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Research Article

Effect of Nanoclay on Wind Erosion a Sandy Loam Soil in Segzi Region (Isfahan, Iran)

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Abstract

Wind erosion is one of the major causes of sandy desertification in arid regions. Wind erosion is considered to be the main process of land degradation, crop damage and sedimentation. In this study, wind tunnel experiments were conducted to investigate the effect of nanoclay at three different application rates on soil wind erosion control. The nanoclay isolated from soils was dominant in montmorillonite clay. A sandy loam soil was applied, which was from the Segzi, Isfahan. The soils of this area are structurally unstable and these are highly erodible for most seasons. The soil samples were treated with three treatments: Untreated samples as control, nanoclay at a rate of 0.5 and 1.5 g L^{-1} were uniformly spread on the soil surface. The treatments were performed in the condition with wind velocity of 10 m sec^{-1} at 5.0 min, in three repetitions. The results showed that the content of soil erosion was significantly higher in control compared to the nanoclay treatments. The soil erosion content significantly decreased with the increase of nanoclay concentration and 97.4 and 100% decreased in 0.5 and 1.5 g L^{-1} in compared with control, respectively. The results showed that the mean weight diameter significantly increased in 0.5 g L^{-1} (0.403 mm) and 1.5 g L^{-1} (0.481 mm) in compared with control (0.345 mm). Also, the proportion of aggregates >1 mm significantly increased with the increase of nanoclay concentration.

Key words: Aggregation, sandy soil, Central Iran, wind tunnel, nanoclay

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Soil erosion is extremely efficient to change agricultural crop yields and soil properties (Oguz *et al*., 2006). The soil erosion realized in croplands has destructive impacts on the soil productivity. This negative effect of the soil erosion is caused by loss of nutrients from the soil (Li *et al*., 2014a). Soil erosion prevents agricultural productivity by reduction of soil quality. Soil erosion decreases the soil chemical characteristic by loss of soil organic matter and nutrient minerals (Zougmore *et al*., 2009). Soil erosion and land degradation, has been recognized to as an important problem. Erosion led to changes in soil physical properties (texture, infiltration rate, bulk density and water holding capacity) (Wolka, 2014). Wind erosion decreases land productivity, decreases the potential of the soil to carbon sequestration, damages agricultural crops through wind-blasts, pollutes air and decreases visibility, damages human health and consequently causes desertification (Lal, 2001; Churchman *et al*., 2010).

Soil erosion and its consequences is one of the more important problems in Iran. This phenomenon is one of the pervasive forms of land degradation in Iran (Mahmoudzadeh, 2007). In this country, 90% of land is arid or semiarid (Qadir *et al*., 2008). In arid regions of Iran, the desert soils are recognized by very low organic matter and structure less or week structure (Fallahzade and Hajabbasi, 2012). Therefore, these soils in these regions are prone to wind erosion during the windy period.

In many previous studies, laboratory-based wind tunnels have been applied to investigate the links between soil erodibility and various physical parameters to conclude a numerical relationship between them (Han *et al*., 2009; Liu *et al*., 2006). However, there are various forms of efforts to control the wind erosion have been underway for recent decades. The most widely used control measure is mulching with gravel mulch (Ekhtesasi, 1996), crop residues (Sterk, 2003), petroleum mulch (Hashemimanesh and Matinfar, 2012) and polyacrylamide (PAM) (He *et al*., 2008; Mamedov *et al*., 2010; Yang and Tang, 2012). However, data regarding the effects of nanoclay for control soil loss through wind erosion is scarce. Thus, the main objective of this study was to analyses the effects of nanoclay on soil wind erosion control.

