(From the University of Agriculture in Vienna and the Suez-Canal-University in Ismaelia)

Potentiality for Soil Erosion Control and Improving Plant Production in Arid Zones *

2nd Communication: Green-house and Phytotron Investigations of Soil Stabilizers and Evaporation Inhibitors

By H. NEURURER, A. GENEAD and W. STEINMAYR

(With 3 figures)

1. Introduction

Beside the fundamental investigations in the laboratory and by electron microscopy (NEURURER et al. 1991), extensive tests must be made to investigate soil conditioners in the green-house and in the phytotron. Such tests should include inhibition of evaporation, infiltration and crop emergence under defined environmental conditions. The behaviour of some evaporation inhibitors, e.g. bitumen, in the green-house was reported by many researchers, such as WANG JIUZHI and WU DONGTANG (1986) and COLLIS- GEORGE et al. (1963). However, the behaviour of Sarea Soil Stabilizer and Sarea Evaporation Inhibitor has not been described until now.

2. Materials and Methods

The materials used in these investigations are:

Bituplant 22, anionic, a 25 % (50 % respectively) bituminous emulsion, at a dosage of 1000 to 3000 l/ha;

Sarea Soil Stabilizer (SSS), 100 kg/ha, diluted with 1000 l of water;

Sarea Evaporation Inhibitor (SEI), 75 l/ha, diluted with 15.000 to 30.000 l of water; city garbage compost.

Products proved to be promising by laboratory investigations and by electron microscopy, were submitted to the following tests in the green-house and in the phytotron.

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2.1 Tests carried out in the green-house

2.1.1 Reduction of evaporation

Mitscherlich containers (d = 20 cm, h = 20 cm) were filled with sandy soil, moistened with water up to field capacity, after having been supplemented with soil conditioners, i.e. 75 l/ha of SEI in 15.000 l water, 1500 l/ha of Bituplant 22, 75 l/ha of SEI followed by 1500 l/ha of Bituplant 22, 5 mm compost layer as a soil cover, 5 mm compost layer followed by 15.000 l/ha of 25 % Bituplant and 5 mm compost layer followed by 1500 l of a mixture consisting of 25 % (50 % respectively) Bituplant 22 and 2 % SSS.

On the following 5th and 10th days irrigation was applied by a rain simulator. The fall height of the droplets was 3 m, the droplet mean volume diameter was 1 mm and the depth of each irrigation was 7 mm. Green-house temperature was 20°C. The change of sand moisture content was gravimetrically determined after 4, 9 and 18 days. Three test replications were established.

2.1.2 Germination and vegetative power

Germination tolerance to SEI was tested for chicory. Its seeds were soaked in undiluted SEI, in 80 kg SEI (diluted in 25.000 l of water) and in 80 kg SEI (diluted in 50.000 l of water). Some soaked seeds were lifted off every minute. The total soaking period was one hour. Then the seeds were put upon filter-paper for drying. Twentyfour hours later, the germination capacity was assessed according to ISTA standards.

2.1.3 Determination of the optimum dose of SEI

Polystyrol containers of the dimensions of 170 x 120 x 70 mm, were filled up to 50 mm with sand. SEI was atomized upon the sand at different dosages. Irrigation water was applied at 80 % of field capacity. Afterwards, the reduction of evaporation and the retained soil moisture were gravimetrically assessed.

2.2 Experiments carried out in the phytotron

These investigations were made by PROF. DR. H. G. FREDE and by DIPL.ING. D. LÜTKEMÖLLER at the Justus-Liebig-University in Gießen.

2.2.1 Inhibition of evaporation

This test was made to investigate various substances for their evaporation inhibiting capacity. PVC columns of 177 cm^2 surface and a height of 25 cm were filled with sand or loess loamy sand, rich of silt.

Particle size distributions are given in table 1.

Loess contains 8,6 weight % of $CaCO_3$ and 0,24 weight % of organic carbon.

Soil densities were adjusted to 1,41 and 1,46 g/cm^3 for sand and loess soil, respectively. During 24 hours, the soils were saturated by water until field capacity was reached. Cationic or anionic Bituplant bituminous emulsions were used at the following doses and concentrations:

Nr. 7 = cationic, 750 l/ha, 25%
Nr. 7 x 2 = cationic,1500 l/ha, 25%
Nr. 7 a = cationic,1500 l/ha, 50 %
Nr. 22 = anionic, 750 l/ha, 50%

They were applied to the surface of the wet soil by a handsprayer similar to that used for plant protection products (nozzle: TeeJet 110 06). After the formed films had appeared to be dry, the columns were placed into the phytotron at 30°C and 45% relative humidity under 32.000 lux illumination during 12 hours. Under such conditions, the potential evapotranspiration is 5,8 mm/day, according to the formula of HAUDE (1954). Development and intensity of evaporation were gravimetrically assessed daily.

