20

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Hydrophobic (Polyvinyl Acetate)-Hydrophilic (Poly- acrylamide Gel) Combination for Calcareous Soil Conditioning and Plantation

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FROM PREVIOUS studies on calcareous soil conditioning, a conclusion was drown that materials which turn the soil hydrophobic such as bitumen emulsions, polyvinyl acetate emulsions and ureaformaldhyde were more effective for conservation practices while these give the soil hydrophilic nature (polyacrylamides) were for increasing water retentively. It is expected that applying both types of soil conditioners together to highly calcareous soil will overcome most of the obstacles related to their hydro-physical properties besides improving their chemical properties and nutritional status. With this respect a polyvinyl acetate emulsion (PVAc) as a cheap and safe (hydrophobic) and an acrylamide hydrogel (hydrophilic) soil conditioners were examined. Both are locally prepared.

A completely randomized field experiment was conducted in a new reclaimed farm at El-Gharbaniat, Bourg El Arab, 30 km west the Cairo Alexandria Desert Road, where Eucalyptus (*Eucalyptus Sp.*) the common windbreak trees in the area was chosen as the indicator plant. The soil is sandy clay loam, highly calcareous. The following treatments for the soil of each plant pit (5kg) were examined: a) untreated soil. b and c) soil treated with a locally prepared PVAc emulsion 50 % active material at the rates of 0.5 and 1.0 % w/w active material, *i.e.* 50 and 100 g of the emulsion plant pit. d and e) soil was treated with PVAc as in treatment b and c. After drying, the soil was retreated with 0.2 % w/w of a polyacrylamide potassium polyacrylate gel (PAMG), *i.e.* 10 g of the hydrogel crystals / plant pit. Eucalyptus seedlings of 6 months old were transplanted. Normal irrigation at 7 and 14 days intervals in summer and winter months, respectively was adopted. Fertilization and pest control were the normal treatments for the soil and the plant. After 12 months from transplantation, soil samples were collected from the plant pits to express the conditioning effect of examined treatments. Dry matter production and water and fertilizes use efficiency by growing plants were also evaluated.

The possibility for natural structurization in untreated soil is limited. Treating the soil with PVAc enhanced the formation of water stable structural units, and significanlty increased both MWD of these structural units and erosion index. Positive changes in void ratio, total porosity, drainable pores, water holding pores, hydraulic conductivity and mean diameter of soil pores were recorded revealing an improvement in soil aeration, water retention and movement through soil profile. Mechanical strength particularly at low soil moisture tensions was improved and surface crackilng was reduced to a great extent. More improvements in the aforementioned properties of the soil were obtained by treating PVAc conditioned soil with PAMG.

Growth response and both water and fertilizers use efficiency by plants indicate that conditioning the soil with PVAc +PAMG can furnish adequate conditions for crust forming highly calcareous soil plantation.

Under the conditions of conducted experiment, conditioning the plant pits of windbreak transplants for one feddan (30-60 plant pits) needs 3-6 kg PVAc and 300-600 g PAMG that costs 16.5-33.0 L.E.

Keywords: Calcareous soils, Soil conditioners, Hydrophilic polymer. Hydrophobic polymer, Eucalyptus, Soil properties, Plant growth, Water use efficiency, Fertilizer use efficiency.

Highly calcareous soils are widely spread in Egypt. They cover vast areas that can help in solving the shortage in food production. High calcium carbonate content-particularly the active fraction with high specific surface area-in these soils distinctly affects their hydro-physical, and chemical characteristics, their fertility status and water use for crop production. Reclamation and land utilization of these soils are faced by several obstacles namely: 1) The particular structure of such soils and changes in hydro-physical properties according to their water content. With irrigation, they become muddy, less pervious and highly erodible. Besides, heavy cracks that appear when drying out can damage roots. 2) Crusting on the surface and its effect on infiltration and soil aeration from one side and seedling emergence and crop stand on the other side. 3) The high Ca CO_3 content and its effect on soil fertility and nutrients availability. This includes: a- High pH level, low organic matter and available N. b-Low availability of phosphorous and applied P quickly reverts to insoluble forms. c- Problems of K and Mg nutrition as a result of the nutritional imbalance between these elements and calcium. d- Problems of micronutrients availability especially Zn, Fe, Mn and Cu. Deficiencies of these micronutrients result in chlorosis of varying severity.4) Problems of water availability. Besides, the cemented condition of the sub-soil layers(El-Hady, 1979).

