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EFFECT OF SOME SOIL STABILIZERS AGAINST WATER EROSION UNDER RAINFED CONDITIONS

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Abstract

The experiments were carried out under rainfall simulator DRC lab conditions and field conditions in the North Western Coastal Zone (NWCZ). The aim of this study evaluate the susceptibility of Guar Gum and Polyvinyl acetate (PVAc) stabilizers by two application methods (spray and mixed application method) to mitigate water erosion hazards as one of the risks of climate change. At the same time, how to sustainably enhance sandy soil properties without environmental side effects. The best treatments under lab conditions were C, D, F, G, I, J, L, and M. The optimal stabilizer concentrations were 1% and 0.5% Guar Gum (C, D, I, and J) for both application methods. Otherwise, the infiltration rate decreased with increased concentration of two types of stabilizers. Its reduction percentage reached about 24%, 28%, 32%, and 39% for I, J, L and M treatments, respectively. The results of the evaporating rate Ee% decreased with increased time to 96 hr for D and J. Furthermore, Guar Gum has a stronger effect on increasing MWD than PVAc for the two application methods. On the other hand, the field experiment results showed a non-significant increase in I and J plant vegetation than C and D. Therefore, the best reduction treatment for the ER was arranged in order D< J < C < I. From an economic point of view, the best treatments were C and I treatments. Overall, the 0.5% stabilizer concentration gave a sufficient concentration for mitigating water erosion hazards and increased crop yield with a higher net profit, particularly for Guar Gum, than PVAc.

Keywords: Guar Gum, Poly Polyvinyl Acetate, Rainfall Simulator, Runoff, Soil Loss, Water Erosion.

INTRODUCTION

Climate change is a complex phenomenon that is not easy to limit (Dadamouny and Schnittler 2015). It can be referred to long-term changes in average weather variables, all climate changes induced their impacts, and human-induced climate change and changes in climatic variability continue to be major global change issues for present and future generations Roushdi *et al*., (2016). On the other hand, climate change is the change in weather variability phenomena such as temperature and rainfall (Roushdi *et al*., 2016; Dadamouny and Schnittler 2015). Water erosion is one of the most important global environmental problems and is highly sensitive to climate change and/and variability Xu and Tang (2022). Also, water erosion is sensitive to climate change-associated events such as increasing extreme rainfall events in the USDA, NIFA (2013), and Xu and Tang (2022). Recently, soil stabilizers have been used as a new, environmentally friendly, improved material (Song *et al.,* 2019). Polymer soil stabilizer is one of five types of soil stabilizers (Song *et al.,* 2019). It is characterized by less incorporation, stable curing effect, and ecological and environmental protection (Ayeldeen *et al.,* 2016 a, b Song *et al.,* 2019 Algadwi *et al.,* 2021). In recent times, the use of biopolymers, polyvinyl acetate, and Bentonite as a replacement for conventional stabilizers like lime and cement and chemical materials which have many side effects such as toxic and can contaminate soil

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groundwater and environment (Dorcas *et al.,* 2020, Sujatha and Saisree 2019, Algadwi *et al.,* 2021, Wade *et al*., 2021, Rizwan *et al.,* 2021, Abdel-Raouf *et al.,* 2022). Song *et al.* (2019) confirmed that the PVAc is the best of the synthesized polymer type of organic aqueous polymer with a mass of hydrophilic carboxyl groups (-COOH) and hydroxyl groups (-OH) in the polymer chain. In addition, PVAc has many advantages, such as easy and wide application, low cost and availability, and no toxicity problems (Petkovic *et al.,* 2018). Otherwise, it has limitations such as low resistance to weather and moisture, slow setting speed, poor resistance to most solvents, and a curing time of 1- 7 days is recommended before handling (Petkovic *et al*., 2018).

On the other hand, Guar Gum is considered the best biopolymer, as green materials replace these chemicals (Ayeldeen 2016a). It is a type of biopolymer used as an environmentally friendly material in various fields to reduce the negative impact on humans and their environment (Dorcas *et al*., 2020; Ayeldeen, 2016 a,b). Guar Gum is a natural biopolymer and form of a white smooth powder obtained from seeds of a drought–tolerant legume plant, i.e., *Cyamopsis tetragonoloba* (Sujatha and Saisree 2019 and Ayeldeen 2016a). Ayeldeen (2016a) reported that the basis of its composition is a linear chain of β 1,4 linked mannose remains to which galactose residues are 1,6 linked at every second mannose, creating short side-branches (Ayeldeen 2016a, b). Moreover, it is reported that it has unique functional properties such as pH stability, good thickening, high viscosity, storage stability, water saving, contribution to global climate change, successful biodegradable, sustained release of optimum level of nutrients can be achieved after one application (Ayeldeen 2016a, b, Thombare *et al.,* 2018, Wade *et al.,* 2021 Abdel-Raouf *et al.,* 2022). Otherwise, it has a few limitations: insoluble in most organic solvents, reduced permeability, poor mechanical strength when absorbed higher and higher amounts of water, and has not been prevalent in agriculture because of high cost (Ayeldeen 2016a, b and Abdel-Raouf *et al.,* 2022). In addition, two methods for using polymers in soil application, the mechanical method by mixing with soil and the spray method by spraying on the soil surface (Thombare *et al.,* 2018, Algadwi *et al.,* 2021and Rizwan *et al.,* 2021). This study aimed to evaluate the efficiency of Guar Gum as a biopolymer (green material) and polyvinyl acetate (PVAc), as a synthetic polymer, both as environmentally friendly, to protect soil from water erosion or/and mitigate climate change risks as well as to achieve sustainable productivity for sandy soil. At the same time, how to sustainably enhance sandy soil properties without environmental side effects.

MATERIALS AND METHODS

To achieve such aims, two procedures were used, first, under Lab conditions using a Desert Research Center rainfall simulator. Secondly, under field conditions at Northwestern Coast Zone of Egypt. This study used two types of stabilizers Polyvinyl acetate (PVAc) as a synthetic polymer and Guar Gum as biopolymer (green material), as shown in Fig. (1). PVAc is a type of organic aqueous polymer, its main component is Acetic-Ethylene-Ester polymer, and it contains a large number of ($-OOCCH_3$) functional

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groups (Zumrawi and Mohamed, 2019). PVAc was synthesized by the polymerization reaction of polyvinyl alcohol and vinyl acetate in the presence of persulfate as a free radical initiator in the reaction kettle commonly used for polymerization (Bu *et al.,* 2019). In addition, Guar Gum is a polysaccharide consisting of galactose sugars and mannose. The backbone in Guar Gum is a linear chain of β 1,4- linked mannose remains to which galactose residues are 1,6-linked at every second mannose, creating short side-branches (Ayeldeen *et al.,* 2016). Also, it is hydrophilic due to numerous hydroxyl groups along with the main chain and the side branches (Abdel-raouf *et al.,* 2022). Therefore, the basic physical and chemical properties of PVAc are shown in Table 1 and the chemical composition of Guar Gum is shown in Table 2.

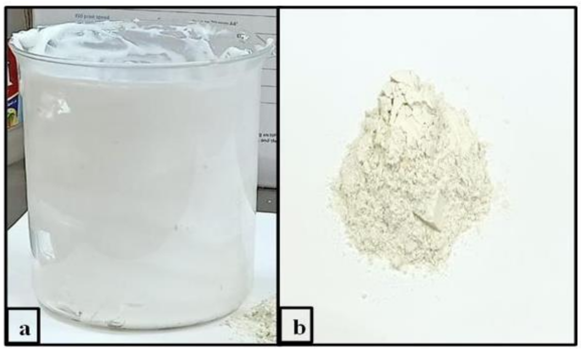

Fig 1: a) Polyvinyl Acetate is a white emulsion (PVAc) and b) Guar Gum is a white powder.

Table 1: Basic physical and chemical properties of Poly Vinyl Acetate polymer

pH	Viscosity (Mpa.s)	Relative density (Gs)	Solid content (%)	Water Absorption (%)	Gel rate (%)
6-7	500-3000	1.06-1.07	42-45	35-38	1.49-1.53

Table 2: Chemical composition of Guar Gum

Oxide	Concentration (%)	Oxide	Concentration (%)
K_2O	40.80	MgO	3.15
CaO	16.22	CuO	2.36
Fe_2O_3	10.20	Na_2O	1.77
SO_3	7.00	SiO_2	1.63
P_2O_5	5.83	Pd	1.04
pbO	4.3	ZnO	0.50
Cl	4.21	Al_2O_3	0.42

Soil characteristics

The soil used in the lab and field experiments was obtained from the Wadi El Raml area in west Mersa Matrouh city. The study was conducted in 2019/2020. The study area is geographically located between (latitude: 31° 09' 20'' - 31° 21' 58'' N, and longitude: 27° 04' 27''- 27° 12' 30'' E).

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The soil characteristics in the laboratory and field experiments are shown in Table 3. It shows some physical and chemical properties of the initial soil. The particle size distribution using the pipette method was sandy loam, 68.43% sand, 17.37% silt, and 14.2 % clay. Such properties were measured according to methods described by Klute (1986) and Page et al. (1982). Soil erodibility was measured according to Morgan (2005). This area was suffering from water erosion, as shown in Table 3 because the soil erodibility (K) was > 0.50 $Mg.ha.mj^{-1}.mm^{-1}$ according to Vopravil *et al.,* (2007) soils are most susceptible to water erosion which is a severe problem to agricultural productivity.

