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The influence of sugarcane mulch on sand dune stabilization in Khuzestan, the southwest of Iran

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ABSTRACT- Over the past 50 years, oil mulching has been a common technique for sand dune stabilization in the southwest of Iran (Khuzestan province). However, concerns over the release of heavy metals from oil mulching have led to the search for alternative mulches that are capable of stabilizing sand dunes without environmental hazards. This study investigates the feasibility of using sugarcane residues for producing environment-friendly mulches. Dunder, Press Mud, and clay soil from the surrounding area near the sand dunes were used to make sugarcane mulches for comparison with the traditional oil mulch. A sand dune was selected as a sample bed for applying the mulch. To select the proper ingredients and treatments, Dunder, Press Mud, and clay soil were mixed with water by a trial-and-error method. The selected batch mix was then used to make the desired mulch and sprayed on a sand dune bed. Shear strength of surface soil (SSS), penetration resistance (PR), soil surface shear resistance (SSR), and erodibility of selected treatments were measured by the shear torvane, hand penetrometer, Zhang's surface shear device, and the wind tunnel. The treatments were arranged in a factorial experiment within a completely random design with the factors including mulch type (seven sugarcane mulches and one traditional oil mulch), thickness (1 or 2 layers), and rainfall (rain and no rain). The results indicate that SSS and PR increased with mulch thickness; the average values of SSS and PR obtained with the two-layer treatments were 1.27−1.33 and 1.13−1.15 times as great as the single-layer treatments. Increasing fraction of sugarcane residues significantly increased the SSS and PR. Higher concentrations of organic matter, $CaCO_3$, and electrolyte in the sugarcane mulches may have helped the bonding of soil particles and increased the SSS and PR. However, the oil mulch had the lowest SSS but the highest PR. This might be due to the lower viscosity of oil mulch that allows it to penetrate sand dunes more easily than sugarcane mulches do.

INTRODUCTION

Wind erosion is one of the most serious problems in the southwest of Iran (Khuzestan province) which hosts sand dunes and where dust storms occur frequently (Ahmadi, 2002). Single-grained, fine sand dunes are usually composed of none-strength materials with low water retention that make them susceptible to wind erosion. They lack organic matter and are inherently of low fertility (Ahmadi, 2002). Therefore, sand dunes and drift areas require non-oil artificial covers for their stabilization and that of the vegetation cover (Rezaie, 2009). The covering material types include oil (Rezaie, 2009), flat crop residues (Chepil, 1944; Bilbro and Fryrear, 1994), standing residues (Siddoway et al., 1965; Bilbro and Fryrear, 1994), pebble (Li et al., 2001), cotton gin trash, clay, gravel, picket fence, brush, straw, and hay (Fryrear, 1985).

Oil mulching has been used to stabilize sand dunes in Khuzestan province for the past 50 years or more because of the abundance of oil and gas resources in the region. Many studies have shown oil mulch to be effective in reducing dust storms and in improving sand dune stabilization before the vegetation is established (Rezaie, 2009). The drawback is that mulch made from oil is a potential source of heavy metals release into the environment and is highly water-repellent. In addition, the cost of preparing oil mulch has increased with increasing oil prices in recent years, which makes it difficult to apply oil mulch in a large scale. An alternative is to use organic mulches produced from sugarcane residues such as Dunder and Press Mud that are widely produced by a number of agro-industries in Khuzestan province.

Studies have shown that non-erodible materials reducing the potential for wind erosion include bentonite clay (Diouf et al., 1990), ureamelamine formaldehyde and urea–formaldehyde with 0.25% sodium chloride (Lahalih and Ahmed, 1998), acids, enzymes, lignosulfonates, polymers, tree resins (Santoni et al., 2001), mixed cement (6–8%) and rice husk ash (10–15%) (Basha et al., 2005), waterborne polymer emulsion (Alkhanbashi and Abdalla, 2006), polyvinyl alcohol and a polyvinyl acetate emulsion (Newman et al., 2005; Han et al., 2007), and ash and polyacrylamide (Yang and Zejun, 2012). Soil properties including compressive strength, plasticity, compactibility, strength characteristics, elastic modulus, crushing strength, unconfined compressive strength, erodibility, shear strength, and permeability have been investigated for evaluating mulch effectiveness. Improvements have been achieved in sand dune stabilization by decreasing permeability and enhancing strength properties. The effect of soil properties on wind erosion has been studied through shear strength of soil surface (SSSS) which includes a frictional term (due to inter-particle frictional strength) and a cohesive term (due to intrinsic bonds among particles) (Koolen and Kuipers, 1983; Alizade, 2009). As regards the factors influencing soil shear strength, soil particle diameter, bulk density, cohesion, aggregate index, water content, crust, and organic matter have all been found to influence wind erosion (Raji et al., 2004; Homauoni and Yasrobi, 2011). Based on these observations, it may be hypothesized that soil cohesion caused by mulching operations could be effective in reducing wind erosion.

