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Assessment Sugar Factories Wastes' Performance on Wind Erosion Control

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ABSTRACT: Wind erosion is considered a major global environmental problem. Dust storms from the migration of sand dunes can seriously damage civil, industrial, and agricultural areas and a method to stabilize these sand dunes is mulching. The present study investigates the feasibility of using organic wastes of Press mud and Dunder with clay for the production of environmentally-friendly mulches. Sandy soil from the Dejgah Region, Fars Province, has been used as bed treatment. The treatments have been prepared, using different ratios of the above mentioned materials and 250 ml of water has been added to the each mulch combination to be sprinkled on a plot of sand, 50 × 30 × 1 cm in size. The research has measured Mechanical parameters such as Compressive Resistance (CR), Abrasion Resistance (AR), and Impact Resistance (IR), created by mulches, along with Wind Erodibility (WE) of the treatments and has analyzed the resultant measured data by means of SPSS software. An increase in the fraction of organic wastes has significantly increased CR, IR, and AR values, thus reducing WE. Higher amounts of organic matter and clay increase the CR and the application of 100g Dunder plus 100g Clay has been considered the best composition of organic mulch for stabilization of sand dunes.

Keywords: Sand dune, Organic, Press Mud, Dunder, Iran

INTRODUCTION

Wind erosion and sand storms are important indices in occurrence of desertification phenomenon, being also a serious treat for dry areas (Ekhtesasi and Hazirei, 2016). Important consequences of this type of erosion include air pollution (Vermeire et al., 2005), reduced visibility, amortization of industrial machinery (Hagen, 2010), destruction of soil structure (Zhao et al., 2006), and decrease of soil fertility (Gomez et al., 2003). There are different strategies to control wind erosion, the most widely-applied of which is mulching with crop residues (Bielders et al., 2000), clay (Hazirei and ZareErnani, 2013), gravel (Li et al., 2000), oil (Vaezi, 2012), chemical polymers such as polyacrylamide (Mamedov et al., 2009; Yang and Zejun., 2012), and nano-clay matters (Padidar, 2015).

The impact of mulch type on mechanical properties of the soil, such as the shear strength of surface soil (Alizade, 2009; Jamshid Safa et al., 2014), compaction, unconfined compressive strength (JanalizadehChoobbasti, 2015), penetration resistance (Baumhardt et al.,

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2004; Jung et al., 2010), thickness, impact resistance, and abrasion resistance (Hazirei & ZareErnani, 2013), has been studied to confirm firstly the improvement of the aforementioned characteristics and –ultimately-- wind erosion control. Dunder and Press Mud are two organic matters of sugarcane residues, generated as waste by sugarcane processing. Recently, these residues have been released into water bodies to become environment pollutants. It can be illustrated by the fact that over 800,000 m^3 of dunder is annually stored in each agro-industry. Although rich in K, Ca, Mg, P, and N, dunder contains no toxic complex. The other substance, Press Mud, is composed of cellulosic substances, $CaCO_3$, N, P, K, OM, and clay.

Several studies have evaluated the effects of organic wastes such as dunder (Tejada et al., 2006; Bebe et al., 2009; Meng et al., 2009; Barros et al., 2010; Zolin et al, 2011; Jiang et al., 2012) and press mud (Ossem et al., 2010; Utami et al., 2012) on biological, chemical, and physical properties of soil; however, there are few researches to evaluate the combined amendment effect of Dunder and Press mud on wind erosion control. As a result, this study investigates the effectiveness of organic wastes from sugar factories (Dunder, Press Mud) with clay as an organic mulch on mechanical properties and wind erodibility of drifting sand dunes. It has hypothesized that soil cohesion, caused by this mulching, could be effective in controlling wind erosion.