The possibility of using synthesized soil conditioners to improve the hydrophysical, chemical and biological properties of crust forming calcareous soils, to obtain better conditions for seedling emergence and plant growth and for more effective conservation practices were investigated. The response to treatments varied with conditioners used and their application rates. All examined conditioners increased aggregate stability, soil aeration, water movement under saturated conditions and mean pore diameter. Soil mechanical strength was improved and surface cracking was reduced with conditioning. On the other hand, the changes in the characteristics of solid- water system and in turn water retention in the soil and available water to plants due to conditioning differ according to the hydrophilic or the hydrophobic nature of the soil after conditioning. In other words, conditioners with hydrophobic effect on the soil such as bitumen emulsions, polyvinylacetate emulsions and urea formaldehyde were more effective for conservation practices while hydrophilic ones (polyacrylamides) for increasing water retentivity (El-Hady, 1979 and 1988; El-Hady &Tayel, 1981; El-Hady & Abou Saif, 1984; El-Hady & Lotfy, 1986 and 1987; Khattab *et al.*, 1989; El-Hady *et al.*, 1991 and Arafat & El-Hady, 2000).

It is expected that applying both types of soil conditioners (hydrophobic and hydrophilic) together to highly calcareous soils will overcome most of the obstacles related to hydro-physical properties of such soils besides their chemical properties and nutritional status. With this respect, a polyvinyl acetate (PVAc) emulsion as a cheap and safe (hydrophobic) and an acrylamide hydrogel (hydrophilic) soil conditioners were examined. Both are locally prepared. Eucalyptus as the common windbreak trees in the studied area was chosen as the indicator plant. Effect of examined treatments on the dry matter production as an indication for the growth response - and both water and fertilizers use efficiency by Eucalyptus plants after 12 months from transplantation were investigated.

Material and Methods

A completely randomized field experiment with four replications for each treatment (Cochran and Cox, 1957 and Snedecor & Cochran, 1980) using Eucalyptus transplants as indicator plant for each treatment was conducted in a newly reclaimed farm at El-Gharbaniat, Bourg El-Arab, 30 km west on the Cairo Alexandria Desert Road. This experiment can be summarized as follows:

1. Soil

The soil is sandy clay loam, and highly calcareous. Its main analytical data are shown in Table 1.

2. Soil conditioners

a) Poly vinyl acetate (PAVC) emulsion

50% active material was prepared by emulsion polymerization of vinylacetate. Polymerization conditions were: a) polymerization was carried out under nitrogen atmosphere, *i.e* in the absence of air, b) initiator used was the redox pair initiator system, *i.e.* Sodium bisulphite (Na HSO_3) and potassium

TABLE 1. Some analytical properties of the Bourg El- Arab calcareous soil.

a)Mechanical analysis

Course sand 2000-200 µ %	Fine sand 200-20 µ %	Silt 20-2 µ %	Clay < 2µ %	Texture	$CaCO_3$ %	OM %
15.0	37.5	17.8	29.6	Sandy clay loam	41.2	1.11

Distribution of carbonates as % $CaCO_3$ content equivalent 31.4 sand 43.5 silt, and 25.1 clay.

b)Hydro-physical analysis

Bulk density g cm^3	Void ratio	Total porosity %	Moisture retained θ w % at			Hydraulic conductivity m day^{-1}	Mean diameter of soil pore (µ)	Maximum strength of soil surface kg cm^{-2}
			Water holding capacity	Field capacity	Wilting percentage			
1.365	0.94	48.5	35.5	29.2	14.9	0.51	4.4	40.36