The sugarcane is cultivated more than 130,000 ha in Khuzestan province. Dunder and Press Mud are two organic ingredients of sugarcane residues generated as waste by sugarcane processing. These residues have been released in recent years into the environment polluting water bodies. Over 800,000 m^3 of Dunder is annually stored in each agro-industry. While Dunder is rich in K, Ca, and Mg with moderate amounts of P and N, it contains no toxic complex or heavy metals. Press Mud is another residue produced in huge amounts by the agro-industry that is composed of cellulosic substances, $CaCO_3$, N, P, K, organic matter, and clay.

This study was done to investigate the feasibility of using sugarcane residues as a type of mulch for sand dune stabilization. Another objective of the study was to compare waste material sugarcane mulching and oil mulching with respect to their capability for sand dune stabilization.

MATERIALS AND METHODS

Experimental design

The experiments were conducted in the laboratory of Ramin Agricultural and Natural Resources University of Khuzestan. Sugarcane residues were used to produce organic mulch for sand dune stabilization. Table 1 shows the properties of Dunder, Press Mud and the clay soil. A sand dune was selected according to a classification of sand dune bulk densities in Khuzestan as the sample bed to which the mulch was applied (Fig. 1).

Different quantities of Dunder, Press Mud, and clay samples (Table 1) were mixed in water to select the best batch mix (Table 2). A mulch sprayer was then used to spray the batch mixes on sand dune beds packed with thickness (2 or 4 mm), in trays with dimensions of 105×45×10 cm (Fig. 1). In addition, the same procedures were employed to select an oil mulch treatment as control for comparison with the sugarcane mulch treatments.

Table 1. Some chemical properties of the selected materials

Property	Dunder	Press Mud	Clay soil
EC (dS m^{-1})	102.0	9.4	24.5
pH	5.00	7.50	8.07
SAR	3.5	9.3	22.4
TN (%)	0.56	1.51	0.01
P (mg kg^{-1})	22.15	9.67	7.04
K (meq L^{-1})	522.32	9.50	0.51
Fe (mg kg^{-1})	25.19	10.59	4.07
Zn (mg kg^{-1})	1.12	5.34	2.74
Cu (mg kg^{-1})	0.75	1.74	0.65
Texture	–	–	Clay

EC: Electrical conductivity, SAR: Sodium adsorption ratio

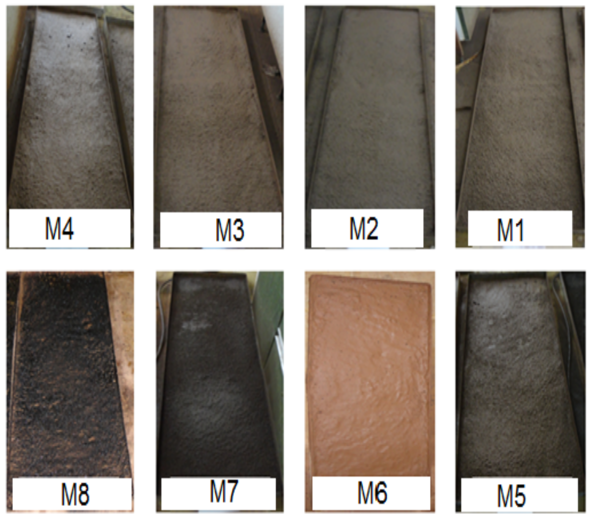

Fig. 1. A view of the studied treatments (mulches).

Characterization of mulch properties

Common properties of each mulch type including calcium carbonate ($CaCO_3$), sodium adsorption ratio (SAR), electrical conductivity (EC), pH, and soil particle-size distributions were determined using back-titration with NaOH (Nelson, 1982), standard method (Page et al., 1986), in aqueous extract (Page et al., 1986) and saturation past, and pipette method (Gee and Bauder, 1986), respectively. Total N (TN) was determined by the Kjeldahl method (Bremner and Mulvaney, 1982). Available phosphorus was measured by the method of Olsen as outlined by Van Reeuwijke and Vente (1993). Exchangeable K^+ was extracted by NH4OAc buffered at pH 7.0 and the soluble K^+ was determined by a flame photometer (Knudsen et al., 1982). Micronutrients (Fe, Zn and Cu) concentrations in the digested and extracted solutions were analyzed using an atomic absorption spectrometer (Model PerkinElmer 3110).