Table 1

Particle size of the soils investigated

Soil	Particle size (Ø in µm)						
	Sand		Silt			Clay	
	≥200	200 – 63	63 – 36	36 – 20	20 – 6	6 – 2	≤2
Sand	4,8	95,2	0	0	0	0	0
Loess	4,2	8,8	31,5	22,9	15,4	8,9	8,3

Weight %, fine soil without any rendzina

2.2.2 Soil moisture contents and film quality

It was investigated, whether soil conditioners should be applied to dry or moist soil surfaces. After the previous experiment had been finished, sandy soil columns, not treated by any soil conditioner, were sprayed by a 25% 7-cationic bituminous emulsion (750 l/ha). Spraying was made upon soil having been saturated by capillarity during 40 hours, and upon surface air-dry soil columns. These had been also saturated by capillarity. For 10 days, development and intensity of evaporation was daily assessed by gravimetry, under similar environmental conditions as those used for the previous experiment. Such tests were repeated for several times.

3. Results and Discussion

3.1 Green-house tests

3.1.1 Reduction of evaporation

The results for the gravimetric periodic change in soil moisture content were used to calculate percent evaporation reduced (table 2).

The results indicate that by all these soil conditioners evaporation was significantly reduced from soil surface. From the single application of soil conditioners the following results concerning reduction of evaporation were obtained: SEI > compost > Bituplant 22. The reason for this trend may be attributed to:

1) Mode of action of the conditioner by partially sealing some soil pores, as for SEI and Bituplant bituminous emulsions, or breaking the continuity of capillary water by the three conditioners used, owing to the hydrophobicity of SEI and Bituplant 22, or to a mulching effect of the compost layer.
2) Concentration of the conditioners, which is directly related to the degree of sealing soil pores.
3) Stability of the conditioner film or cover.

From the results obtained for applying more than one conditioner it was found that adding a 5 mm compost layer, stabilized with 1500 l Bituplant 22, containing 2% SSS, was favoured. This treatment was followed by adding 75 l/ha SEI, then by adding 1500 l/ha of 50% Bituplant 22. The latter treatment was also favoured by adding a 5 mm compost layer, stabilized with 1500 l/ha of 25% Bituplant 22. The reason for such preference is related to percent evaporation reduction. Apparently, the effect of applying soil conditioners on the reduction of evaporation is not promoted by applying another one. However, the stability of a soil conditioner may be improved by the presence of another one, as for the 75 l/ha SEI, followed by 1500 l/ha Bituplant 22, where the percent reduction of evaporation only varied from 40±4,0 to 35±6,0 during 4 and 18 days.

Table 2

Effect of various soil conditioners on the reduction of soil-water evaporation (arithmetic mean and standard deviation, measuring repeated 3 times)

Treatment	Evaporation reduced in %					
	4 days		9 days		18 days	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
1. Control	0		0		0	
2. 75 l/ha SEI in 15.000 l of water	30	1,2	30	1,6	28	2,1
3. Bituplant 22, 50 %, 1500 l/ha	15	0,6	10	0,3	8	0,1
4. 75 l/ha SEI in 15.000 l of water, followed by 1500 l/ha Bituplant 22, 50 %	40	1,7	38	0,8	35	1,2
5. Compost (5 mm layer)	20	0,4	20	0,6	15	0,2
6. Compost (5 mm layer) + 1500 l/ha Bituplant 22, 25 %	30	0,7	30	0,8	20	0,5
7. Compost (5 mm layer) + 1500 l/ha Bituplant 22, 25 %, + 2 % SSS *)	45	1,8	40	2,1	30	1,5

*)Tank-mixture consisting of 1500 l Bituplant 22 and 30 kg/ha of Sarea Soil Stabilizer

3.1.2 Results from germination and vegetative power experiment

Data obtained for chicory germination and vegetative power are presented in table 3.

Chicory seed germination power was reduced by about 8% from the control when soaked in undiluted SEI. Apparently, diluted SEI did not affect its percent germination. Moreover, the effect of soaking seeds in all SEI concentrations did not significantly affect percent germination.

3.1.3 Determination of the optimum dose of SEI

Figure 1 shows that reduction of evaporation increases when the rate of SEI application increased. Evidently, the optimum rate of application is 80 kg/ha, as evaporation was reduced more than 60%. The reason for such a result may be related either to the presence of soil moisture lower than field capacity or to the SEI penetration depth (NEURURER et al. 1991). Moreover, SEI is apparently effective in sealing some soil pores (tab. 2).