C) Chemical analysis

TSS g/100g soil	pH	Anions in soil paste extract meq /100 g soil				Cations in soil paste extract meq /100 g soil				CEC meq/ 100 g soil	Exchangeable cations meq/100 g soil		
		CO_3^{-2}	HCO3	Cl	SO_4^{-2}	Ca^{++}	Mg^{++}	Na^{+}	K^{+}		Ca^{++} + Mg^{++}	Na^{+}	K^{+}
0.15	8.2	-	0.8	0.8	1.7	1.0	0.6	1.4	0.3	10.8	7.9	1.8	1.1

persulphate ($K_2S_2O_8$) at the ratio of 1 :2.5. Initiator: monomer (w/w) was 0.5%, c) emulsifying agent was 0.5% polyvinylalcohol solution of b.p 120°C and Mol. Wl. 700,000 and d) temperature used and time of polymerization were 60°C and 8hr with continuous stirring, respectively.

b. Polyacrylamide hydrogel (PAMG)

Polyacrylamide K polyacrylate hydrogel was prepared in the Polymer and Pigments Dept, NRC (Abd El-Hady *et al.*, 1997) Main constituents and properties of the prepared hydrogel are shown in Table 2.

3. Soil treatments

Five treatments were examined namely:

a. Untreated soil; b and c. the soil of the plant pit (5 kg) was treated with PVAc at the rates of 0.5% and 1% (active material) w/w. *i.e.* 50 and 100 g emulsion (50% active material), respectively. The optimal conditions for conditioning process such as, initial and final soil moisture content and appropriate conditioner dilution were taken into consideration to obtain optimal soil aggregation and stability (El-Hady and Tayel, 1981). d and e, the soil of the plant pit was treated with PVAc at the aforementioned rates. After drying, the soil was re-treated with 0.2% (PAMG). *i.e.* 10g of hydrogel crystals/plant pit.

4. Transplanting

Eucalyptus seedlings of six months old (bar rooted seedlings) were transplanted.

5. Irrigation

Normal irrigation at 7 and 14 days intervals in summer and winter months, respectively was adopted.

6. Fertilization and pest control

Fertilization and pest control were the usual treatments for the soil and the examined plant.

After 12 months from plantation, soil samples were collected from the plant pits. The following indices were determined to evaluate the improving effect of the conditioning treatments. The size distribution of water stable structural units and their mean weight diameter (Black, 1982).

b) Erosion index (Vadvetde *et al.* 1974).

c)Bulk density, void ratio, total porosity and pore size distribution (Hillel, 1971 and Loveday, 1974).

d) Hydraulic conductivity of 2-1mm fractions after perculation for three hours under constant water heat (Azzam and El-Hady, 1983). Data of hydraulic conductivity were used in calculating the mean diameter of soil pores (El-Hady, 1979).

e) Soil water equilibrium values over a range for 0.0 to 15 bars (moisture characteristics) and available moisture in the soil (Loveday, 1974).

f) Soil resistance to a penetrating probe, as an index for soil mechanical strength, was measured during drying process (El-Hady and Lotfy, 1986).

Growth response (dry weight of roots stem and leaves) and both water use efficiency (expressed as the dry matter produced in kg by m^3 of irrigation water) and fertilizer use efficiency (expressed as the dry matter produced in kg by units of added nutrients (N, P_2O_5- and K_2O)). After 12 months from transplantation were evaluated.

TABLE 2. Description of the main constituents and properties of examined hydrogel*.

a – Main constituents and polymerization conditions	
Active substance	Poly acrylamide K acrylate copolymer
Ionization degree	30mole %
Cross linker	Tri – ethanol amine
Cross linker ratio	1: 10^{-4} mole/mole
Temperature used for polymerization	30-35 °C
Time of polymerization	~ 1.5 h.
Presence or absence of nitrogen	Prepared in air
Monomer content	Not higher than 200 ppm
Percentage of active substance	Greater than 95%
b- Properties	
Appearance:	*White to slightly yellow grains*
Grain size :	0.25 - 1 mm
Bulk density (dry):	≈ 600 kg/m^3
Solubility :	Insoluble in water and organic solvents
pH 0.1 % in distilled H_2O	7.1
Absorption capacity in g/g hydrogel :	
Deionized water	= 400
0.9 % NaCl	= 55-60
Saline water 2500 ppm	= 85
Absorption time :	
Up to 50 %	20 minutes
Total absorption	60 minutes