MATERIALS AND METHODS

Description of soil samples: The soils were supplied from Segzi, Isfahan, the study area is arid in with a flat topography and an elevation of around 1550 above sea-level, nearly 25 km East of Isfahan, Central Iran (51°56'N, 32°23'E). The climate of this area is arid and in the experimental area, the mean annual precipitation and evaporation are 50 and 3000 mm, respectively. In this area, the soils are generally saline, low native fertility and low organic matter values. The soils have unstable structure, prone to crusting by wind. Some chemical and physical properties of experimented soil are listed in Table 1 and 2, respectively. Soil surface is mainly bare and without suitable wind erosion control measures. Moreover, the dry climatic condition and sandy texture make theses soils highly erodible for most seasons of the year.

Table 1: Some chemical properties of experimented soil

$CaCO_3$ (%)	pH (-)	EC (dS m^{-1})	OM (cmol kg^{-1})	CEC (%)
62.9	7.96	45.56	0.043	1.12

EC: Electrical conductivity, OM: Organic matter, CEC: Cation exchange capacity

Table 2: Some physical properties of experimented soil

Particle size (%)				
Sand	Silt	Clay	Texture	BD (g cm^{-3})
76.7	20.0	3.3	Sandy loam	1.6

BD: Bulk density

Experimental design: The wind erosion experiment was carry out in a straight line forces wind tunnel with 2.2 m in length, 0.3 in width and 0.3 m in height (Fig. 1). Velocity of wind can be regulated continuously from 0.2-18.7 m sec^{-1}. Soil samples were covered on trays, which had a length of 30 cm, a width of 100 cm and a height of 5 cm.

After packing the soil samples in the trays and before setting them in the wind tunnel, the soil samples were treated with three treatments: Untreated samples as control, nanoclay solutions at a rate of 0.5 and 1.5 g L^{-1} and volume 1 L were uniformly spread on the soil surface. Then, the treatments were performed in the condition with wind velocity of 10 m sec^{-1} at 5.0 min. For each treatment, three replications were made. The threshold wind speed was investigated by exposing the soil sample trays to a series of continuous increasing wind speeds. Starting at 4 m sec^{-1}, the wind speed was increased until soil particles began to be blown away by wind; at this stage, the wind speed was recorded.

Soil analysis: Soil pH (saturation paste), Electrical Conductivity (EC) (saturated extracts), soil organic matter (Walkey and Black method), cation exchange capacity (ammonium acetate method), particle-size distribution (hydrometer method) and bulk density (core method) were determined via, procedures described in Baruah and Barthakur (1997).

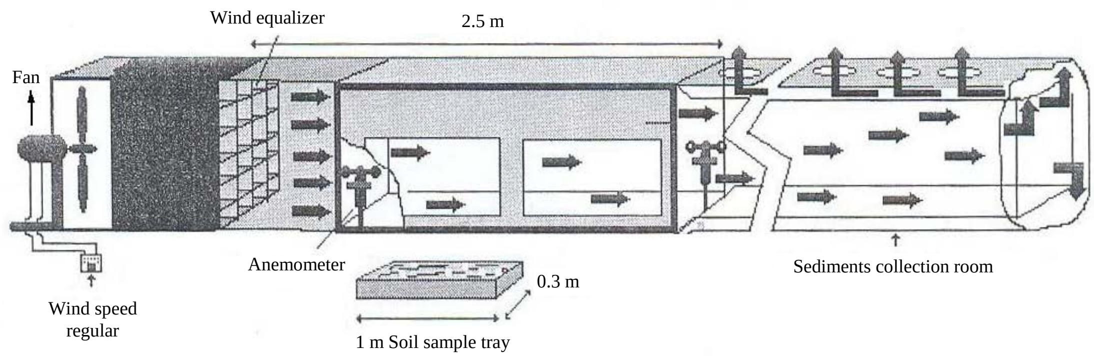

Fig. 1: Schematic diagram of the wind tunnel structure

Fractionation of dry-stable aggregates: The distribution of aggregate-size was determined according to a dry-sieving procedure. The size distribution of soil aggregates was determined by dry sieving through a series of sieves (2, 1, 0.425, 0.25, 0.106 and 0.053 mm). In present study, it was investigated that stability of aggregate >1 mm.