Table 3: Soil properties and erodibility for the studied area at Wadi El-Raml at NWCZ, Egypt

Particle Size Distribution (%)									Texture class	Soil erodibility ($Mg.ha.mj^{-1}.mm^{-1}$)
Treatment	pH	EC (ds/m)	$CaCo^3$ (%)	Coarse sand	Fine sand	Silt	Clay	BD (Mgm^{-3})		
Control	7.5	1.08	10.5	56.65	11.78	17.37	14.2	1.67	Sandy Loam	0.63

Lab experiment design

The lab experiment was carried out using the FEL3 Rainfall Simulator lab in the soil erosion unit, Desert Research Center (DRC), as shown in Fig. 2. The schematic diagram of the rainfall simulator is shown in Fig. (3). The size of tray used in the experiment was 45cm × 55cm × 10cm. The tray was full of dried soil. The bulk density of the soil was 1.67 $Mg/m^{3.}$ After finishing compaction, the whole tray was weighted.

Fig 2: FEL3 Rainfall Simulator lab for water erosion test in Soil Erosion Unit, Desert Research Center (DRC)

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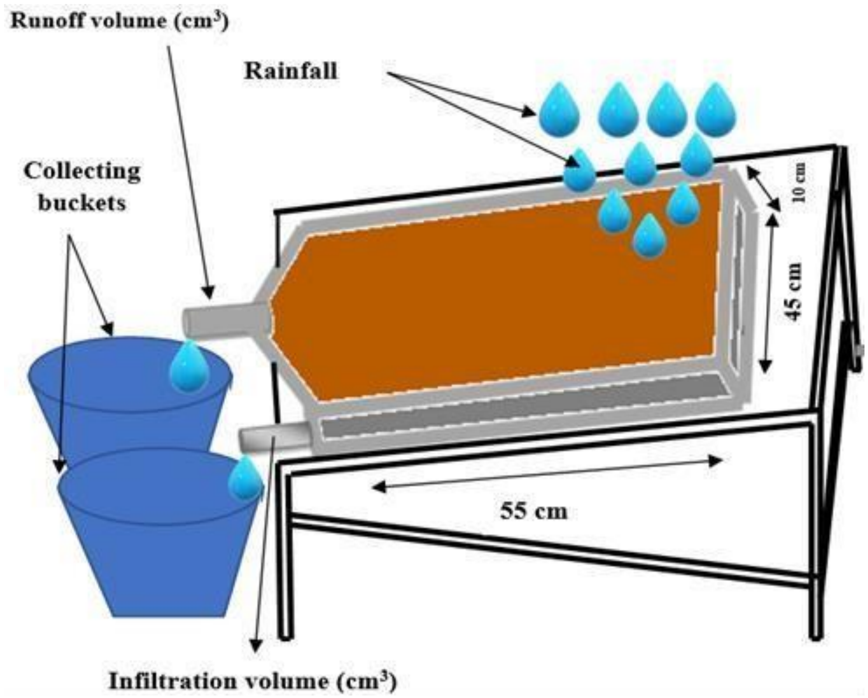

Fig 3: Schematic diagram of rainfall simulator lab for water erosion test

The rainfall intensity was 40 mm/hr, the maximum precipitation intensity of the highest rainfall storm in Wadi Raml. Soil loss determination and the rainfall time occurred after 15 min erosion. In addition, a collecting bucket was used to collect sediment loss and infiltration rate as shown in Fig. 3. The weight of soil in the collecting bucket was weighed after being dried for 24h in the oven at 105°.

The experiment was established as a split-split plot design with three replicates. The main plots were occupied by two types of polymers (PVAc and Guar Gum). The subplot used two application methods: adding polymers to the soil, spraying on the surface, and mixing with the soil (Ayeldeen 2016a and Song *et al.,* 2019). The subplot was divided for each application method type area into three concentrations (0.25%-0.5%-1%) and control treatment in slope 13%. So all study treatments in the lab experiment were thirteen treatments as follows: (A)- carried out as a control treatment, (B)- Guar Gum type with 0.25% concentrated rate with added method by spray on soil surface. (C): Guar Gum type with 0.5% concentrated rate with the added method by spraying on the soil surface. (D): Guar Gum type with 1% concentrated rate with the added method by spraying on the soil surface., (E): PVAc type with 0.25% concentrated rate with the added method by spraying on soil surface, (F): PVAc type with 0.5% concentrated rate with the added method by spraying on the soil surface,(G): PVAc type with 1% concentrated rate with the added method by spray on the soil surface, (H): Guar Gum type with 0.25% concentrated rate with added method by mixed with soil, (I): Guar Gum type with 0.5% concentrated rate with added method by mixed with soil, (J): Guar Gum type with 1% concentrated rate with the added method by mixed with soil. (k): PVAc type with 0.25% concentrated rate with

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the added method mixed with soil, (l): PVAc type with 0.5% concentrated rate with added method mixed with soil (M): PVAc type with 1% concentrated rate with the added method by mixing with soil.

Experimental procedure

The PVAc and Guar Gum diluents with the above concentrations for the study were prepared by spraying the diluted polymer solution on the soil surface. Other samples were prepared by mixing the diluted polymer with the soil. The solution was prepared for mixed PVAc and Guar Gum with soil until homogeneity. The spray and mixed amount were 3L/m^2 for each polymer type. The solution concentrated is calculated as the ratio between the used powder's weight and the solution's overall weight in percentage. PVAc was a white emulsion and Guar Gum was delivered as a powder when mixed with water as a colloid to produce the gels used in this study as shown in fig. (1) (Ayeldeen 2016a and Algadwi *et al.,* 2021). The solution concentration was gently added to the distilled water to avoid clumping, and then the solution was mixed until it became homogeneous. The solution was obtained and mixed for 24 hours to be completely dissolved. In addition, the concentrations (0.25%,0.5%,1%) by volume for PVAc and weight for Guar Gum were used in this study. The solution preparation was achieved by a curing time of 10 days according to Ayeldeen 2016a and Algadwi *et al.* (2021). Curing time is the solution of diluted polymer infiltrates and fills the space between soil particles. Then the film develops an interconnected bond between soil particles that binds them together, creating a crust. The crust will form on the soil surface when the polymer cures as spray application method. Both types of polymers form a film within the top layer of the soil when the water evaporates. The curing time for each polymer type was prepared at the maximum soil density according to their soil compaction properties (Ayeldeen 2016a, Wadi *et al.,* 2021 and Siddiqi and Moore 1981). The tray was placed on a slope of 13%, the maximum slope percentage in the study area.

Field experimental design:

The solution was prepared 10 days in curing time, and the soil was irrigated before the rainy season in the middle of October 2019. Moreover, all polymer preparations and procedures were applied in the lab experiment. The field experiment was carried out using the same soil as the lab experiment.

Wheat crops cultivated the soil under rainfed agriculture, and it was conducted in the 2019/2020 winter season. Each treatment with 3 replicates was carried out in a rectangular plot (50×12m) oriented in NW to SE direction with leave distance between treatments as a buffer zone area. Soil loss plots (5×10m) were used to measure soil loss and runoff using Gerlesh trough (FAO 1993). This existed at the end of the slope. The amount of rainfall was measured with a rain gauge for the study area. Runoff and associated soil loss for each effective rainstorm were determined according to FAO (1993).

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The field experiment was established as a split-split plot experimental design with three replicates. The main plots occupied two types of polymers (PVAc and Guar Gum) subplot with two add methods to the soil, including spraying on the soil surface and mixing with soil (Song *et al.,* 2019 & Ayeldeen 2016a). The subplot was divided into two concentrations (0.5%-1%) for each polymer and control treatment type. So, all study treatments in the field experiment were nine treatments as the following: (A) carried out as a control treatment, (C) Guar Gum type with 0.5% concentrated rate with the added method by spraying on the soil surface, (D) Guar Gum type with 1% concentrated rate with the added method by spraying on the soil surface,(F) PVAc type with 0.5% concentrated rate with the added method by spraying on the soil surface, (G) PVAc type with 1% concentrated rate with the added method by spraying on the soil surface, (I) Guar Gum type with 0.5% concentrated rate with the added method by mixed with soil, (J: Guar

gum type with 1% concentrated rate with the added method by mixed with soil, (L) PVAc type with 0. 5% concentrated rate with added method by mixed with soil, (M) PVAc type with 1% concentrated rate added method by mixed with soil. The field slope percent was 13% in the South-North direction. At harvesting, three randomized samples were taken from each plot using a square wooden frame (1 m^2) to determine wheat yield.

Determination of the parameters

For the field experiment, a composite soil surface sample was collected at the surface soil layer (0-20 cm). Runoff and associated soil loss in the lab and for each effective rainstorm for the field experiment were determined according to FAO (1993). The Enrichment Ratio (ER) was calculated as the following equation: ER= Ce/Co Where Ce is the concentration of nutrients in the sediment, and Co is the concentration of soil nutrients in the original soil according to Are *et al.,* (2011). The evaporation test was calculated under lab conditions and a constant level under room temperature 20ºc as following equation (1):

$$Ee = \frac{M1 - M2}{M0} \times 100\%$$

$Eq.1$

Where Ee (%) is defined as the evaporatively of soil; M1 (g) is the weight of soil at the beginning; M2 (g) is the weight of soil after a while of evaporation; M0 (g) is the weight of the dried soil according to Song *et al.,* (2019) and Bu *et al.,* (2019). The mean weight diameter (MWD) of the water-stable aggregates was calculated to give an index of aggregation according to Hillel (2004) as follows in equation (2):

$$MWD = \sum_{i=1}^{n} Xi\, Wi$$

$Eq.2$

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Where the proportion by weight "Wi" of the proportion of the total water-stable aggregates in the corresponding size fraction after deducting the weight of sand/gravel particles (upon dispersion and passing through the same sieve). It is multiplied by the mean diameter "Xi" arithmetic mean diameter of each size fraction of the same fraction (mm), and the sum of these products for all size fractions is called MWD (mm).