Results and Discussion

It is obvious that the possibility for natural structurization in the untreated soil is limited. Treating the soil with PVAc enhanced the formation of water stable structural units > 0.5 mm, 1-2 mm and > 2 mm in diameter on the expense of the smaller ones. Formation process increased with the application rate of PVAc. Therefore, MWD of water stable structural units was significantly increased. Further increase in water stable strtictural units and their MWD were attained by application of PAMG to PVAc treated calcareous soil. Consequently, stability of the soil against erosion was improved. Erosion indices were highly increased (Fig. 1).

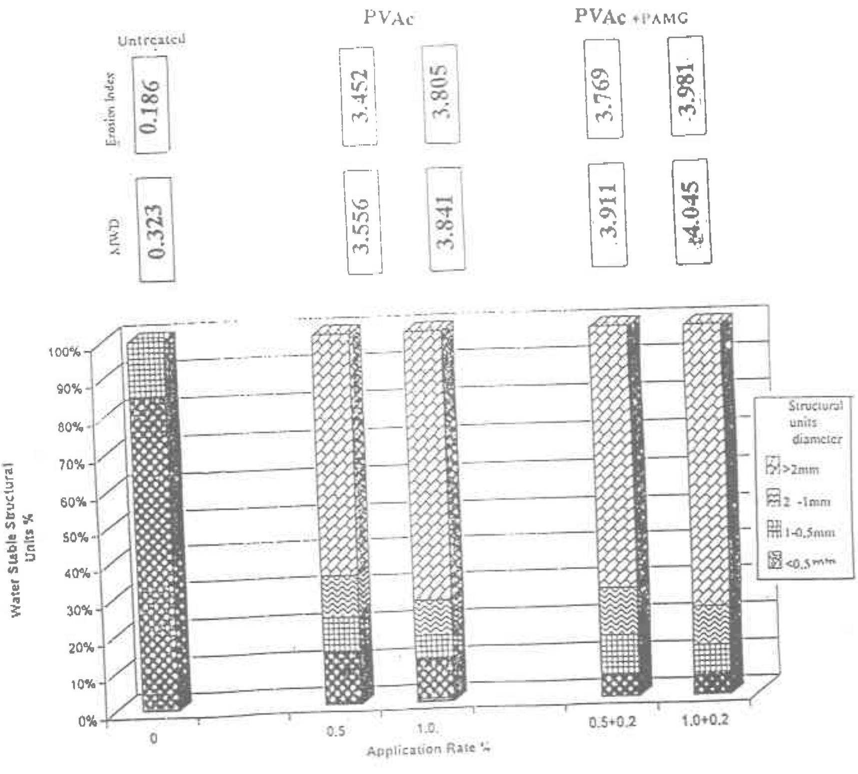

Fig. 1. Effect of conditioner type and rate of application on the distribution of water stable structural units and their MWD and erosion index for the Bourg El-Arab calcareous soil.