Surface shear strength (SSS)

A shear torvane (Fig. 2a) was used to make surface shear strength (SSS) measurements in saturation condition after mulching. The procedure used in this study was to push the vane into the soil surface until the blades were covered (about 8 mm depth); a clockwise rotation rate was then applied to ensure that failure developed within 5 to 10 s. The maximum stress value was recorded on a dial at the top of the van driver. Vanes with a stress range between 0 and 100 kPa were used in all cases to induce shear failure. A non-return pointer assisted in readings (Khalil Moghadam et al., 2009).

Table 2. Selected treatments (mulches) composition

Mulch type	Clay soil (g)	Dunder (g)	Press Mud (g)	Water (g)
M1	250	250	70	500
M2	250	250	50	500
M3	250	150	70	500
M4	250	100	20	500
M5	125	250	-----	500
M6	125	100	-----	500
M7	-----	250	-----	500
M8	Oil mulch			

Penetration resistance (PR)

An Eijkelkamp hand cone penetrometer (Fig. 2b) was used to determine the penetration resistance (PR) of soil after mulching. The principle of the hand penetrometer is based on measuring the highest PR of a cone-tip rod insertion over a distance of about 10 cm. The penetration force is measured by means of a proving ring. A number of cones and proving rings were available. A certain combination of a cone size and a proving ring is selected based on the expected PR. If the expected PR was high, a small cone and a proving ring with a large maximum force were selected and *vice versa* (Majdi et al., 2006).

Surface shear resistance (SSR)

For the measurement of surface shear resistance (Wójciga et al., 2009) of soil after mulching, a surface shear test apparatus (Eijkelkamp model) was used (Fig. 2c). In this study, small vertical stresses (between 1 and 30 hPa) were applied to a fixed round soil sample (diameter 100 mm and height 30 mm) via a cylindrical shear container, covered with top sandpaper (rough) shear plane. The horizontal force was applied with a manual precision-winding mechanism. The spring construction transferred the distance to force and damped for force increments. The 'Surface Shear Test' was a comparison test so it was important to use the same initial conditions to enable a reliable comparison between different measurements. The shear container, on the top of the sample loaded by vertical stress, was horizontally forced until it started to move visually. The shear stress was calculated by dividing the weight over the area of the shear container.

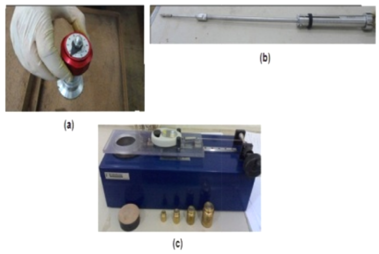

Fig. 2. Measurement device: a) shear torvane, b) hand cone penetrometer, c) surface shear test apparatus

Three replicates of shear test for each normal stress were used for each type of soil core. Measurements can be performed on soils with different predetermined water tension values. The same sample cannot be used for repeated measurements because of irreversible damage to the surface structure caused by shearing. The soil container with soil sample was placed into the shear apparatus and a shear container (Ø = 68 mm) with high-quality sandpaper was placed on the top of the soil sample. The normal stress was applied on the soil sample by the placement of the weights on the shear container. A horizontal load was applied manually to the shear container by slowly turning (for about max. 1 turn per s.) the hand wheel of a precision-winding mechanism. The surface shear load was measured by a digital balance. This balance logs the horizontal force with 5 s intervals. The maximum shear stress versus normal stress pairs were regressed using a modified Mohr-Coulomb's equation (Zhang et al., 2001):

$$\tau = C_a + \sigma_n \tan\varphi \quad (1)$$

where τ is soil shear strength (hPa), C_a is adhesion between sandpaper and soil (hPa), σ_n is the normal stress acting on the soil surface (hPa), and φ is sandpaper-soil interface angle of friction (°).

Wind erodibility

The wind erosion experiments were conducted in a wind tunnel. A straight line forces wind tunnel with a test section which had a length of 9 m and a cross section of 0.75×1 m was used. The sample tray was placed on the floor of the test section, 7.5 m in the downwind direction from the air source. The wind speed was controlled in the range of 2–9 m s^{-1} in three replicates because 97–99% of the wind speeds which cause wind erosion are in the range of 4–8 m s^{-1} in nature (Wu et al., 2003). The amount 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.

Statistical analysis

Two experiments were carried out using a factorial experiment within a completely randomized design replicated three times. The rainfall was simulated by rainfall simulator (Raesian rainfall simulator, 2005). The factors included mulch type (seven sugarcane mulches and one traditional oil mulch), thickness (1 or 2 layers), and rainfall (250 mm and no rain). Data were analyzed using the general linear models (PROC GLM) of SAS Institute (SAS, 1999). Mean comparisons were conducted using Fisher's LSD test.