Statistical analysis: The impact of treatments (nanoclay concentration) on wind erosion control was analyzed by one-way analysis of variance. Means were compared by Duncan test at $p<0.05$. All statistical procedures were performed with SAS 9.1 software for windows.

RESULTS AND DISCUSSION

The threshold wind speed of the untreated soil (control) was 5.6 m sec^{-1}, while the threshold wind speed of the soil treated with 0.5 and 1.5 g L^{-1} was increased by 30-50%. The threshold wind speeds of the soil treated with 0.5 and 1.5 g L^{-1} were 8.4 and 7.4 m sec^{-1}, respectively.

Effect of nanoclay on the wind erosion: Table 3 shows the effect of nanoclay on the wind erosion at a wind speed of 10 m sec^{-1} for 5 min. The results of ANOVA indicated that the effect of nanoclay on the wind erosion was significant at 0.01 level. As shown in Fig. 2, the soil erosion amount significantly decreased with the increase of nanoclay concentration. The findings of this study indicated that the application of nanoclay on the soil surface can improve the capability of soil against the wind erosion. The content of soil erosion was significantly higher in control compared to the nanoclay treatments. The amount of soil erosion in 0.5 and 1.5 g L^{-1}, nanoclay concentrations were about 57.6 and 0.0 g m^{-2} h^{-1}, however, the amount of soil erosion in control treatment was 2198.87 g m^{-2} h^{-1} that approximately 38 times

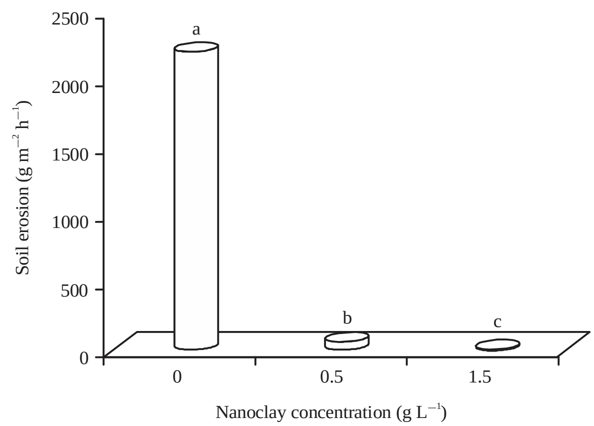

Fig. 2: Effect of nanoclay on the wind erosion at a wind speed of 10 m sec^{-1} for 5 min. The means with the same letter are not significantly different, according to the Duncan test at $p<0.05$

Table 3: Summary ANOVA results for the effects of nanoclay on the wind erosion

Source of variation	df	Mean square	F-value	P>F
Nanoclay	2	44.44	2388.40	<0.01
Error	6	0.019		

higher than that 0.5 g L^{-1} nanoclay. The effect of nanoclay with 1.5 g L^{-1} on controlling wind soil erosion was better than with 0.5 g L^{-1} nanoclay (Fig. 2). The studied soil is structurally unstable. Therefore, nanoclay seems to have some beneficial impacts in formation and maintain the soil structure, it has high aggregate stability when used in soils, which is a major reason to control wind erosion. Therefore, nanoclay is as a cementation function and cause improvement of aggregate stability. There is however, no data regarding the effect of nanoclay on soil wind erosion control. The content of clay in soil has more effect on soil aggregates; thus, soil with higher clay has more stable aggregates, which could increase the capacity of soil against wind erosion (He *et al*., 2008). Tisdall *et al*. (2012) found that six saprotrophic fungi could