MATERIAL AND METHODS

The experiments were conducted in the laboratory of Faculty of Agriculture, Shiraz University. Organic wastes (Dunder and Press mud) with clay were used to produce this type of mulch. Table 1 shows the properties of dunder and press mud. Sand samples were taken from the surface of sand dunes (0 - 5 cm deep) in the Dejgah region and clay soil samples were taken from the BajGah region in Fars province. Physical and chemical properties of sand and clay such as Electrical Conductivity (EC), soil acidity (pH), Organic Matter (OM), calcium carbonate ($CaCO_3$), and particle-size distributions were determined, using standard methods (Pansu, & Gautheyrou, 2006).

After preparing the samples, aggregation was done via dry sieve method Particle aggregation was measured via a mesh with six stool classes, containing 0.075-2 mm. (Ekhtesasi and Azim Zadeh, 2012).

Due to economical issues, different quantities of dunder, press mud, and clay samples were mixed in water to select the best batch mix (Table 2). A mulch sprayer was used to spray the batch mixes on trays containing sand, 50×30×1 cm in size. In order to homogenize the conditions a non-mulching water spray was employed for the control treatment simultaneously with other treatments. Thereafter, the trays were placed in free air for seven days (Fig. 1).

Table 1. Chemical properties of the selected materials

Property	Dunder	Press mud
pH	5	7.50
EC (ds/m)	102.1	9.14
SAR (%)	3.5	9.3
TN (%)	522.35	9.50
P (mg/ kg)	22.15	9.67
K (meq/L)	0.56	1.51
Fe(mg/ kg)	25.19	10.59
Zn (mg/ kg)	1.12	5.34
Cu (mg/kg)	0.75	1.74

Table 2. Composition of the selected treatments (mulches) (g /0.15 m^2)

Mulch type	Clay (g)	Dunder (g)	Press mud (g)	Water (g)
M1	100	100	25	250
M2	100	50	25	250
M3	100	-	25	250
M4	-	100	25	250
M5	100	100	-	250
M6	50	100	-	250
M7	50	25	-	250
M8	-	100	-	250
M9	-	-	-	250

Fig. 1. Samples of experiment trays

Penetrometer is the most common method to evaluate soil strength, being characterized by the force required to advance a cone of specific base size into the soil (Bradford, 1986). The Compressive Resistance (CR) of the crust was determined by a cylindrical penetrometer at seven points of the sample trays with the same dispersion. The principle of the hand penetrometer is based on measuring the amount of penetration force, required to roll the flat-tip rod in the soil in Kg cm^{-2} (Khalil Moghadam et al, 2015).

Impact Resistance (IR) was measured by a steel rod with a conical tip tilted 45° and weighing 150 g, to be released vertically from a height of 1 m on the seven points of the sample trays. Thereafter, the impact strength of each treatment was ranked according to Table 3 (Hazirei1 & Zare Ernani, 2013).

Abrasion Resistance (AR) was measured by a drawing sandpaper with a rough average of 100 microns and a compressive force of 0.5 Kg at its surface. This process was continued until the layer became thin and reached the soil surface. The abrasion resistance of each treatment was ranked according to Table 4 (Hazirei1 & Zare Ernani, 2013).

Table 3. Classes of impact resistance (Hazirei1 & Zare Ernani, 2013)

The conditions of impact resistance classes	Class
If upon releasing the rod, it does not break the crust of the soil surface.	1
If upon releasing the rod, it breaks the crust and falls down 1 cm deep in the soil.	0.75
If upon releasing the rod, it breaks the crust and falls down 1-2 cm deep in the soil.	0.5
If upon releasing the rod, it breaks the crust and falls down 2-4 cm deep in the soil.	0.25
If upon releasing the rod, it breaks the crust and falls down beyond 4 cm deep in the soil.	0

Table 4. Classes of abrasion resistance ((Hazirei1 & Zare Ernani, 2013)

The conditions of abrasion resistance classes	Class
Crust is broken, moving the sand paper more than 30 time.	1
Crust is broken, moving the sand paper 15- 30 time.	0.75
Crust is broken, moving the sand paper 5- 15 time.	0.5
Crust is broken, moving the sand paper 2- 5 time.	0.25
Crust is broken, moving the sand paper 1-2 time.	0