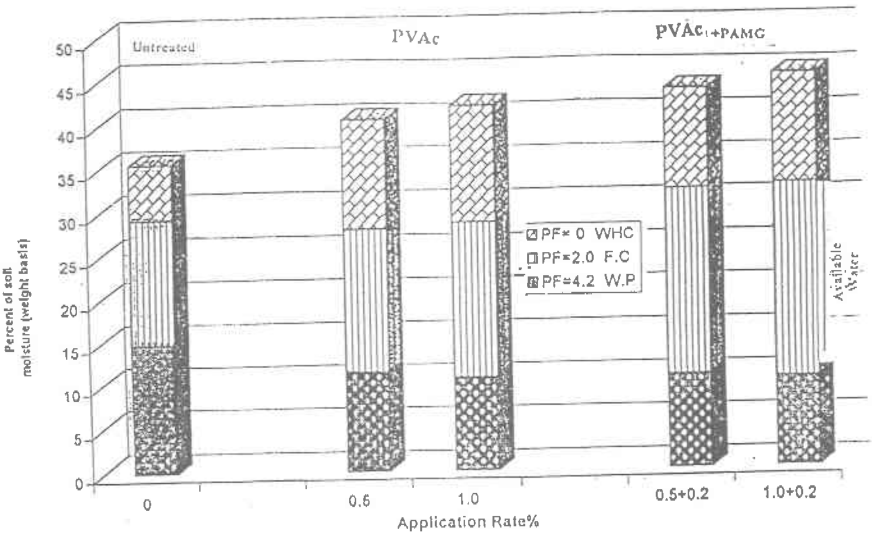

Fig. 3. Effect of conditioner type and rate of application on water retention in the Bourg El-Arab calcareous soil.

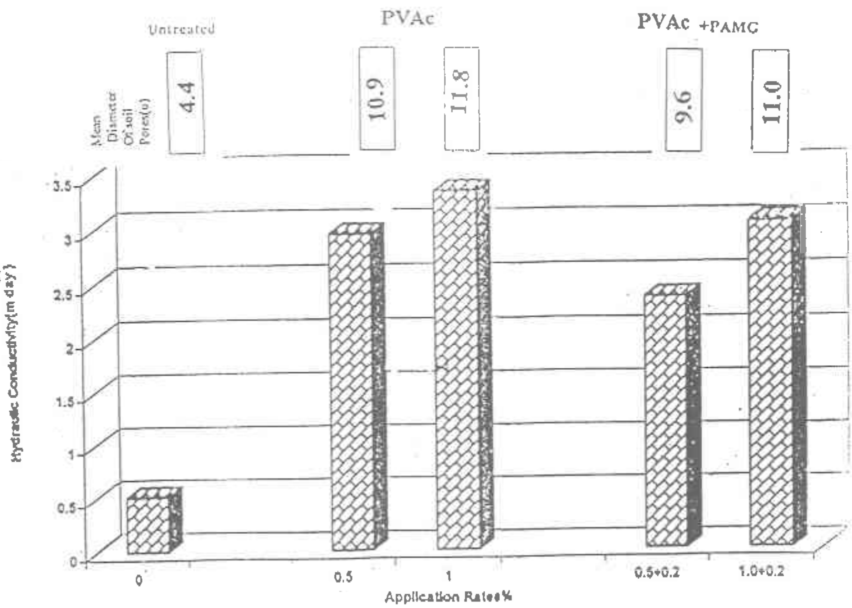

Fig. 4. Effect of conditioner type and rate of application on soil hydraulic conductivity ($m\ day^{-1}$) and mean porediameter (μ) of the Bourg El-Arab calcareous soil.

Although treating the soil with hydrophobic material (PVAc) did not increase the availability of water by more than 25%, it is expected that the presence of a top layer of hydrophobic structural units can conserve moisture (El-Hady, 1979). In soils containing sufficiently large stable and water repellent structural units, water can easily enter through the spaces among the structural units and by -pass the internal porosity of the structural units themselves. The structural units remain relatively dry but allowing water to pass between them. Thus a given amount of water can penetrate deeper and possibly more rapidly than in the untreated soil. At the end of the infiltration (irrigation) process, the surface zone of the hydrophobic conditioned soil reduces water loss through evaporation (El-Hady *et al.*, 1981), consequently, the amount of availabe water in the subsoil may increase. On the other hand, the hydrophilic PAMG highly increased the available water. This increase reached 55% by weight relative to the control.

Regarding soil mechanical strength (Table 3), its response to conditioner treatments differs according to soil moisture tension and soil moisture content at this tension. At low moisture tension, *i.e* at pF = 2, the mechanical strength of the conditioned soil was higher than that of the untreated one. It increased with increasing the application rate. This phenomenon is desired and beneficial. It protects soil surface from budling after heavy irrigations. The rate of increase in soil strength during drying in the range of available water, *i.e.* from pF = 2 to pF=4.2 decreased by soil conditioning. It was 1485% in the untreated soil versus 1040, 1000, 810, and 600 % in the case of treating the soil with PVAc 0.5%, PVAc 1%, PVAc 0.5%+0.2% PAMG and PVAc 1%+0.2 % PAMG, respectively. In all cases, mechanical strength of the conditioned soil at wilting percentage is lower than that of untreated one being much lower with PAMG addition. When conditioning with hydrophobic material (PVAc), the air dry soil has a strength higher than that of control.