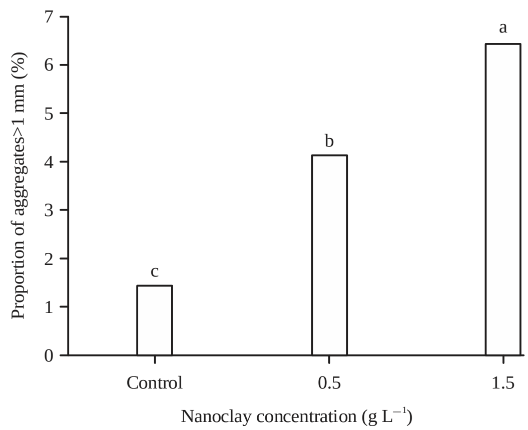

Fig. 3: Effect of nanoclay on the proportion of aggregates >1 mm. The means with the same letter are not significantly different, according to the Duncan test at p<0.05

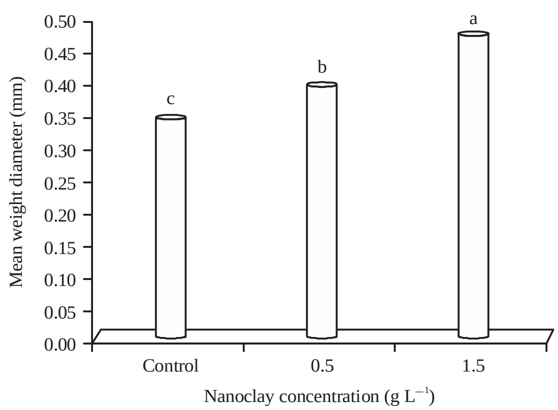

Fig. 4: Effect of nanoclay on the mean weight diameter. The means with the same letter are not significantly different, according to the Duncan test at p<0.05

lead to stabilization of soil against wind erosion. Also, were found to be a viable alternative to agricultural straw for wind erosion control. Copeland *et al.* (2009) reported that wood strands, which could increase the capacity of soil against wind erosion. They found that wood strands reduced soil sediment loss from bare soil surfaces at wind speeds of up to 18 m sec^{-1}.

Effect of nanoclay on soil aggregation: As shown in Fig. 3, the proportion of aggregates >1 mm significantly increased with the increase of nanoclay concentration. The findings of this study indicated that the application of nanoclay on the soil surface can increase the proportion of aggregates >1 mm. The proportions of aggregates >1 mm in control, 0.5 and 1.5 g L^{-1} nanoclay concentrations were about 1.45, 4.14 and 6.43%, respectively (Fig. 3). Previous studies documented the effects of clay on soil stability against wind erosion. For example, Chepil (1956) and Chen (1991) reported that the soil with higher clay content could form stable aggregates that this resulting in higher soil resistance to wind erosion and reduction the soil erosion by wind. However, Funk and Engel (2015) investigate the effects of the two most common row crops (maize and sugar beet) on wind erosion in Germany. They showed that the high capacity of row crops in conventional tillage systems to wind erosion.

Effect of nanoclay on mean weight diameter: As shown in Fig. 4, the proportion mean weight diameter significantly increased with the increase of nanoclay concentration. The findings of this study indicated that the application of nanoclay on the soil surface can increase the mean weight diameter. The values of soil mean weight diameter in control, 0.5 and 1.5 g L^{-1} nanoclay concentrations were approximately 0.345, 0.403 and 0.481 mm, respectively (Fig. 4). Zhang *et al.* (2008) reported that wind erosion is most high where soil textures are sandy and less presumably to be powerfully aggregated unless moist. Ciric *et al.* (2012) confirmed a highly significant correlation between soil clay content and aggregate stability. They also found that clay particle is a cementation agent for stable aggregates. In this study, the application of nanoclay into soil, led to formation of stable structures. Thus, the application of nanoclay reduces soil erosion by wind activity. Generally, larger size soil aggregates and particles are less sensitive to wind erosion (Li *et al.*, 2014b).

CONCLUSION

Present study documented that the soil erosion amount significantly decreased with the increase of nanoclay concentration. But, the impacts of nanoclay at concentration of 1.5 g L^{-1} on controlling wind soil erosion was better than with 0.5 g L^{-1}. Generally, the reason of wind erosion control by nanoclay is increasing dry aggregates stability.

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