RESULTS AND DISCUSSION

Mulch properties

Some of the chemical properties of the treatments (selected mulches) are shown in Table 3. The minimum, maximum, and mean values of reaction (pH) were 5.21, 8.50, and 7.69, respectively, with standard deviation of 1.22. The wide range of pH values obtained depended on the different batch mixes of Dunder, clay soil, and Press Mud. The pH of Dunder was lower (5.00) than those of Press Mud (7.5) and clay soil (8.07). This could be due to the higher $CaCO_3$ contents of Press Mud and soil. The pH values of treatments M1 to M4 were higher than those of M5 to M7. Another factor affecting pH is the acidity of Dunder; hence, the lowest pH value was observed in M7.

The SAR varied from 4.61 to 8.51 and EC had minimum, maximum, and mean values of 32.9, 112.4, 50.22 dS m^{-1}, respectively, with a standard deviation of 28.05 among the treatments (Table 3). The EC and SAR values of the treatments were both affected by Dunder, soil, and Press Mud. This could be due to higher EC and lower SAR in Dunder compared to soil and Press Mud. The EC and SAR are two major chemical factors known to affect sand dune stabilization (Jamshidsafa, 2014). The salinity and sodicity could affect soil strength and its biological activities (Barzegar et al., 1994; Rahimi et al., 2000). Based on Table 3, N, P, K, Fe, Zn, and Cu in sugarcane mulches varied in the ranges of 0.15−0.66 %, 10.82−28.46 mg kg^{-1}, 133.01−633.33 meq L^{-1}, 15.22−36.76 mg kg^{-1}, 2.19−2.93 mg kg^{-1}, and 0.92−4.10 mg kg^{-1}, respectively (Table 3).

Table 3. Chemical characteristics of the studied mulches

Property	M1	M2	M3	M4	M5	M6	M7	M8
EC (dS m^{-1})	43.2	34.7	34.8	32.9	48.4	45.2	112.4	−
pH	8.38	8.30	8.40	8.50	8.20	6.90	5.21	−
SAR	8.51	7.74	6.23	6.32	7.31	6.78	4.61	−
N(%)	0.31	0.26	0.33	0.19	0.18	0.15	0.66	−
P (mg kg^{-1})	28.46	25.99	26.50	21.12	21.82	10.82	27.95	−
K (meq L^{-1})	429.49	462.82	410.26	339.74	570.51	133.01	633.33	−
Fe (mg kg^{-1})	31.95	34.29	19.82	18.42	32.76	15.22	36.79	−
Zn (mg kg^{-1})	2.67	2.92	2.38	2.92	2.93	2.88	2.19	−
Cu (mg kg^{-1})	4.10	3.97	3.72	2.54	2.33	2.23	0.92	−

EC: Electrical conductivity, SAR: Sodium adsorption ratio, M8: Oil mulch

Effects of mulch type, thickness, and rainfall on soil mechanical properties

Based on the analysis of variance (ANOVA), the effects of mulch type, thickness, and rainfall on SSS and PR were highly significant (p<0.01) (Table. 4). The effects of mulch type on SSS (Fig. 3a) and PR (Fig. 3d) were significantly different. The M6 and M7 mulch types recorded significantly higher values of SSS (948 and 1005 hPa, respectively) than the other treatments which exhibited values similar to those obtained for sugarcane mulch. The average SSS for M7 treatment was 1.14, 1.27, 1.19, 1.12, 1.18, 1.06, and 3.10 times as great as those obtained for M1, M2, M3, M4, M5, M6, and M8 treatments, respectively. The M7 also exhibited significantly higher PR (5708 hPa) than the other sugarcane mulches, all of which had similar PR values. Increasing Dunder fraction in the mixtures resulted in a significant increase in SSS and PR values. The oil mulch had the lowest SSS value, but the highest PR value. The PR value of oil treatment was 1.36, 1.47, 1.36, 1.57, 1.51, 1.60, and 1.40 times as great as those of M1, M2, M3, M4, M5, M6, and M7 treatments, respectively.

Table 4. Analysis of variance (ANOVA) of mulch (M), its thickness (T) and their interaction effects on surface shear strength (SSS), penetration resistance (PR), sandpaper-soil adhesion (C_a), and sandpaper-soil angle of friction (φ).

Source of variation	dF	MS: SSS (hPa)	PR (hPa)	C_a	φ
Mulch	7	528456*	11385342.26*	20.46^{ns}	625.13^{ns}
Thickness	1	1292672*	14337604.17*	0.41^{ns}	740.23^{ns}
Rainfall	1	906771*	16088437.5*	6.00^{ns}	236.52^{ns}
Mulch × Thickness	7	72260.7*	1438794.64*	5.69^{ns}	412.62^{ns}
Mulch × Rainfall	7	55124.7*	605342.26*	6.66^{ns}	118.74^{ns}
Thickness × Rainfall	1	830538*	16088437.5*	6.00^{ns}	236.52^{ns}
Mulch × Thickness × Rainfall	7	47752.5*	605342.26*	6.66^{ns}	118.74^{ns}
Error	64	6400.59	204895.8	12.87^{ns}	395.79

*, significant at p≤0.05; ns, not significant.