Table 3

Effect of SEI on chicory germination and vegetative power

Treatment	Time (minutes)	% germination	standard deviation
untreated seeds, SEI undiluted	–	94,0	2,8
	1	86,0	5,7
	5	88,0	2,8
	15	88,5	4,7
	30	86,0	4,3
	60	85,5	1,9
SEI, 80 kg diluted in 25.000 l of water	1	96,5	1,9
	5	91,5	4,1
	15	92,0	4,9
	30	94,0	3,5
	60	94,0	3,3
SEI, 80 kg diluted in 50.000 l of water	1	95,0	1,2
	5	92,5	1,0
	15	92,5	1,9
	30	95,5	5,3
	60	96,0	1,9

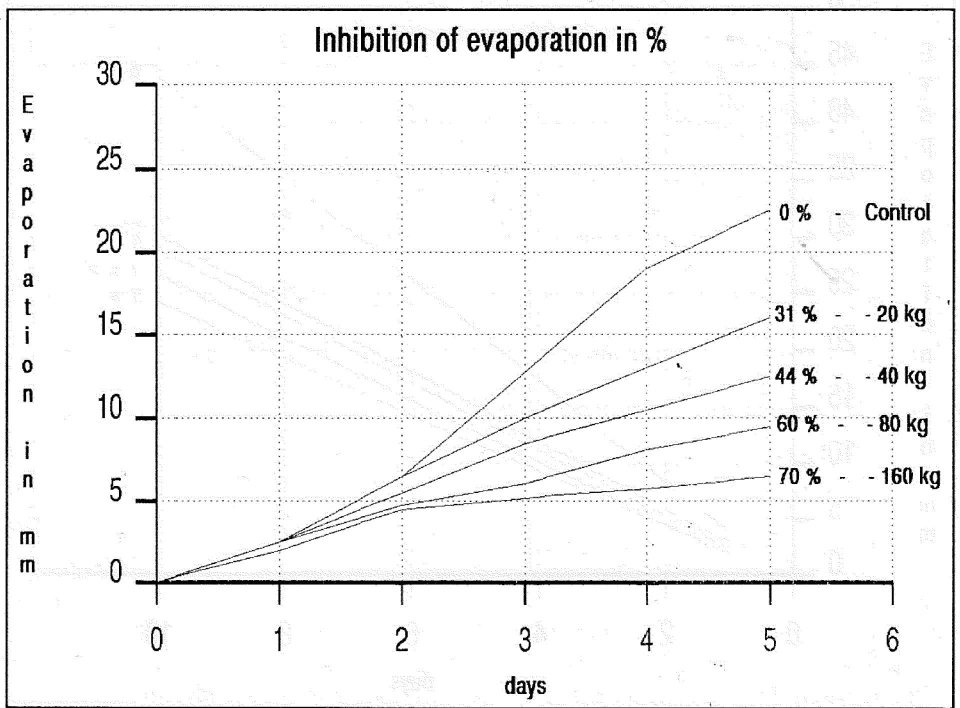

Figure 1: Influence of the dosage of Sarea Evaporation Inhibitor on evaporation

3.2 Phytotron tests

3.2.1 Inhibition of evaporation

Data obtained for evaporation from sandy and loamy soils treated with various soil conditioners are presented in tables 4 and 5.

Table 4

Evaporation response to treated sandy and loamy sand soils by various Bituplant bituminous emulsions (arithmetic mean and standard deviation, measuring repeated 4 times)

Treatment	Sandy soil			Loamy sand soil (loess)		
	Average evap., mm	s	% of control	Average evap., mm	s	% of control
Control	43,70	1,7	100	35,93	2,2	100
7	28,71	2,0	65,69	25,04	1,2	69,69
7 a	24,10	0,3	55,14	22,03	3,4	61,31
7 x 2	26,36	1,3	60,32	10,73	3,5	29,86
22	29,42	3,2	68,46	20,30	1,2	56,49