The infiltration rate (mm/hr) was calculated as follows:

Infiltration rate (mm/hr) = infiltration depth (mm) ×60min/Duration for each treatment (min)

Statistical Analysis

The significant differences in yield as affected by the treatments were evaluated by Duncan's Multiple Range Duncan (1955).

RESULTS AND DISCUSSION

Rainfall simulator lab experimental

Impact of polymer types on water erosion

The results of runoff and soil loss after a curing time of ten days are shown in Table 4. The addition of both polymers can enhance the erosion resistance. The runoff and soil loss in treatment A were 57.53% and 2.32 Mg/ha/hr. It was a water erosion phenomenon, and a large number of gullies were developed. The results in the spray application method clarified that the runoff increased with the concentration of both polymers compared to the runoff rate in the mixed application method. But it was vice versa with the soil loss values. Therefore, the runoff rates of B, C, and D for Guar Gum were 25.31%, 34.79%, and 44.27 %, respectively. Soil loss was 0.64, 0.50, and 0.37 Mg/ha/hr, respectively. Also, the runoff values of E, F, and G for PVAc polymer were 14.12%, 22.95%, and 32.99 %. In addition, the values of soil loss were 0.56, 0.44, and 0.38 Mg/ha/hr, respectively. Because the stabilizer was sprayed on the soil surface, the hydrophilic groups in both types of stabilizers are connected to the soil particles by hydrogen bonding and cation exchange. Also, it can be considered as a miniature reservoir for water. In addition, the effect of polymers on soil moisture, permeability, and soil structure will be explained later. Therefore, the integrity of the soil has been greatly enhanced, consequently increasing runoff and reducing soil loss in the spray application. On the other hand, there was a positive relationship between runoff, polymer concentrations, and soil loss. There was a negative relationship, as shown in Fig 4 and 5. These results agree with those of PVAc stabilizers by Song et al. (2019) and Wadi et al. (2021) under semi-arid and arid conditions. In the same context, the results of adding polymers by mixed application for runoff and soil loss were decreased with increased concentration. Furthermore, the runoff results for Guar Gum concentrations were 21.62%, 16.21 %, and 13.35% for H, I, and J, respectively, and for PVAc were 30.95%, 23.21%, and 16.70% for K, L, and M, respectively. Also, the soil loss results for Guar Gum and PVAc were 0.94, 0.86, 0.75, 1.24, 1, and 0.81Mg/ha/hr for H, I, J, K, L, and M, respectively.

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Both types of polymers can interact with the soil particles in many ways such as connecting to the negatively charged particles through ionic bridges and effective attraction between polymers, surrounding solutes, and soil particles. Also, there was a negative relationship between runoff, soil loss, and polymer concentrations, as shown in Fig. 6 and 7. These results are in agreement for both types of polymers with Ayeldeen *et al*., (2016) a, Abdel-raouf *et al*., (2022), and Algadwi *et al.,* (2021) under semi-arid and arid conditions. Observable from the results given in Fig. 8 and 9 of the two added methods, the values of runoff and soil loss for B and H treatments were approximately equal to F and L treatments, which meant the 0.25% Guar Gum concentration corresponding to the same concentration of 0.5 % of PVAc in both methods. Because of this, PVAc polymer is less water sensitive and lacks adhesion between polymer molecules and polar substrate i.e., quartz surface of sand particles when compared with Guar Gum considered natural rubber has very flexible molecules and very good adhesive. In addition, as a result of good absorption, there will be an effect on increased Vander Waals bond forces which will improve adhesion and reduce water erosion risks. Similar results for both types of stabilizers were obtained by Dorcas *et al*., (2020) and Siddiqi and Moore (1981). However, its results show evaluated the failure susceptibility of biopolymers and PVAc stabilized soil samples. The last one was water-sensitive in various degrees with a lack of adhesion and consequently did not perform well. Otherwise, Guar Gum was observed to be the best stabilizer

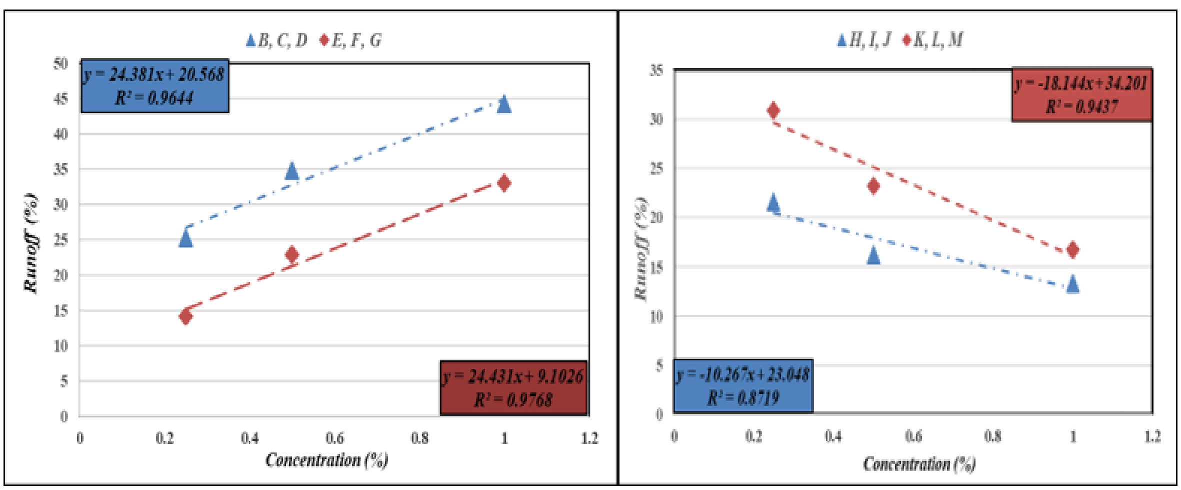

Fig 4: Relationship between Guar Gum (B, C, D), Poly Vinyl Acetate (E, F, G) concentration, and the Runoff (%) with spray method by 13% slope

Fig 5: Relationship between Guar Gum (H, I, J), Poly Vinyl Acetate (K, L, M) concentration, and the Runoff (%) with the mixed method by 13% slope

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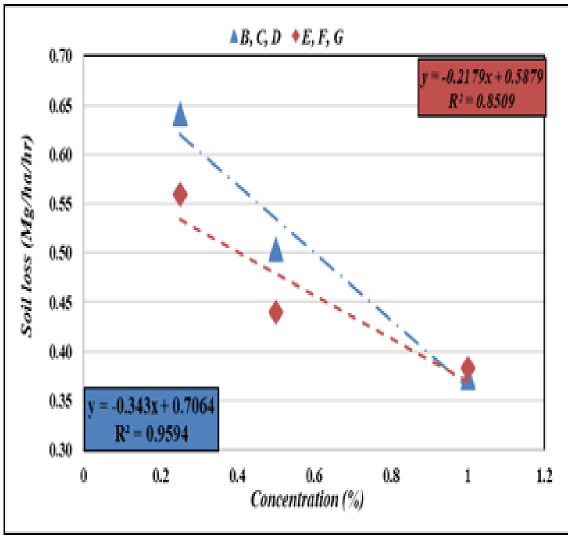

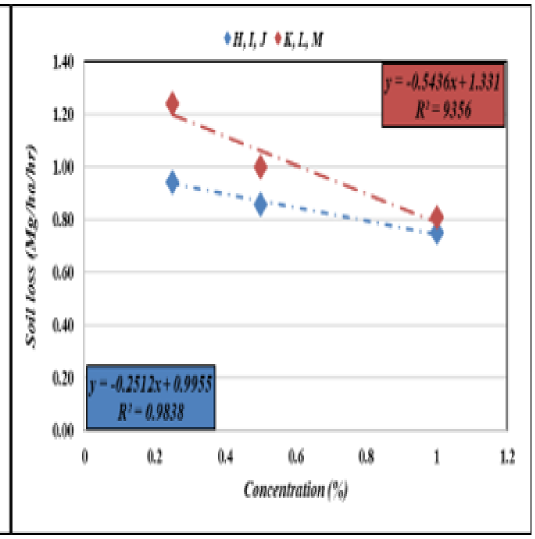

Fig 6: Relationship between Guar Gum (B, C, D), Poly Vinyl Acetate (E, F, G) concentration, and the soil loss (Mg/ha/hr) with spray method by 13% slope

Fig 7: Relationship between Guar Gum (H, I, J), Poly Vinyl Acetate (K, L, M) concentration, and the soil loss (Mg/ha/hr) with the mixed method by 13% slope

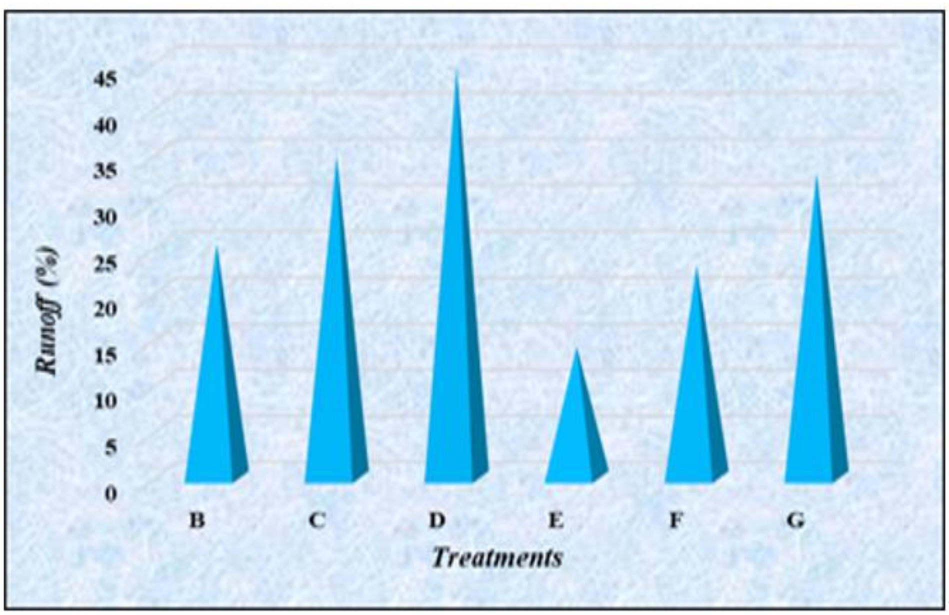

Fig 8: Effect of Guar Gum (B, C, D) and Poly Vinyl Acetate (E, F, G) concentration on the runoff (%) with the spray method