The SSS was significantly influenced by mulch thickness and rainfall. Average values of SSS varied from 701 hPa (single-layer) to 933 hPa (two-layer) and from 719 hPa (no rain) to 914 hPa (with rain), respectively (Figs. 3b and 3c). The PR pattern was similar to that of SSS. The average values of PR were 5372 hPa (single-layer) to 6146 hPa (two-layer) and from 5350 hPa (no rain) to 6169 hPa (with rain), respectively (Figs. 3e and 3f).

The SSS values in two-layer treatments with rain were on average 1.27 times as great as those of the single-layer treatments with no rain while PR values for the former treatment were on average 1.15 times as great as those of the latter.

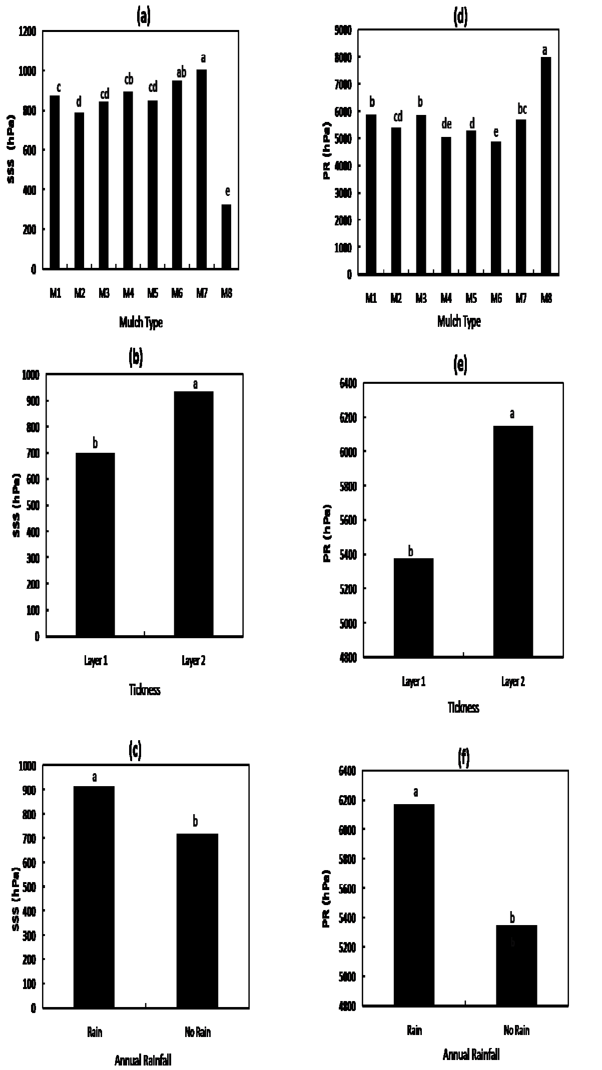

Fig. 3. Effects of mulch type, thickness, and rainfall on SSS: Surface shear strength (left) and PR: Penetration resistance (right).
M1(250 gr Clay, 250gr Dunder, 70gr Press Mud); M2(250 gr Clay, 250gr Dunder, 50gr Press Mud); M3(250 gr Clay, 150gr Dunder, 70gr Press Mud); M4(250 gr Clay, 100gr Dunder, 20gr Press Mud); M5(250 gr Clay, 250gr Dunder); M6(250 gr Clay, 100gr Dunder); M7(250gr Dunder); M8(oil mulch).

Table 4 presents the effects of rainfall and mulch type and thickness on the SSR parameters including soil-sandpaper angle of friction (φ) and the sandpaper-soil adhesion (C_a). The SSR parameters were not significantly influenced by the treatments. This may be because the measuring device was not sensitive enough to SSR parameters (φ and C_a) of sand dunes, especially in the range of small normal stresses that indicates the presence of micro-scale inter-particle and/or organo-mineral bonds. Inappropriate sandpaper may cause sliding of shear media over the sand dune samples, leading to determination of 'sliding shear stress' which is smaller than the peak shear stress (Wójciga et al., 2003). Selection of proper sandpapers appropriate for a given soil type should be the subject of another study.

According to Wu et al. (2003), 97–99% of the winds causing wind erosion naturally blow at a speed range of 4–8 m s^{-1}. Hence, the wind speed was controlled in the range of 2–9 ms^{-1}. However, wind erosion was not observed in this speed range in the treatments.