Wind Erodibility (WE) experiments were conducted in a wind tunnel, in which a straight-linear force wind tunnel was employed which had a working section, 2 m long, a cross section, 0.3×30 m in size, and a conic entrance at the end of the tunnel to reduce the wind speed (Fig. 2). The sample trays were placed in three replicates on the floor of the test section against a speed of 18 m s^{-1} for 5 minutes. The extent of wind erosion was determined by exposing the sample trays to different velocities of wind conditions and measuring the mass of sand, lost from each sample tray (Koopaeenia & Afzali, 2015).

The experimental design was a completely randomized one. Statistical analysis was performed by means of Analysis of Variance (ANOVA) with Duncan’s multiple range tests, used to evaluate significant differences among the means at P ≤ 0.05 for CR and WE parameters. As for IR and AR parameters, Kruskal-Wallis test was employed. All statistical analyses were performed with the program SPSS 24.0.

RESULTS AND DISSCUTION

Table 5 shows some of the physical and chemical properties of soil.

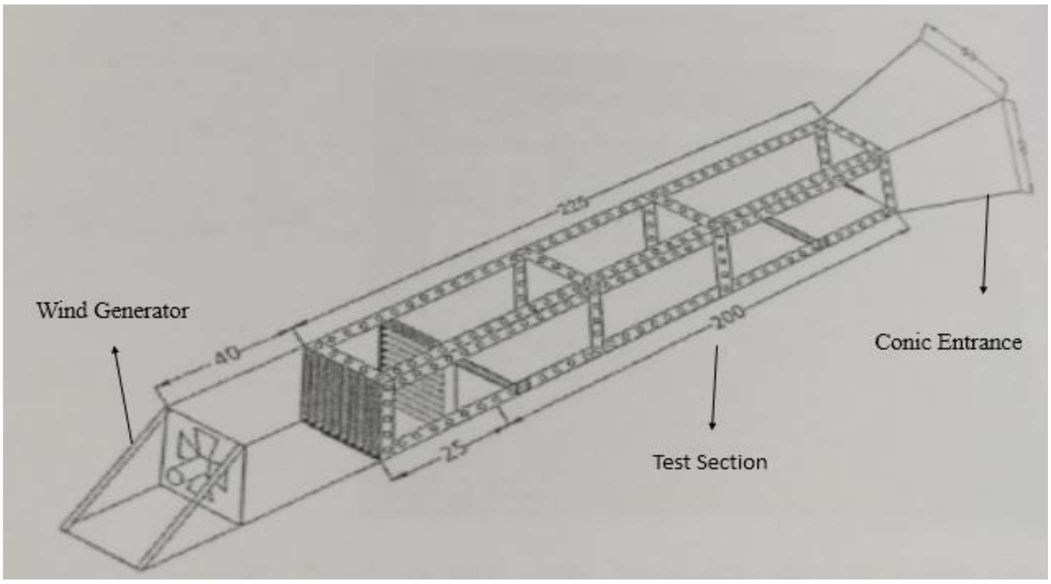

Fig. 2. Three- dimensional view of the used wind tunnel

Table 5. Chemical and physical characteristics of the studied soils

Soil texture	Sand	Silt (%)	Clay	pH	EC (ds m^{-1})	OC (%)	OM (%)	CEC (%)
Fine Sand	94	0.7	5.3	10.38	0.77	0.75	1.30	65.5
Clay	12.1	39.9	48	8	0.52	0.46	0.7	44

Based on the curve of particle aggregate, the maximum percentage of the sand particle was with a diameter less than 1 mm (Fig. 3).