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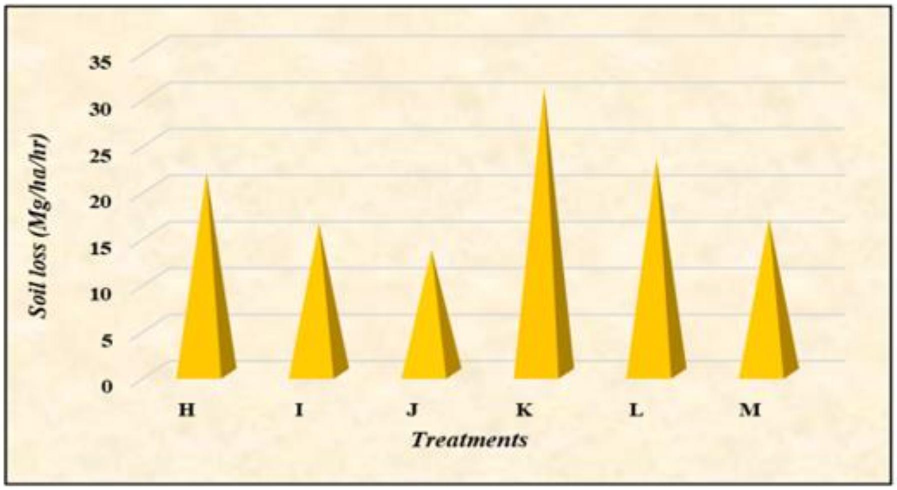

Fig 9: Effect of Guar Gum (H, I, J) and Poly Vinyl Acetate (K, L, M) concentration on the soil loss (Mg/ha/hr) with mixed method

Effect of Polymers on Infiltration Rate

The results of the infiltration rate as affected by the curing time of 10 days of both polymer types are given in Figs. 10 and 11. It is clear that the infiltration rate increased with additional time, but the rate of this increment varied with the concentration of both types of polymers and the methods of application. It is one of the phases of the hydrological cycle, and it is the process by which rainwater seeps into the soil; it is a source of moisture in the soil on which agriculture is based and natural plants grow on it. It depends on many factors such as soil particles' size and structure. Infiltration is the action of a fluid moving into or through the interconnected pores in a permeable material. From the results of the infiltration rate, it increased with additional time, but the rate of this increase varied with the concentration of both types of polymers and the types of add methods. Therefore, in Fig. 12 and 13 in Guar Gum and PVAc, the infiltration decreased a little bit with increased polymer concentration in the spray application method compared with the mixed application method. Because of the shrinkage due to the time of the polymer cross-linkage inside the soil particles directly increased the ratio of the pore and increased the infiltration rate (Petkovic *et al.,* 2018, Sujatha and Saisree 2019 and Algadwi *et al.,* 2021). The decrement obtained from Guar Gum was decreased than PVAc due to the endpoint of the shrinkage process is the transition from the rubbery state to the glassy one through this period the Guar Gum gained more strength, and its volume decreased inside the soil pores which decreased infiltration rate (Ayeldeen *et al.,* 2016b). Otherwise, the results showed a decreased infiltration rate with increased concentration of two polymers. It decreased by about 19%, 24%, and 28% for H, I, and J, respectively. Also, K, L, and M were about 25%, 32%, and 39%, respectively. Dehydration by shrinkage of the polymer matrices inside the pores caused a decreased infiltration rate (Zumrawi and Mohamed 2019). On the other hand, the effect of the treatments on infiltration rate is shown in Fig.

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12 and 13. The infiltration rate of Guar Gum was less in the spray method than mixed method. The D and J treatments were reduced by approximately 25% and 28%, respectively, compared to low concentrations. The infiltration rate of G and M decreased by approximately 22% and 24%, respectively, when compared with low concentration. This may be due to the cross-linkage elements inside the soil matrices that fill the voids and obstruct the flow through the soil. Moreover, the volume of such links increased with concentration. In addition, the PVAc is due to an acid group, making the PVAc polymer more sensitive to the effects of water than Guar Gum (green and rubber materials) (Siddiqi and Moore 1981). This is also reflected in a greater decrease in infiltration rate in Guar Gum than PVAc. Consequently, the permeability was decreased in the spray application than mixed application (Thombare *et al*.,2018; Ayeldeen *et al*., 2016).

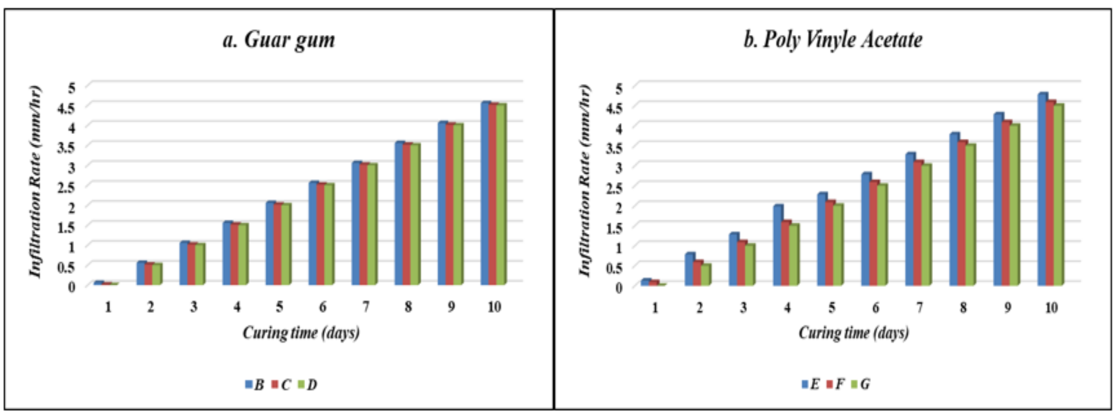
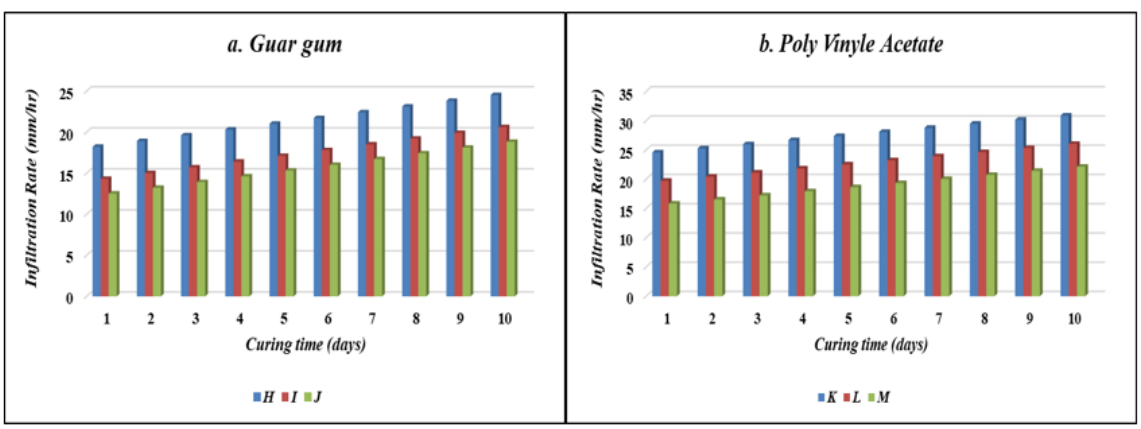


Fig 10: Effect of curing time (10 days) on infiltration rate by spray method: a. Guar



Gum b. Poly Vinyl Acetate

Fig 11: Effect of curing time (10 days) on infiltration rate by mixed method: a. Guar Gum b. Poly Vinyl Acetate

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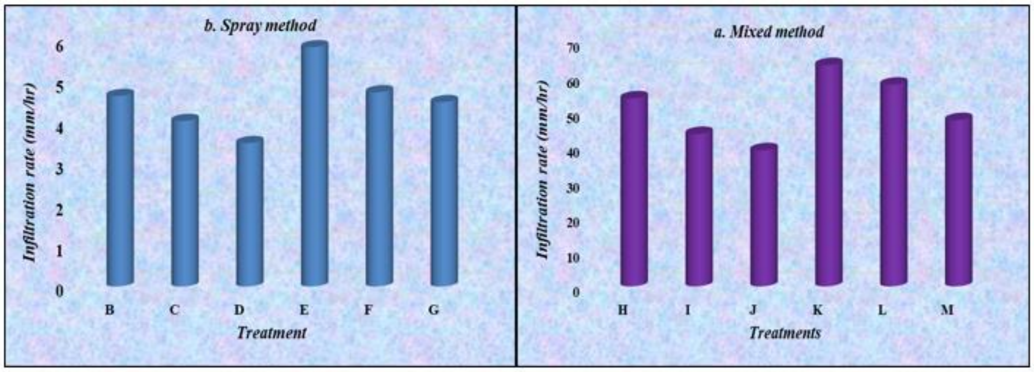

Fig 12: Effect of Guar Gum (B, C, D) and Poly Vinyl Acetate (E, F, G) concentration on the infiltration rate (mm/hr) with the spray method.
Fig 13: Effect of Guar gum (H, I, J) and Poly Vinyl Acetate (K, L, M) concentration on infiltration rate (mm/hr) with the mixed method.