Interaction effect of mulch type at thickness, mulch type at rainfall, and thickness at rainfall on soil mechanical properties

Mulch type×thickness, mulch type×rainfall, and mulch thickness×rainfall had significant interaction effects on SSS and PR; however, they had no significant effect on the φ and C_a (Table 4). The interaction effects of mulch type×thickness, and mulch type×rainfall on SSS and PR were significantly different (Fig. 4). The results indicate that application of Dunder significantly affected the SSS (Fig. 4a) and PR (Fig. 4d) measured in the M7 treatment compared to other sugarcane mulches in each layer. The values obtained for SSS in the two-layer mulch used in M1, M2, M3, M4, M5, M6, M7, and M8 were, respectively, 1.60, 1.18, 1.17, 1.41, 1.84, 1.14, 1.08, and 1.62 times as great as those for the one-layer mulch and the values obtained for PR were, respectively, 1.04, 1.43, 1.19, 1.17, 1.29, 0.97, 1.17, and 1.0 times as great as those for the one-layer mulch. In the two-layer mulch, oil mulch recorded the lowest value for SSS, but the highest for PR. Although M6 and M7 treatments had significantly higher values of SSS and PR (884, 962 and 4933, 5250 hPa, respectively) than other treatments with the single-layer mulch, this pattern was not observed with the two-layer mulch (Fig. 4). Mulch and thickness interaction also revealed that SSS and PR were strongly affected by sugarcane residues, particularly by Dunder. Improvements were achieved in SSS and PR by using sugarcane residues rather than oil mulch.

The SSS and PR were significantly influenced by the interaction effects of mulch type×rainfall and thickness×rainfall treatments (Table 4). The sugarcane mulch after rainfall led to significant differences in soil strength compared to the no-rainfall treatment (Fig. 4). After the Khuzestan annual rainfalls, SSS for M1, M2, M3, M4, M5, M6, M7, and M8 mulches would increase by 1.50, 1.51, 1.34, 1.27, 1.40, 1.01, 1.11, and 1.00 times, respectively, the values recorded before the rainfalls. Similarly, PR values after the rainfall events in the same treatments increased by 1.08, 1.29, 1.14, 1.24, 1.25, 1.13, 1.18, and 1.00 times compared to the values before the rainfalls. The interaction effect of mulch type×rainfall was found to affect SSS (Fig. 4b) and PR (Fig. 4e) as a result of modified mulch penetration into sand dunes; increased rainfall led to increased values of SSS and PR. However, one interesting observation was the insignificant differences between SSS and PR values associated with sugarcane mulches after rainfall events, as all the treatments exhibited similar values. Rainfall was also found to have different effects on SSS (Fig. 4c) and PR (Fig. 4f) values with single-layer and two-layer mulches.