TABLE 3. Effect of conditioner type and rate of application on the pentration resistance during drying process of the Bourg El-Arab calcareous soil.

Treatments	At field capacity		At wilting percentage		Air dry soil	
	θ_w %	Penetration resistance Kg cm^{-2}	θ_w %	Penetration resistance Kg cm^{-2}	θ_w %	Penetration resistance Kg cm^{-2}
Untreated	29.2	1.21	14.9	19.2	2.6	40.36
PVAc 0.5%	27.5	1.39	12.3	15.8	2.1	45.36
PVAc 1%	28.7	1.63	11.3	17.9	1.8	51.12
PVAc 0.5%+PAMG 0.2%	32.2	1.31	10.6	11.9	3.1	24.64
PVAc 1% + PAMG 0.2%	32.9	1.40	10.1	9.8	3.4	20.97

In this case, the strength is proportional to the concentration used. The reverse is true when applying PAMG. A point of practical importance is the optimal moisture condition of the soil for each treatment-at which its mechanical strength is suitable for reduced tillage operation without dangers of destroying soil structure, increasing erosion and soil compaction by heavy tillage equipments.

It should be noted that a visual difference was obvious between the surface of conditioned and untreated soil. Due to the changes in pore geometry of the untreated soil, subsequent wetting and drying causes the appearance of heavy cracks. Treated soil shows normal shrinkage without any crack formation. The aggregating effect of applied soil conditioners and the stability of the conditioned soil structure posses stable pore geometry. In this way, soil conditioning reduces to a great extent the formation of cracks during the normal shrinkage. This will be a big advantage because it may protect young plant roots during drying out the soil.

Significant increase in the dry weight of plants that reached 29.0% over that of the control -(untreated soil) - and consequently, both water and fertilizers use efficiency by the plants were recorded by treating the soil with PVAc at the rate of 0.5% active material (w/w). Doubling the application rate of PVAc to be 1% (active material w/w) raised the aforementioned increases to be ≈ 1.5 times that of untreated soil. Applying 0.2% w/w PAMG to the conditioned soil with PVAc increased either the dry weight of growing plants or their water and fertilizers use efficiency to be 174% and 186% that of untreated soil using 0.5% and 1% PVAc, respectively (Table 4) .

Taking into consideration that the preparation of one ton of PVAc emulsion (50% active material) costs about 4000 L.E (Egyptian pounds) and the price of the used hydrogel is about 3 dollars / kg, *i.e.* about 15 L.E ,costs of conditioners needed for the plant pit (5 kg) will be ≈ 20, 40, 35 and 55 p.t when applying the treatments b, c, d, and e, respectively (Table 5).

Since the required windbreak trees for one feddan ranges between 30-60 trees according to the area of the farm, distances between trees and number of rows of

TABLE 4. Growth response and water and fertilizer use efficiency by Eucalyptus plants (after 12 months from transplantation) as affected by conditioner type and rate of application for the Bourg El-Arab calcareous soil.

Treatments	Dry weight g / plant				% of increase over the untreated soil	Water use efficiency Kg /m³	Fertilizer use efficiency Kg/ unit		
	Roots	Stem	Leaves	Whole plant			N	P_2O_5	K_2O
Untreated	126.18	89.16	151.11	366.45	----------	0.349	3.57	4.73	1.47
PVAc 0.5%	161.37	110.33	201.15	472.65	29.0	0.450	4.61	6.10	1.89
PVAc 1%	188.16	121.16	233.74	543.06	48.2	0.517	5.30	7.01	2.17
PVAc 0.5%+PAMG 0.2%	213.68	156.39	269.63	638.60	74.3	0.608	6.23	8.24	2.55
PVAc 1% + PAMG 0.2 %	231.32	172.16	276.39	679.87	85.5	0.647	6.63	8.77	2.72
L.S.D at 0.05	12.15	10.76	7.85	26.35					

Each figure is the average of 48 plants.