Effect of polymers on evaporation rate

Water retention is one of the soil properties that can prevent the soil from hardening and allow the vegetation to absorb sufficient moisture and nutrients. The relationship between the evaporative nature of soil and time with different treatments and the results are shown in Fig. 14, 15, 16 and 17. The results of Ee% for all treatments decreased continuously due to a gradual increase in the concentration of both polymers. Therefore, the higher the concentration of both types of polymers, the stronger the water retention property. So, in the spray application method, the decrease of evaporated for D and G treatments was about 63%, 32.5%, 36%, 26.5%, for D, 46.9%, 18.35%, 24.9%, 20% for G at 0hr, 48hr, 72hr and 96hr, respectively as compared with A treatment. Also, in the mixed application method, the decrease was about 51.8%, 25.8%, 28.4%, 23.9% for J treatment and 32.07%, 25.85%, 22.07% and 17.65% for M treatment at 0hr, 48hr, 72hr and 96hr, respectively as compared with treatment. From the above mentioned, it is clear that the end of the shrinkage process was the transition from a rubbery state to a glassy one through which it gains more strength and the volume of the polymer decreased inside soil gaps and increased water retention (Ayeldeen *et al.,* 2016a). In addition, the PVAc polymer is more sensitive to the effects of water and lack of adhesion, flexibility, and polarity than Guar Gum (green and rubber materials), which will have strong electrical force between it and soil particles (Siddiqi and Moore 1981). This is reflected in the decreased evaporatively in Guar Gum more than PVAc. On the other hand, the polymers as hydrogel particles act as miniature reservoirs through which water is drawn when required by the osmotic pressure difference (Thombare *et al*., 2018, Abdel-raouf *et al*., 2022and Algadwi *et al*., 2021). Also, due to the hydrophilic groups in the polymers, they form a close bond with soil particles through hydrogen bonds and cations exchange. For this reason, it forms reticulated membranes, filling the existing pores between soil particles, and increasing the strength of the overall structure. In addition, the reticular membrane structure has good water absorption and can absorb more water. Therefore,

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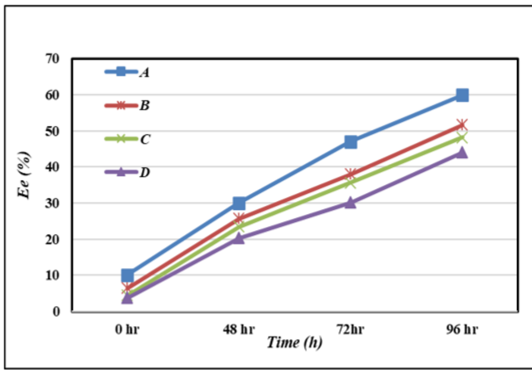
the water inside it gradually does not dissipate when compared with the soil without polymers. It caused a decreased infiltration rate in Guar Gum compared to PVAc. Conversely, as shown in Fig. 18 the internal soil structure without polymers is still very loose and the water inside it gradually evaporates to the outside more than the soil with added polymers (Song *et al.,* 2019 and Bu *et al.,* 2019). Which caused increased moisture retention in the spray application method than mixed application method. On the other hand, the reticular membrane of both polymers improved the soil's anti-aging properties. From this point, its structure was hardened, and strength increased after water loss. Conversely, it softened after water absorption (Song *et al.,* 2019).



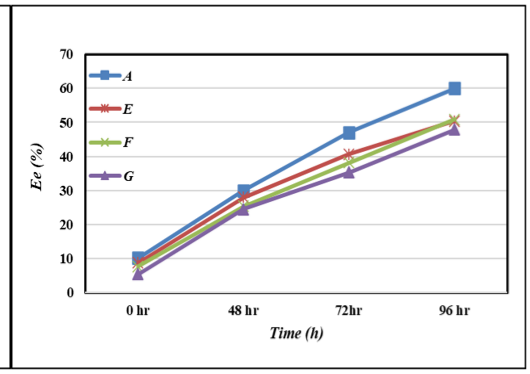
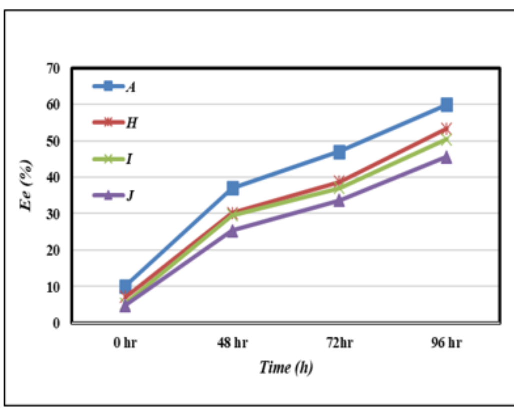


Fig 14: Relationship between evaporatively (Ee %) for A, B, C, and D treatments of Guar Gum and time.

Fig 15: Relationship between evaporatively (Ee%) for A, E, and G treatments of Poly Vinyl Acetate and time.



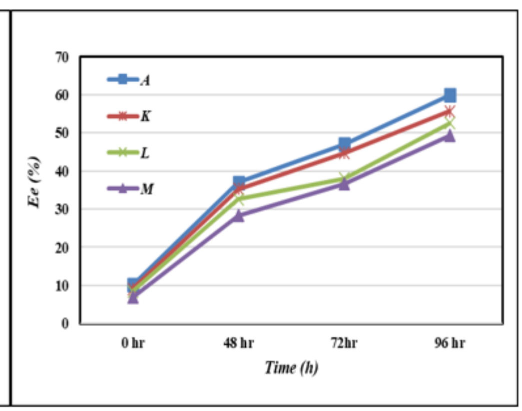


Fig 16: Relationship between evaporatively (Ee %) of A, H, I, and J treatments of Guar Gum and time

Fig 17: Relationship between evaporatively (Ee %) of A, K, L, and M treatments of PVAc and time

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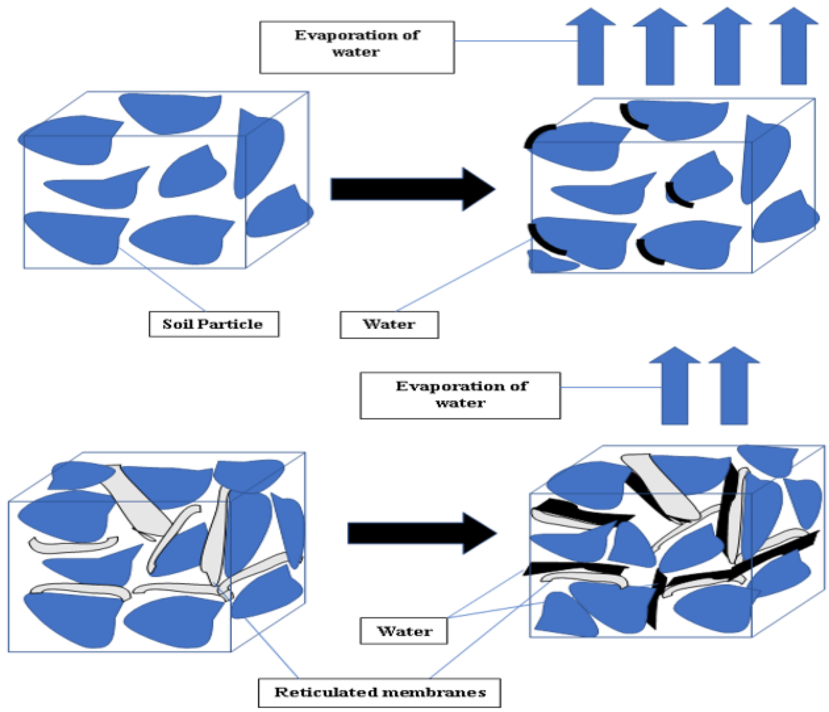

Fig 18: Schematic diagram of water evaporation by using both polymer types (Guar Gum and PVAc): (a) The water evaporation of soil without polymers, (b) The water evaporation of soil decreased by polymers.

Effect of polymers on Mean Weight Diameter (MWD):

The MWD is the sum of the weight size fraction of aggregate multiple to mean diameter to the same fraction. The results of MWD, as shown in Fig 19, clarify that Guar Gum has a stronger effect on increasing MWD than PVAc in two-application methods. In the spray application method, the MWD of B, C, and D treatments increased more than E, F, and G treatments by approximately 44%, 22%, and 17%. Otherwise, in the case of the mixed application method, the treatments H, I, and J for Guar Gum increased MWD by approximately 70%, 65%, and 32.5%, respectively, compared to K, L, and M for PVAc. Meanwhile, the mean weight diameter or dry aggregate increased with the concentration of polymers. Because of this, the PVAc lacked adhesion with soil particles and was more sensitive to water. Also, when the concentration of PVAc increases, it becomes rigid and adhesive properties decrease. Guar Gum has very flexible molecules and good adhesive (Zumrawi and Mohamed 2019; Siddiqi and Moore 1988). Also, it was distinguished with high durability and very stable *aggregate (Abdel-raouf et al.,* 2022, Ayeldeen *et al*., 2016a, Algadwi *et al*., 2021 and Wade *et al.,* 2021). Based on the results mentioned earlier, Guar Gum treatments were better than PVAc treatment's effect on improved soil properties and consequently enhanced soil resistance to water erosion hazards under lab conditions.