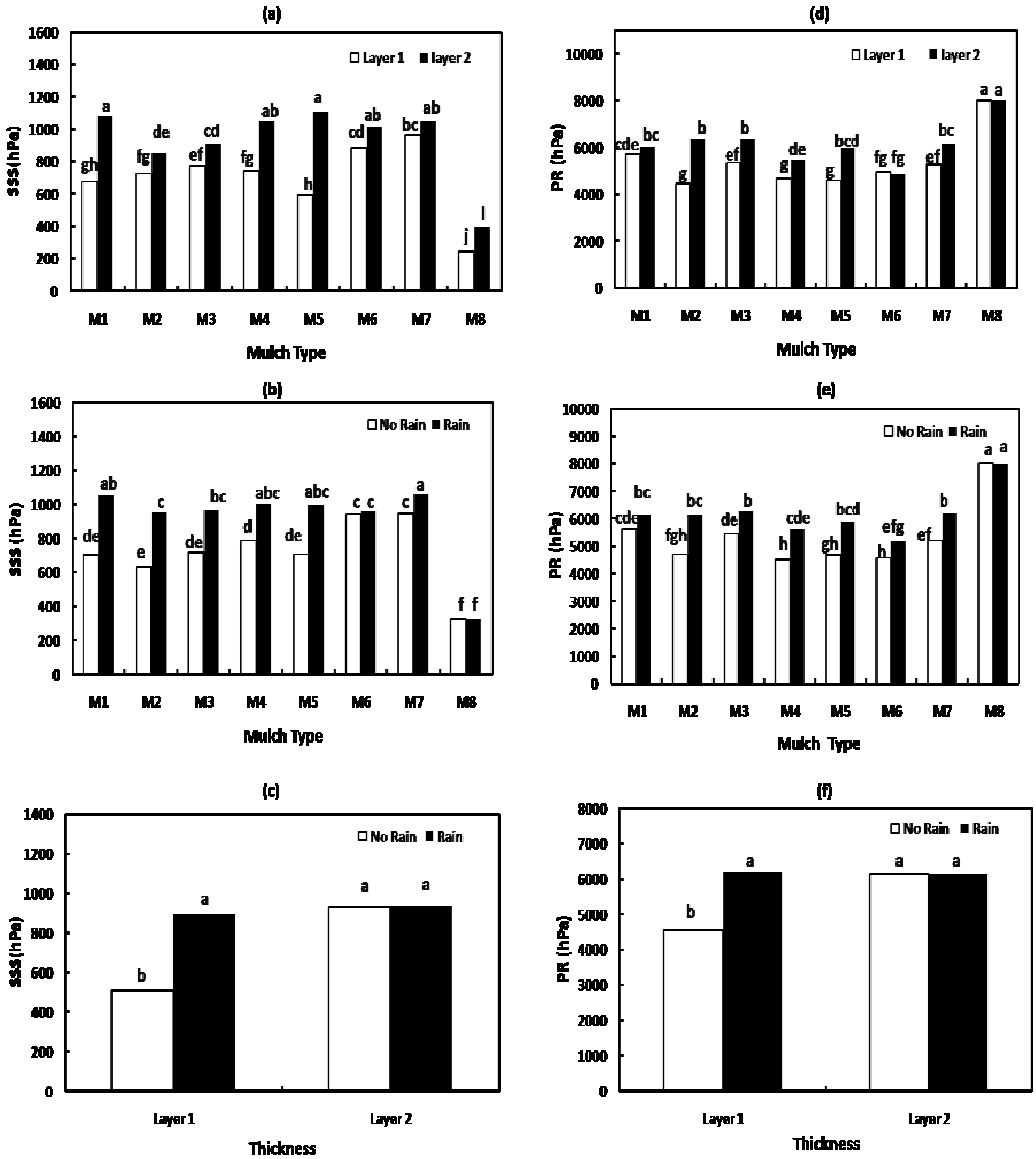

Fig. 4. Interaction effects of mulch type×thickness, mulch type×rainfall, and thickness×rainfall on SSS: Surface shear strength (left) and PR: Penetration resistance (right).
M1(250 gr Clay, 250gr Dunder, 70gr Press Mud); M2(250 gr Clay, 250gr Dunder, 50gr Press Mud); M3(250 gr Clay, 150gr Dunder, 70gr Press Mud); M4(250 gr Clay, 100gr Dunder, 20gr Press Mud); M5(250 gr Clay, 250gr Dunder); M6(250 gr Clay, 100gr Dunder); M7(250gr Dunder); M8(oil mulch).

Soil shear strength is the key mechanical property influencing its wind erodibility (Yang et al., 2005; Alizade, 2009). It is defined as the resistance soil materials can offer against shear stress. This property is directly related to the cohesive and friction forces between soil particles (Koolen and Kuipers, 1983; Knapen et al., 2007; Khalilmoghadam et al., 2009) and, therefore, related to soil intrinsic properties such as clay content, salinity, and organic matter content (Horn et al., 1994). Sugarcane residues due to their effects on cohesive forces affect soil strength via the physical and chemical properties of Dunder and Press Mud. In this study, increases in SAR were found to be inversely proportional to SSS and PR. With identical values of SAR, treatments with higher EC values exhibited greater saturated SSS and PR. This shows the adjusting effect of EC on SAR effects. Barzegar et al. (1994) suggested that the dispersive effects due to SAR in increasing soil strength are modified by electrolyte concentration. They concluded that the effect due to sodicity on soil strength can be modified by improving soil salinity.

The SSS and PR were also found to be influenced by the presence of $CaCO_3$ in soil and Press Mud. The effect of soil texture on SSS and PR is either through frictional forces attributed to coarse particles (sand) or clay cohesive forces (Barzegar et al., 1995). Wuddivira et al. (2013) found that a midrange clay content and a high organic content increased the SSS and PR. Soil organic content could affect the SSS and PR dynamics by modifying the soil cohesiveness and structural stability (BlancoCanqui et al., 2005). In this study, higher SSS and PR values were obtained by increasing the Press Mud and Dunder contents of the batch mixes. This is in agreement with the results reported by Majdi et al. (2006). Rahimi et al. (2000) found an increase in soil tensile strength with increased organic matter content. Rachman et al. (2003) reported that soil shear strength increased with increasing organic matter content. Our results showed that the M7 treatment might be considered the best mulch in terms of sand dune stabilization as Dunder has a greater effect on SSS and PR than does the Press Mud. This may be attributed to its cohesive property. The oil mulch had the lowest SSS value, but the highest PR value. This might be due to the semi-liquid state of oil mulch that allows it to easily penetrate sand dunes. Relatively lower penetration of sugarcane mulches could be ascribed to the higher viscosity of these mulches which bonded the soil particles together and increased surface shear strength.