• Expressed as dry matter produced in kilogram by m^3 of irrigation water.

• Expressed as dry matter produced in kilogram by unit of added nutrients.

-Irrigation water used = 1.05 m^3 / plant (35 irrigation x 30 L/ plant).

-Fertilizers used were 0.5 kg of each of ammonium sulphate 20.5% N, superphosphate 15.5% P_2O_5 and potassium sulphate 48-52% K_2O / plant .

TABLE 5. Conditioners needed for plantation of wind break trees in one feddan of Bourg El-Arab calcareous soil and their costs.

Treatments	Conditioners needed for plant pit (5 Kg soil) in grams		Costs of needed conditioners for plant pit (L.E)			Costs needed for conditioning one feddan (30-60 plant pits) L.E
	PVAc*	PAMG**	PVAc	PAMG	Total	
PVAc 0.5%	50	-	0.2	--	0.2	6 - 12
PVAc 1%	100	-	0.4	--	0.4	12- 24
PVAc 0.5%+PAMG 0.2%	50	10	0.2	0.15	0.35	10.5- 21.0
PVAc 1% + PAMG 0.2%	100	10	0.4	0.15	0.55	16.5- 33.0

*PVAc emulsion 50% active material .

**Crystals of polyacrylamide K pelyacrylate hydrogel.

trees needed to protect the farm against severe winds and wind velocity itself, therefore, the highest costs of soil conditioners needed to improve mechanical, hydro-physical and bio-chemical properties and fertility status of the plant pits of windbreak trees in highly calcareous soil will be only 33.0 L.E per fedden.

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الأثر المشترك لبوليمر كاره للماء (مستحلب البولى فينايل اسيتات) واخر محب له (البولى اكريلاميد جل) على تحسين خواص الاراضى الجيرية واستزراعها

عمر عبد العزيز الهادى وسعيد عبد الحى وهبة

قسم الأراضى واستغلال المياه -المركز القومى للبحوث - الدقى - القاهرة - مصر .

اثبتت الدراسات السابقة ان محسنات التربة الجيرية التى تعطى التربة تأثيرا كارها للماء مثل مستحلبات البتيومين ومستحلبات البولى فينايل اسيتات واليوريا فورمالدهيد تكون اكثر تأثيرا على صيانة التربة وثبات بنائها ضد عوامل الانجراف بينما تلك التى تعطى التربة تأثيرا محبا للماء مثل البولى اكريلاميدات فتصلح لزيادة حفظ التربة للرطوبة. ومن المتوقع انه بمعاملة التربة الجيرية بكلا النوعين من المحسنات معا سوف نتخطى معظم المشكلات الناتجة عن الخواص الهيدروفيزيائية والكيميائية والميكانيكية لهذا النوع من الأراضى وكذا حالتها الغذائية. فى هذا المجال اختبرت معاملة التربة عالية الجيرية بمستحلب بوليمرى كاره للماء (مستحلب البولى فينايل اسيتات) ومركب بوليمرى محب للماء (بولى اكريلاميد هيدروجل) وكلا النوعين من المحسنات محضرا محلياً ورخيص السعر وامن بيئياً.

اجريت تجربة حقلية بنظام تام العشوائية فى احدى المناطق حديثة الاستصلاح ببرج العرب ذات تربة رملية طينية طمية عالية الجيرية (نسبة الكالسيوم كربونات فيها ٤١.٢٪) حيث اختير الكافور (وهو من النباتات الشائع زراعتها كمصدات للرياح فى المنطقة) كنبات دليلى. اختبرت المعاملات التالية لجورة النبات (٥كجم تربة):
المعاملة أ: التربة الغير معاملة. المعاملتين ب و ج: عوملت التربة بمستحلب البولى فنينايل اسيتات (٥٠٪ مادة فعالة) بمعدلات ٠.٥ و ١٪ مادة فعالة وزنا أى ٥٠جم و ١٠٠جم من المستحلب المحضر / جورة نبات. المعاملتين د و ه: عوملت التربة بمستحلب البوليمر بنفس الطريقة المذكورة فى المعاملتين ب و ج وبعد جفاف التربة