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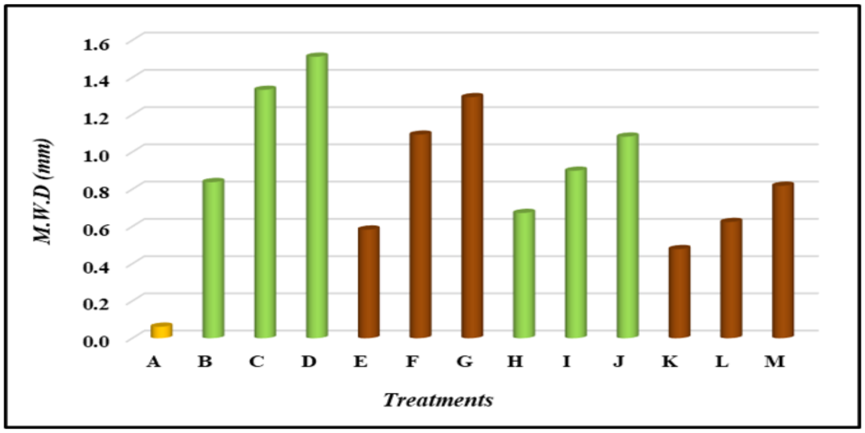

Fig 19: Effect of Guar Gum and PVAc treatments on Mean Weight Diameter (MWD) (mm) after 10 days of curing time.

Field experimental

The results obtained from the lab experiment showed that the best treatments were C, D, F, G, I, J, L, and M for combating water erosion risks. The field experiment under rainfed conditions in NWCZ was conducted to verify the effect of the best treatments on wheat yield under field conditions.

Climatic condition

The rainfall events during the field experiment for the winter season 2019/2020 are shown in Fig. 20. There were five effective storms. The rainy season started in November when the effective storm exceeded 10 mm for the study area in Wadi El-Raml. The highest effective storm events occurred in Jan. and March, exhibiting 37 mm and 43 mm, respectively.

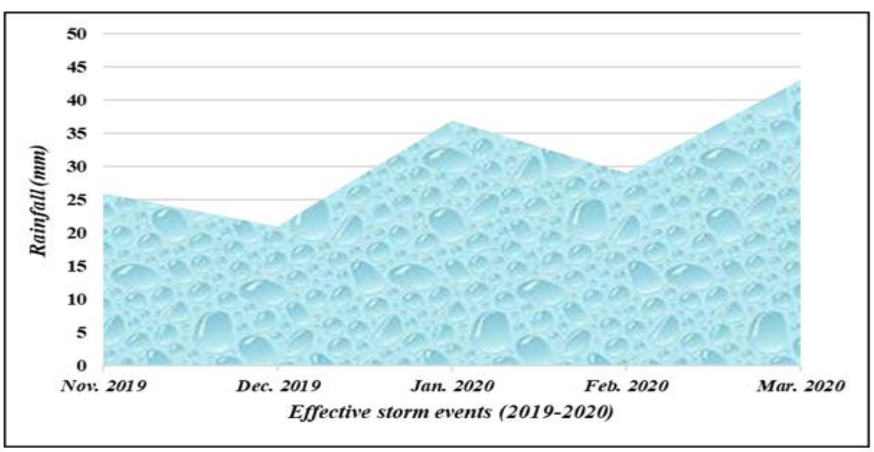

Fig 20: Effective storm events through (2019-2020) and perception depth of rainfall (mm) at the study area recoding by rain gauge

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Runoff and soil loss

The soil loss and runoff results obtained during effective storms are given in Table 4, verifying the rainfall simulator lab results. Therefore, the results showed the treatments of C, D, I, and J had more reduced runoff depth and soil loss rate than the F, G, L, and M treatments, respectively, which were ineffective storms. The C, D, I, and J treatments were recorded at 17.27 %, 13.51%, 20.01%, and 14.66% for runoff (%) and 2.07, 0.92, 2.92 and 1.96 Mg/ha/yr for soil loss, respectively. It is clarified that the Guar Gum by spray method or mixed method was more effective in reducing runoff and soil loss or reducing water erosion risks than PVAc. Also, the 1% concentration of PVAc had the same effect as 0.5% of Guar Gum. Due to the advantages of Guar Gum properties, as mentioned before, when compared with PVAc (Dorcas *et al.,* 2020, Ayeldeen *et al*., 2016a and Siddiqi and Moore 1981). Petkovic *et al.* (2018) reported that the limitations of PVAc included low resistance to weather and moisture and slow setting speed.

Table 4: Effect of study treatments on runoff (%) and soil loss (Mg/h/year) under different effective rainfall storm events

Treatments	Effective storm event (2019-2020)	Rainfall (mm)	Runoff (%)	Soil loss (Mg/ha/yr)
A	Nov.	26	5.19	1.04
	Dec	21	5.07	1.04
	Jan.	37	7.36	1.07
	Feb.	29	6.61	1.05
	Mar.	43	9.10	1.09
	Total annual	156	33.33	5.29
C	Nov.	26	2.75	0.37
	Dec	21	2.37	0.36
	Jan.	37	3.88	0.45
	Feb.	29	3.49	0.38
	Mar.	43	4.79	0.52
	Total annual	156	17.28	2.08
D	Nov.	26	2.13	0.11
	Dec	21	1.69	0.14
	Jan.	37	3.14	0.20
	Feb.	29	2.67	0.15
	Mar.	43	3.88	0.31
	Total annual	156	13.51	0.92
F	Nov.	26	3.82	0.58
	Dec	21	3.29	0.38
	Jan.	37	5.40	0.75
	Feb.	29	4.86	0.62
	Mar.	43	6.68	0.77
	Total annual	156	24.05	3.10
G	Nov.	26	2.62	0.32
	Dec	21	2.18	0.30
	Jan.	37	4.85	0.45
	Feb.	29	3.60	0.42
	Mar.	43	5.01	0.53

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	Total annual	156	18.26	2.02
I	Nov.	26	3.18	0.30
	Dec	21	3.15	0.35
	Jan.	37	4.65	0.70
	Feb.	29	3.65	0.38
	Mar.	43	5.39	1.20
	Total annual	156	16.84	2.92
J	Nov.	26	2.62	0.32
	Dec	21	1.27	0.20
	Jan.	37	3.80	0.41
	Feb.	29	2.82	0.34
	Mar.	43	4.16	0.70
	Total annual	156	14.67	1.96
L	Nov.	26	4.73	0.48
	Dec	21	3.07	0.44
	Jan.	37	6.69	0.84
	Feb.	29	5.02	0.54
	Mar.	43	7.28	1.14
	Total annual	156	26.78	3.45
M	Nov.	26	3.18	0.24
	Dec	21	2.60	0.20
	Jan.	37	4.92	0.64
	Feb.	29	4.32	0.31
	Mar.	43	6.31	0.78
	Total annual	156	21.35	2.17

Enrichment ratio of soil organic matter (SOM) and total nitrogen (TN):

Fertility constituents were determined for eroded materials by runoff within the Gerlesh trough. The results in Fig. 21 for the effects of the treatments of Enrichment Ratio (ER) as a measure of the intensity process of rainfall and from another site clarify the effect of treatments on the status of soil nutrients described by SOM and TN. The increase in soil nutrients by SOM and TN is affected by treatments. Therefore, the best treatment of less ER leads to reduced SOM and TN in eroded material. Moreover, it was arranged in order D<C<G<F by the spray application method and J<I<M<L by the mixed application method for both materials. On the other hand, the best treatments with high content of SOM and TN in other original treatment soil were in order D>C>G>F in the spray application method and J>I>M>L in the mixed application method, respectively. So, from the abovementioned results, the highest values were associated with Guar Gum in both application methods. It is worth mentioning that it can act as a humus-like substance when added to the soil because of its hydrophilicity and free carboxylic groups (Thombare *et al*., 2018; Abdel-raouf *et al*., 2022). Also, the 1% concentration in both types of polymers had the best effect on reduced ER when compared with 0.5% to reduce water erosion risks. These results for Guar Gum agree with Sujatha and Saisree (2019) which indicate that there was no significant degradation in soil samples treated with a concentration of 0.5% Guar Gum during the experimental period of 90 days.

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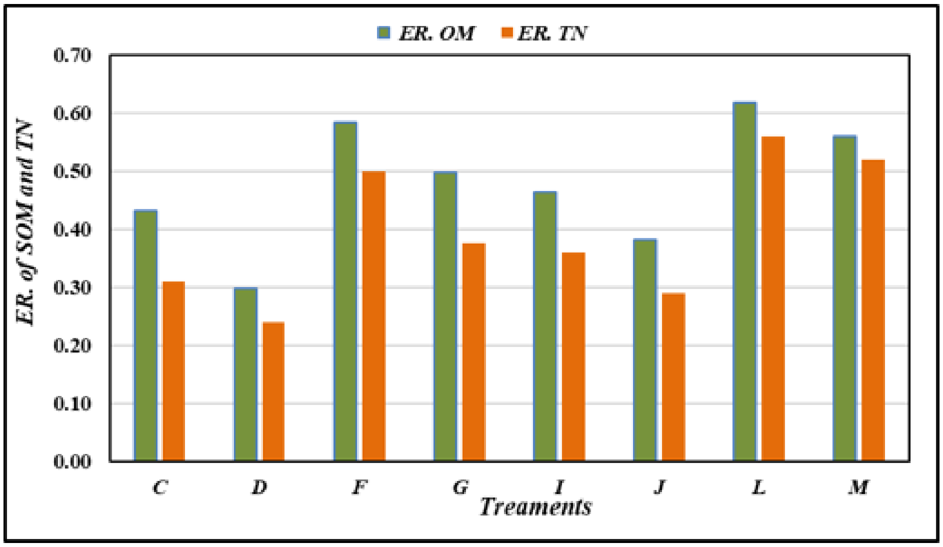

Fig 21: Effect of treatments on Enrichment ratio (ER) of SOM (%) and TN (%) between treatment soil and eroded material

The result of 0.5% Guar Gum treatments was better than 1% PVAc treatments leading to the Guar Gum was the best stabilizer obtained by Dorcas *et al.,* (2020). Consequently, it can be considered that Guar Gum and PVAc are used not only as stabilizers but also as soil amendments (Song *et al*., 2019). Also, Guar Gum and PVAc were controlled for nutrient loss, particularly in sandy soil (Thombare *et al*., 2018).