Based on the analysis of variance (ANOVA), the effect of mulch type on CR and WE were highly significant ($p<0.05$) (Table 6), which was significantly different. Mulch types, M5 and M1, recorded significantly higher values of CR (1.06 and 1.02 Kg/cm^2), while M1, M5, M5, M2, M6, and M8 had considerably lower values (0 kg/cm^2) of wind erodibility index than the other treatments. Also, based on the Kruskal-Wallis test, the effect of mulch type on AR and IR was outstanding ($p<0.05$) (Table 7). M5, M1, M6, M2 recorded significantly higher values of IR (0.75), whereas for M5, M8, and M6, AR (1) was considerably higher. Control treatment had the lowest CR (0 kg cm^{-2}), AR (0), and IR (0) but the higest WE (3.7 kg/cm^2). Increasing the Dunder fraction in the mixtures resulted in a significant increase in CR, AR, and IR, while decreasing WE values (Fig. 4, 5, 6, and 7).

Evaluation of the mulch type and composition is the most important factor that can determine the mulch resistance against wind erosion and, consequently, the selection of the best mulch. The strength of aggregates in a soil depends on the amount of organic matter and texture (Torri et al., 1987, Wuddivira et al., 2013). Aggregate stability is affected by properties such as clay content, organic matter, and calcium

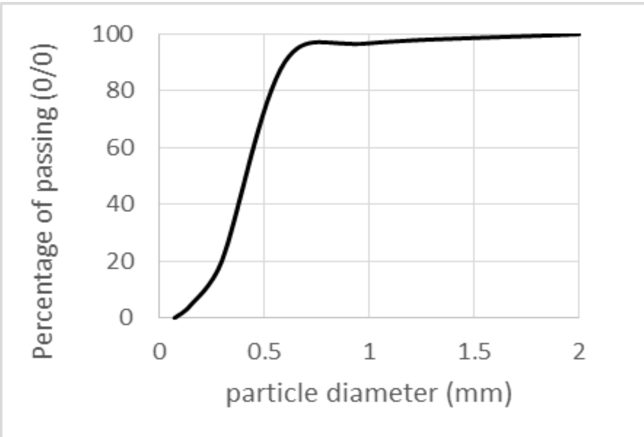

Fig. 3. Curve of Particle aggregate

Table 6. Analysis of Variance (ANOVA) of mulch effects on Compressive Resistance (CR) and Wind Erodiility (WE)

Source of variation	df	Mean Square	F
CR	8	1.51	36.93*
WE	8	4.44	1013.22*

*, significant at p<0.05

Table 7. Kruskal-Wallis test of mulch type effects on Abrasion Resistance (AR) and Impact Resistance (IR)

Source of variation	df	Chi- Square	Sig
AR	3	54.24	0*
IR	3	53.25	0*

*, significant at p<0.05

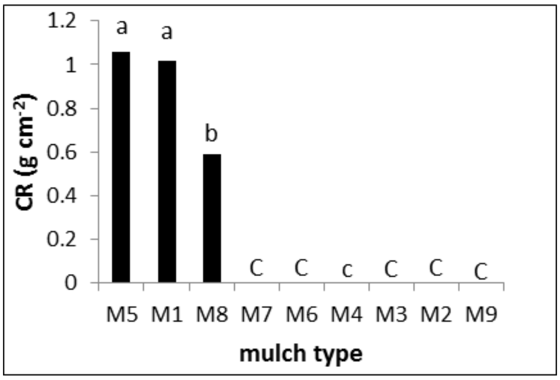

Fig. 4. Effects of mulch type on CR (Compressive Resistance)

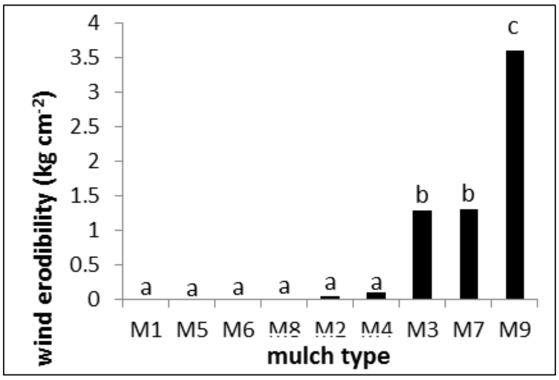

Fig. 5. Effects of mulch type on WE (Wind Erodibility)

