65c
LSD 0.05	0.48	0.32	o.16	0.24

T1: Control, **T2**: 0.025% Nano, **T3**: 0.05% Nano, **T4**: 0.25% <0.15, **T5:** 0.5% <0.15

3.2. Bulk density (g/cm^3), Hydraulic conductivity (cm/h.) and $CaCO_3$ (%)

The data presented in Table (7) showed the effect of different applied soil treatments with Nano-Tafla and non-Nano-Tafla on the properties of sandy soil. The data showed that the bulk density values of the soil decrease with increasing rates of addition of either of the two tafla (nano or non-tafla), as the maximum value reached at T3 compared to the control. It can be seen that the values of H.C. Taking the same trend, while the effect was weak on the values of calcium carbonate when applying either nano-tafla or non-nano-tafla, the data showed that increasing the rate of application of either of the two tafla led to a decrease in the bulk density values. The size of the reduction increases with the increase in the rate of application of any of the tafla, as the maximum value at treatment reached 0.05% Meg. /fed compared to control. The effect is more noticeable with Nano Tafla. This finding can be attributed to the fact that the overall roughness of the nano-tafla is lower than that of the raw tafla, which indicates that the hydrophilic properties of the nano-tafla are more than those of the raw tafla, which enhances the aggregation process and thus increases the apparent volume of the soiland decrease soil bulk.

3.3. Hydraulic conductivity (H.C)

The average H.C values under different application rates for the two tafla are presented in Table (7) the data show that in sandy soil the soil hydraulic conductivity values decreased with increasing application rate for either tafla, Hydraulic conductivity values. It decreased from 27.3 cm/h in untreated soil to 13.6 cm/h and 15.3 cm/h under nano-tafla and raw tafla conditions, respectively, under treatments,0.05% and 0.5% Meg. /fed. at the end of the experiment. This can be attributed to the effect of the overall roughness of the nano-tafla being lower than that of the raw tafla in reducing the total pores and increasing the micro-pores and thus the hydraulic conductivity values decreased. This result clearly indicates that soil particles can effectively fill the void of soil particles and thus the soil additive matrix becomes less permeable in nature. In this case, compared to non-nano particles, nanoparticles can effectively fill the pores of soil particles due to their purity and thus lead to lower permeability values. It was found that nanoparticles mixed with soil gave permeability efficiency 10 times lower than non-nano-sized additions (El-Nagar and Sary, 2021).

Table 7: Bulk density (g/cm^3), Hydraulic conductivity (cm/h.) and CaCO3 (%) under different rates of application of Nano tafla and Tafla.

Treatments	Bulk density (g/cm^3)	Hydraulic conductivity (cm/h.)	$CaCO_3$
T1	1.72a	27.3a	3.9a
T2	1.59d	14.5d	3.86bc
T3	1.57e	13.6e	3.85c
T4	1.64b	16.2b	3.88a
T5	1.62c	15.3c	3.87b
LSD 0.05	0.01	0.52	0.01

T1: Control, **T2**: 0.025% Nano, **T3**: 0.05% Nano, **T4**: 0.25% <0.15, **T5:** 0.5% <0.15

3.4. $CaCO_3$ (%)

The data presented in Table (7) explain the effect of the treatments applied to the sandy soil on their effect on calcium carbonate. It was clear that all the applied treatments used led to a slight decrease in its percentage compared to the untreated soil (control). The efficiency of different treatments can be arranged based on the calcium carbonate values in descending order, i.e. T3 < T2 < T5 < T4 < T1.

3.5. Penetration resistance (P.R) (Compaction)

Penetration resistance depends on moisture content in the soil. The relation between penetration resistance and moisture content was investigated. In general, it was found that penetration resistance increase gradually with increasing moisture content in the soil. This is because sandy soil shows a kind of stickiness when it is wet water acts as a lubricant, so soil particles are easily rearranged and pressed together more firmly in wet conditions than in dry conditions. These have a direct impact on the soil water system (Pham *et al.,* 2012) Mean values of the penetration resistance in the soil treated with different application rate of Nano Tafla and Non - Nano Tafla Shown in Table (8) the data shows that the values of P.R. were increasing with increasing the application rates of any of the two Tafla (nano or non Tafla) where reached the maximum value at 0.05% from nana Tafla compared to control.

Table 8: Moisture content (%) and Resistance of soil penetration (kg/cm^3) under the different rates of application of Nano tafla and Tafla

Treatments	Moisture content (%)	Penetration resistance (kg/cm^3)
T1	3.36c	3.85d
T2	7.99a	6.75ab
T3	8.11a	6.98a
T4	7.03b	6.14c
T5	7.36a	6.68b
LSD 0.05	0.49	0.25

T1: Control, **T2**: 0.025% Nano, **T3**: 0.05% Nano, **T4**: 0.25% <0.15, **T5:** 0.5% <0.15

The penetration resistance (P.R) at end experiment can be arranged descending as follow T3 >T2 > T5> T4 > T1. This is mainly attributed to the total roughness of the nano-tafla is lower than that of the raw tafla, which indicates that the properties of the nano- tafla are more hydrophilic than that of the raw tafla. Which leads to increased retained moisture, increased contact between sand grains, and thus increased resistance to penetration into the soil.

3.6. Germination percentage (%)

The data presented in Table (9) showed that the effect of different applied soil Nano Tafla and Non - Nano Tafla treatments on Germination percentage (%) of corn seeds in sandy soil. The data revealed that the percentage of germination of corn seeds was increased by nano-treatment, compared to the treatment of raw Tafla, and it was the best treatment T3. The Germination percentage (%) can be arranged descending as follow T3 > T2 > T5> T4 > T1. This is mainly attributed to the total roughness of the nano-tafla is less than that of the raw tafla, which indicates that the hydrophilic properties of the raw nano-tafla are greater than those of the raw tafla.

Table 9: Germination percentage (%) under the different rates of application of Nano tafla and Tafla.

Treatments	Germination percentage (%)
T1	45e
T2	82b
T3	89a
T4	63d
T5	75c
LSD 0.05	1.63

T1: Control, **T2**: 0.025% Nano, **T3**: 0.05% Nano, **T4**: 0.25% <0.15, **T5:** 0.5% <0.15

4. Conclusions

It could be concluded that application the nano-tafla improved soil properties i.e. increased total porosity, fine capillary pores, available water(AW), water holding capacity (WHC), compaction properties, Germination percentage, the Maximum Compaction of soil was 6.98 kg/cm^3 with addition of 0.5% Nano Tafla. The soil mixed with nanoparticles gave a lower permeability coefficient than the non-nano clay additions, and the bulk density values took the same trend.

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