Yield and economic return

The results of plant growth are illustrated in Fig. 22, which clarifies that polymers have no adverse effect on vegetation growth and develop well. Also, it was clarified that the polymers are nontoxic, eco-friendly, and have plant growth (Song *et al.,* 2019 and Ayeldeen *et al.,* 2016a). The soil's physical properties were improved after adding polymers, which play a role in germination and vegetation growth. These results agree for both stabilizers with Song *et al*. (2019), Bu *et al*. (2019), and Abdel-Raouf *et al.* (2022). The biological wheat yield straw and grain yield of wheat was improved which was clarified by using treatments as shown in Fig. 23 and Table 5. The biological wheat yield results were significantly ($p < 0.05$) increased with treatments by approximately 94%, 143%, 40%, 59%, 103%, 157%, 51%, and 74% for C, D, F, G, I, J, L and M, treatments respectively as compared to A treatment. On the other hand, the C, D, I, and J treatments increased by approximately 39.3%, 61%, 35%, and 47.4h compared to F, G, L, and M treatments, respectively. Therefore, the Guar Gum increased the wheat yield when compared with PVAc by both application methods. This is a result because of Guar Gum on enhanced soil structure (Wade *et al.,* 2021, Sujatha and Saisree 2019, Ayeldeen *et al*., 2016a, and Dorcas *et al.,* 2020).

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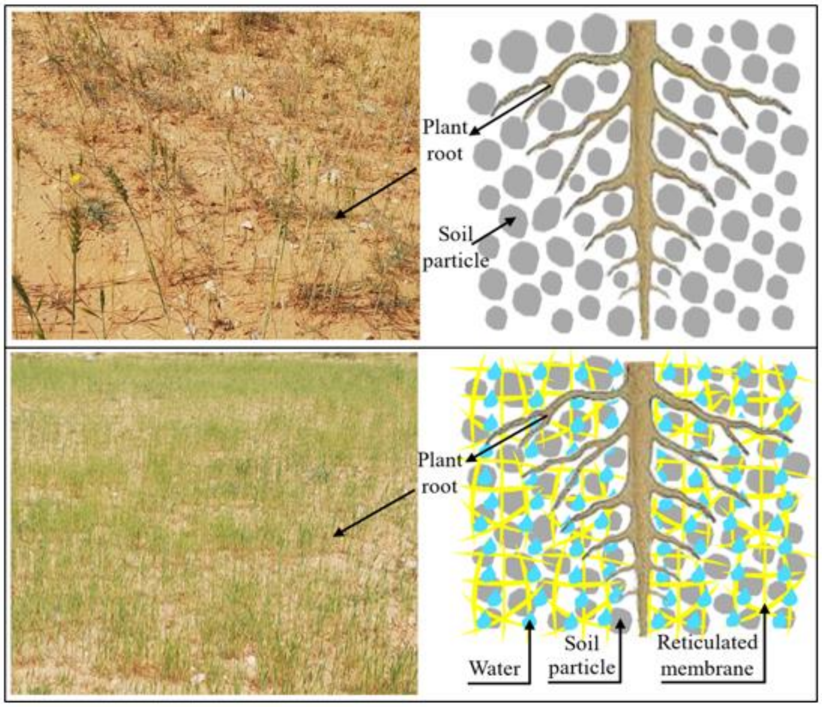

Fig 22: ***Picture and schematic diagram of wheat seedlings' growth without and with treatments after one month***

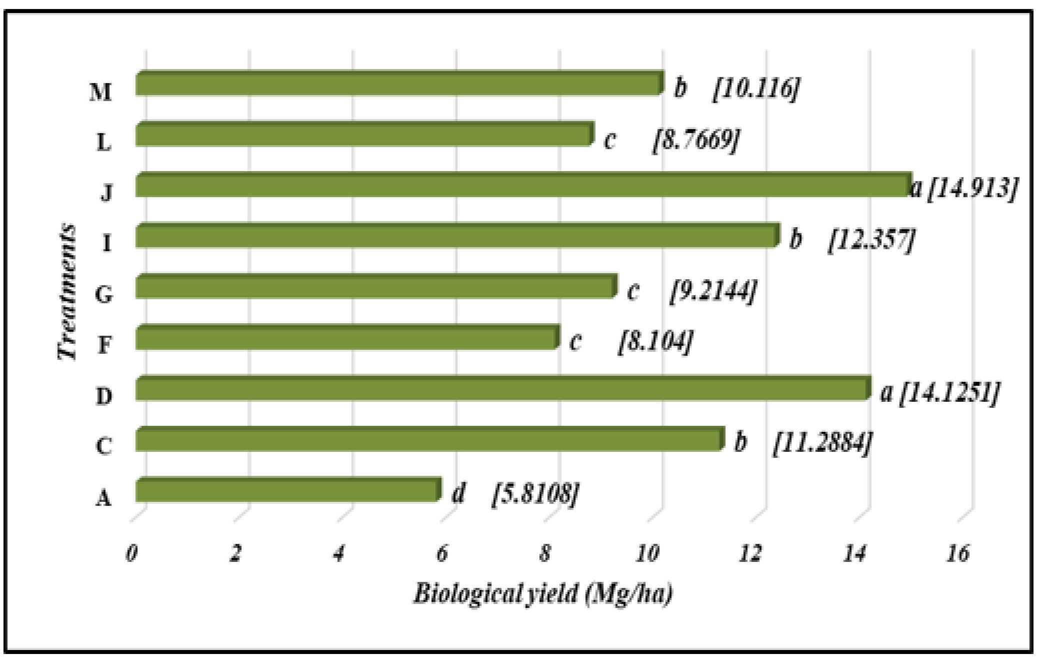

Fig 23: ***Effect of treatments on biological yield of wheat (Mg/ha) (Values followed by different letters are significantly at $p < 0.05$)***

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After added treatments, vegetation plants played a better role in green slope protection. The effect of treatments (C and I) (D and J) for Guar Gum in both two-application methods was non-significant on crop yield. This means, that the effect of the mixed application method has a non-significant increase in comparison to the spray application method. The sprayed polymers may be washed away in a rainstorm, which requires more time to be resprayed (Algadwi *et al.,* 2021). On the other hand, the spraying application method must be checked to ensure its effectiveness. Also, the mixed application method was easy to perfect in slope and field conditions under rainfed agriculture conditions in comparison to the spray application method. This leads to a noticeable enhancement in plants' available nutrients by improving soil structure.

Table 5. **Economic return for the productivity of wheat yield under Guar Gum and Poly Vinyl Acetate treatments**

Treatment	Cost				Wheat yield		Profit			
	Polymers cost (LE/ha)	*Seeds cost (LE/ha)	Machine cost (LE/ha)	Total cost (LE/ha)	Wheat grain yield (Mg/ha)	Wheat straw yield (Mg/ha)	*Wheat grain profit (LE/ha)	*Wheat straw profit (LE/ha)	Total profit (LE/ha)	Net profit (LE/ha)
A	0	1400	2121	3521	2.2444	3.5664	10705.8	6312.5	17018.3	13497.3
C	12500			16021	4.7048	6.5836	22441.9	11652.9	34094.8	18073.8
D	25000			28521	5.9832	8.1419	28539.8	14411.2	42951	14430
F	5000			8521	3.3118	4.7922	15797.3	8482.2	24279.5	15758.5
G	10000			13521	3.8131	5.4013	18188.5	9560.3	27748.8	14227.8
I	12500			16021	5.2336	7.1234	24964.3	12608.4	37572.7	21551.7
J	25000			28521	6.3568	8.5568	30321.9	15145.5	45467.4	16946.4
L	5000			8521	3.6345	5.1324	17336.6	9084.3	26420.9	17899.9
M	10000			13521	4.0158	6.1002	19155.4	10797.4	29952.8	16431.8

Wheat seed cost= 120 kg/ha seeds ×11.66 LE/kg= 1400 LE/ha Wheat grain price = 4770 LE/Mg; Wheat straw price = 1770 LE/Mg

The total cost was increased by about 78%, 87.6%, 58.6%, and 73.9% of (C and I), (D and J), (F and L), and (G and M) treatments, respectively in comparison to A treatment. On the other hand, the total profit increased by about 100.34%, 152.3%, 42.6%, 63.05%, 120.7%, 167.16%, 55.24%, and 76.03% for C, D, F, G, I, J, L, and M respectively when compared with the A treatment. Therefore, the total cost and profit increased with the increase in the concentration of polymers, meaning the concentration of polymers was 1% more than 0.5%. Otherwise, the net profit was arranged in the following order: C> F> D> G for the spray application method and I> L> J> M for the mixed application method. In the same context, 0.5% of treatment concentration was the best treatment consideration for the net profit (Ayeldeen *et al*., 2016b). As it was the lowest total cost treatment, the best treatments for the best economic return were C, F, I, and L. In the same context, Ayeldeen *et al.* (2016a) reported that the economic feasibility of Guar Gum

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will gradually improve over the long term due to the rapid growth of the global Guar Gum market. In addition, comparing Guar Gum (material price + CO_2 emission tax) to cement or other polymers will be less economical. Due to Guar Gum being a green material, it is eco-friendly and consequently has low emissions of CO_2 (Dorcas *et al.,* 2020; Algadwi *et al.,* 2021; Ayeldeen *et al*., 2016a).