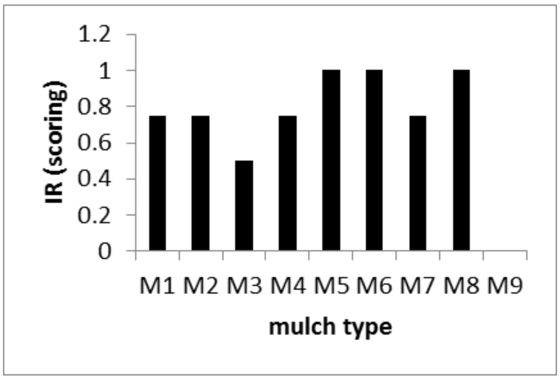

Fig. 6 Effects of mulch type on IR (Impact Resistance)

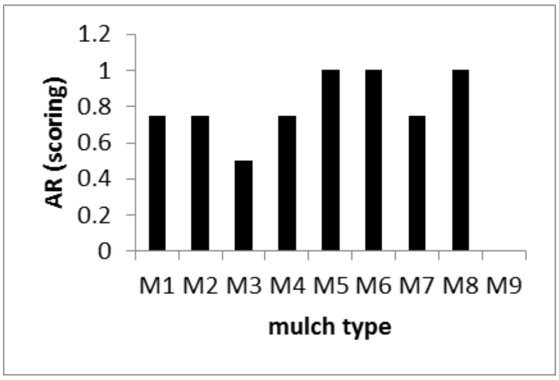

Fig. 7. Effects of mulch type on AR (Abrasion Resistance)

carbonate (Bartis et al., 2008). Organic matter interconnects soil particles, thus playing an important role in the formation and stability of aggregates (Rangasamy and Olsson, 1991; Tejada et al., 2006). Increasing aggregates stability enhances soil resistance to erosion (Follet and Donahue, 1981, Levy et al., 2005). Clay is an important factor in bonding primary particles of soil to each other and formation of aggregates (Bossuyt et al., 2001). The higher the amount of clay used in mulch composition, the greater the adhesion of sand particles to one another, and thus the greater the mulch persistence against abrasion flow (Majdi et al., 2006). In this research, higher CR, AR, and IR values were obtained by increasing the press mud, clay, and Dunder contents of the batch mixes. This was in accordance with the results, reported by Ekhtesasi et al (2014) and Jamili et al (2016).

Vaezi (2012) showed that increasing organic content lowered soil erodibility. In soils with medium to heavy soil texture, erodibility is reduced due to changes in the amount of organic matter. Several studies have demonstrated that the addition of organic matter to soil reduces soil erosion by stabilizing the aggregates (Moutier et al., 2000; Tejada and Gonzalez, 2008; Wuddivira et al., 2009). Six et al. (2004) showed that organic amendments connect soil particles through electrostatic attraction, leading to the formation of micro aggregates. Based on the results of this study, the major reason for reduction of soil loss after adding organic waste was the adhesion force from this material.

CONCLUSION

Wind erosion control and sand dunes stabilization are essential tasks for anti-desertification planning. Results from this research indicated that the application of organic waste (Press mud and Dunder) significantly affected wind erosion control. These conclusions were merely based on laboratory experiments, as further field tests are required to verify them. M5 treatment, with a combination of 100 g clay plus 100 g Dunder, proved to be the best organic mulch treatment. For sand dune stabilization, the use of this organic mulch required 6 ton vinasse for an area of one hectare. The cost of preparing the raw material for this mulch is about 20$, while supplying oil mulch charges 2500$ per hec, making the former mulch type a far better alternative. A comparison of the results of the present study with the results of polymer mulch application in Koopaeenia and Afzali research (2015) showed that the cost of organic mulch was lower than polymer mulch, too.

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