Majdi et al. (2006) reported that mulch thickness was more important for stabilization than mulch type. Our results are in agreement with their findings; hence, the thicker the sugarcane mulch is, the greater its contribution to stabilizing sand dunes will be. Yamanaka et al. (2004) showed that the resistance of the mulch layer to wind erosion increased exponentially with the thickness of the mulch layer. In the single-layer substrata, there is usually an unoccupied spacing on the sand dune surfaces. In the two-layer sugarcane mulches, however, most unoccupied spaces in the lower layers are sheltered by the upper ones. The SSS and PR values for the single-layer mulches exceed the critical threshold of traditional stresses in the Khuzestan province. However, sugarcane mulches with a thickness of 4 mm may be more effective for sand dune stabilization. It is, therefore, essential to simulate desert environmental conditions (Temperature, sunlight,) and determine the sustainability of mulch for use in different arid land systems based on local climatic conditions, properties of mulching materials used, economic considerations, etc. However, the mechanical behavior of sugarcane mulches were the same after receiving a rainfall equal to its annual quantity (250 mm) in Khuzestan. Improvements were achieved in SSS and PR with one-year rainfall due to the modified mulch penetration on sand dunes.

CONCLUSIONS

Sugarcane mulches were shown to be effective in stabilizing sand dunes as compared to oil mulches. Sugarcane mulch thickness was found to be more important than mulch type for sand dunes stabilization as the mechanical behavior of the mulch remained unchanged after receiving annual rainfalls in the region. Regarding the mulch thickness, it was found that two-layer sugarcane mulches outperformed the single-layer ones in sand dune stabilization. However, the surface shear strength and penetration resistance of the single-layer mulch was observed to be higher than the critical threshold of common stresses and these properties primarily depended on mulch sustainability in the region.

It is, therefore, concluded that the combined Press Mud and Dunder could strongly affect soil resistance to erosive shearing stresses and wind erosion.

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تحقیقات کشاورزی ایران (۱۳۹۴) ۳۴(۲) ۷۱-۸۰

اثر مالچ های نیشکری بر روی تثبیت شن های روان در خوزستان، جنوب غربی ایران

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واژه های کلیدی:
ویناس
تثبیت شن روان
مالچ نفتی
مالچ نیشکری

چکیده- در طول ۵۰ سال گذشته، مالچ پاشی نفتی روشی متداول برای تثبیت شن های روان، در جنوب غربی ایران (استان خوزستان) بوده است. با این حال، نگرانی ها در مورد انتشار فلزات سنگین از مالچ نفتی، منجر به تحقیق در زمینه مالچ های جایگزینی شده است که توانایی تثبیت شن های روان را بدون خطرات زیست محیطی داشته باشند. هدف از این پژوهش امکان استفاده از ضایعات نیشکر برای تولید مالچ سازگار با محیط زیست می باشد. ویناس، فیلترکیک و خاک رسی در منطقه نزدیک به شن های روان جهت تولید مالچ های نیشکری در مقایسه با روش سنتی مالچ پاشی نفتی مورد استفاده قرار گرفتند. ویناس، فیلترکیک و خاک رسی به روش آزمون و خطا با مقدار مشخصی آب مخلوط گردیده اند و بر روی شن روان پاشیده شده اند. تنش برشی سطح خاک، مقاومت فروروی، مقاومت برشی سطح خاک و فرسایش پذیری تیمارهای انتخابی به ترتیب با دستگاه پره برشی، نفوذ سنج دستی، دستگاه برش سطحی ژانگ و تونل باد اندازه گیری شدند. تیمارها به صورت آزمایش فاکتوریل در قالب طرح کاملا تصادفی با فاکتورهایی که شامل نوع مالچ (هفت نوع مالچ نیشکری و یک مالچ سنتی نفتی)، ضخامت (یک و دو لایه)، و بارش (باران و بدون بارن) انجام شد. نتایج نشان داده است که مقاومت برشی و مقاومت فروروی با ضخامت افزایش یافتند؛ میانگین مقادیر مقاومت برشی و فروروی اندازه گیری شده در تیمار دو لایه به ترتیب ۱/۲۷ — ۱/۳۳ و ۱/۱۳ — ۱/۱۵ برابر بیشتر از تیمار یک لایه بودند. افزایش مقدار ضایعات نیشکر به طور چشمگیری مقادیر مقاومت برشی و فروروی را افزایش داد. غلظت های بیشتر از مواد آلی، کربنات کلسیم و الکترولیت در مالچ های نیشکری باعث پیوند ذرات خاک و افزایش مقاومت برشی و فروروی می گردد. مالچ نفتی کمترین مقاومت برشی و بیشترین مقاومت فروروی را داشت. که می تواند به دلیل ویسکوزیته کمتر مالچ نفتی نسبت به مالچ های نیشکری باشد که به راحتی در شن های روان نفوذ می نماید.