CONCLUSION

In present study, 1% Guar Gum > 0.5% Guar Gum > 1% PVAc > 0.5% PVAc was deduced to be the best stabilizer concentration to mitigate the water erosion hazards and improve soil properties. However, 0.5% Guar Gum > 0.5 % PVAc was the best treatment for the high net profit of wheat crop yield, and it is considered a sufficient percentage. - Guar Gum interacts to accumulate and connect the soil particles, which improved soil properties without changing their mineral compositions. Under rainfall simulator conditions, the spray application method was the best. Otherwise, the mixed application method was the best under field conditions. - Guar Gum is more promising than PVAc, which has a highly functional carbohydrate polymer containing numerous hydroxyl groups and a linear chain with side branches. Guar Gum has gained many features, such as the high ability of hydrogen bonding formation, gelation at high concentrations, and film–forming features. Guar Gum is a promising material for soil improvement owing to its sustainability and environmental friendliness compared to PVAc. However, it is still not cost effective. Future increased production of Guar Gum will reduce the prices, which may lead to economic viability for use as soil improvement material and amendments.

It is recommended to ensure environmental safety, a soil conditioner it should be using Guar Gum or PVAc polymers, to achieve the best-stabilized results using Guar Gum to water erosion risk by using a mixed application method under field conditions and by spray application during the fallow season to get the best results which Guar Gum is a green material and it behaves like organic matter in the soil. It needs more investigation to use Guar Gum mixed with several materials such as sodium alginate or PVAc or different polymers to increase the efficiency and decrease its high price.

References

1) Abdel-raouf, Manar E., Sayed A., and Mostafa M. (2022). Application of Guar Gum and Its Derivatives in Agriculture © Springer Nature Switzerland AG H. N. Murthy (ed.), Gums, Resins and Latexes of Plant Origin, Reference Series in Phytochemistry, https://doi.org/10.1007/978-3-030-76523-1_5-1.

2) Algadwi, M., Spyropoulos B. E., and Nawaz, B. A. (2021). Erosion Protection by Polymer Additive. Proceedings of the 2nd International Conference on Civil Engineering Fundamentals and Applications (ICCEFA'21) Seoul, South Korea Virtual Conference - November 21 - 23, Paper No. 112 https://doi.org/10.11159/iccefa21.112.

3) Are, S., Babalola, K.O.O., Oke, A.O., Oluwatosin, G.A., Adelana, A.O., Ojo, O.A. and Deyolanu, O.D. (2011). Conservation strategies for the effective management of eroded landform: soil structural quality. Nutrient Enrichment Ratio, and Runoff Water Quality Soil Science, 179 (5): 252-263. http://doi.org/10.1097/SS.0b013e3182172b1b.

4) Ayeldeen, M. K., Negm, A. M., and El Sawwaf, M. A. (2016) a. evaluating the physical characteristics of biopolymer/soil mixture Arab J Geosci 9: 371. http://doi.org/10.1007/s12517-016-2366-1

5) Ayeldeen, M., Negm, A., El Sawwaf M. and Gädda, T., (2016) b. Laboratory study of using biopolymer to reduce wind erosion International Journal of Geotechnical Engineering http://doi.org/10.1080/19386362.2016.1264692.

6) Bu F, Liu J., Bai Y., Kanungo D. P., Song Z., Kong F. and Pan C. (2019). Effects of the Preparation Conditions and Reinforcement Mechanism of Polyvinyl Acetate Soil Stabilizer 11(3), 506 http://doi.org/10.3390/polym11030506.

7) Dadamouny M.A. and Schnittler M. (2015). Trends of climate with rapid change in Sinai, Egypt. J.Water and climate change http://doi.org/10.2166/wcc2015.215.

8) Dorcas, O. A. B., Jayejeje O. O. and George F. O., (2020). Effect of Stabilization on Failure Susceptibility of Oshogbo-Iwo Road in South-Western Nigeria. Journal of Civil Engineering and Urbanism 10(6): 53-61. DOI: https://dx.doi.org/10.54203/jceu.2020.8

9) Duncan, D. B., “Multiple ranges and multiple F- test”. Biometrics (1955), 11: 1- 42. https://doi.org/10.2307/3001478.

10) Food and Agriculture Organization (FAO) (1993). Field measurement of soil erosion and runoff, Soil Bull. No. 68, Rome, Italy.from Part I - Water-Related Risks under Climate Change Climate Risk and Sustainable Water Management Climate Risk and Sustainable Water Management Cambridge University Press, pp.82–109. https://doi.org/10.1017/9781108787291.007

11) Hillel, D. (2004). Introduction to Environmental Soil Physics book. Elsevier Academic Press, Amsterdam, Boston. https://shop.elsevier.com/books/introduction-to-environmental-soil-physics/hillel/978-0-12-348655-4

12) Klute, A. (1986). Methods of Soil Analysis. Part (1): Physical and Mineralogical Methods. No. 9 in the Agronomy Series. Amer. Soc. of Agron. And Soil Sci. Soc. of America (publisher), Second Edition. Madison, Wisconsin, USA. https://search.worldcat.org/title/Methods-of-soil-analysis.-Part-1-Physical-and-mineralogical-properties-including-statistics-of-measurement-and-sampling./oclc/85962062

13) Morgan, R.P.C. (1995). Soil Erosion and Conservation. Second Edition. Longman, Essex.Soil Erosion in the northern countries of the European community. EIW workshop: Elaboration of a framework of a code of good agricultural practices, Brussels, 21-22

14) Page, A.I.; Miller R.H. and Keeney, D. R. Eds. (1982): Methods of Soil Analysis. Part 2: Chemical and Microbiological Properties. 2nd Edition, Amer. Soc. Of Agron., Madison, Wisconsin, U.S.A. American Society of Agronomy. In Soil Science Society of America, Vol. 1159.

15) Petkovic, G., Preprotic S. P. and Vukoje M. (2018). The quality assessment of bookbinding strength for polyvinyl acetate adhesive (PVAc) and nano-modified PVAc adhesives-p13. http://doi.org/10.24867/GRID

16) Rizwan, M., Gilani S. R., Durani A. I., Naseem S., (2021). Materials diversity of hydrogel: Synthesis, polymerization process and soil conditioning properties in agricultural field. Journal of Advanced Research 33: 15–40 https://doi.org/10.1016/j.jare.2021.03.007.

17) Roushdi, M., Mostafa H., and Kheireldin K. (2016) Present and future climate extreme indices over Sinai Peninsula, Egypt. International scholarly and scientific research and innovation 10(1) 87-90. https://doi.org/10.2166/wcc2015.215.

18) Siddiqi, R. A. and Moore J. C. (1981). Polymer stabilization of sandy soils for erosion control. 60th annual meeting of the Transportation Research Board (conference) Washington District of Columbia United States. http://onlinepubs.trb.org/Onlinepubs/trr/1981/827/827- 007.pdf.

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DOI: 10.5281/zenodo.11064917

19) Song, Z., Liu J., Bai Y., Wei J., Li D., Wang Q., Chen Z., Kanungo D. P. and Qian W. (2019). Laboratory and Field Experiments on the Effect of Vinyl Acetate Polymer-Reinforced Soil Appl. Sci., 9, 208; https://doi.org/10.3390/app9010208.

20) Sujatha, E. R. and Saisree S. (2019). Geotechnical behavior of Guar Gum-treated soil. Soils and Foundations J.59(6): 2155-2166. https://doi.org/10.1016/j.sandf.2019.11.012

21) Thombare, N., Ali M., Swami S., Chowdhury A. R. and Srivastava S., (2018). Recent advances in applications of natural gum in agriculture. ICAR- Indian Institute of Natural Resins and Gums Namkum, IINRG Ranchi-834010 (Jharkhand) pp.89-95. http://krishi.icar.gov.in/jspui/handle/123456789/38420.

22) USDA NIFA (2013). The Role of Extension in Climate Adaptation in the United States. Report from the Land Grant - Sea Grant Climate Extension Summit Sponsored by the United States Department of Agriculture's National Institute of Food and Agriculture and the National Oceanic and Atmospheric Administration's National Sea Grant College Program https://www.nifa.usda.gov/sites/default/files/resources/climate_ext_summit.pdf

23) Vopravil, J., janeček M. and Martin T. (2007). Revised Soil Erodibility K-factor for Soils in the Czech Republic Soil & Water Res., 2, (1): 1–9. https://www.agriculturejournals.cz/pdfs/swr/2007/01/01.pdf

24) Wade, E. Zowada R., Foudazi R. (2021). Alginate and Guar Gum spray application for improving soil aggregation and soil crust integrity Polymer Technologies and Applications 2 https://doi.org/10.1016/j.carpta.2021.100114

25) Xu, X. and Tang Q. (2022) Water Erosion and Its Controlling Factors in the Anthropocene Climate Risk and Sustainable Water Management pp.82-109 https://doi.org/10.1017/9781108787291.007

26) Zumrawi, M. M. E. and Mohammed A. E. (2019). Effects of Poly Vinyl Acetate on Characteristics of Expansive Soil journal of materials and engineering structures 6: 167–176. https://www.researchgate.net/profile/MagdiZumrawi/publication/333817219_Effects_of_Poly_Vinyl_Acetate_on_Characteristics_of_Expansive_Soil/links/5d07665892851c900442e20b/Effects-of-Poly-Vinyl-Acetate-on-Characteristics-of-Expansive-Soil.pdf.