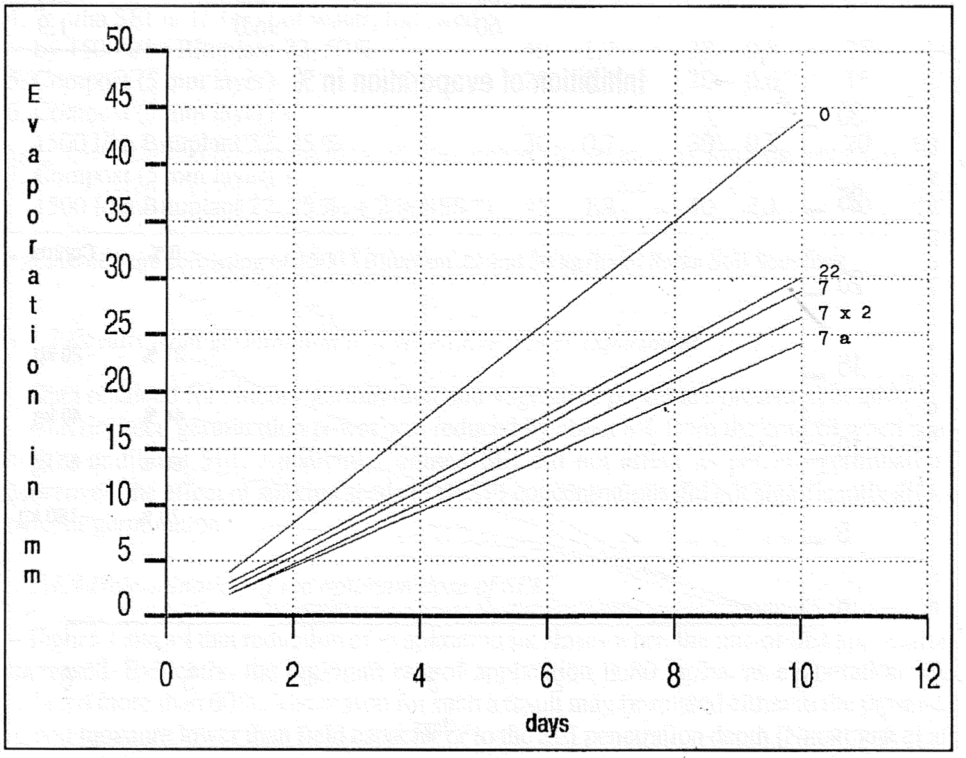

Figure 2: Effect on evaporation from sandy soil treated by various bituminous emulsions

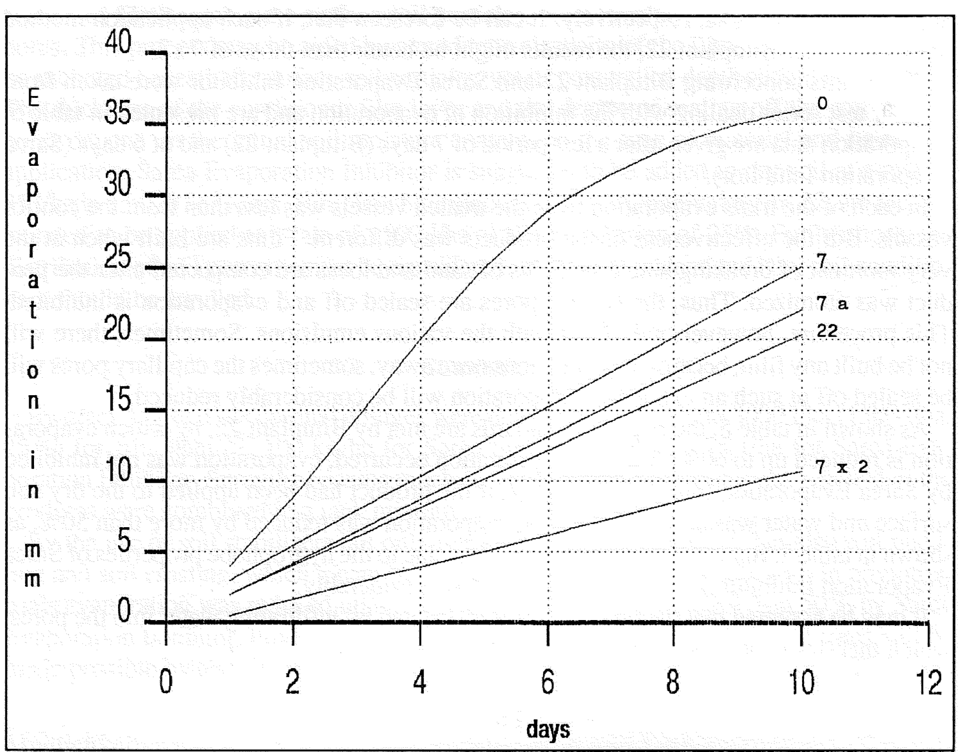

Figure 3: Effect on evaporation from loamy sand (loess) soil treated by various bituminous emulsions

It could be seen from the data that daily evaporation from sandy soil is slightly less than from loamy sand soil (fig. 2 and 3), although total evaporation is higher from the first than from the second soil (tab. 4). However, the rate of evaporation seems to have a simple linear function within the 10 days test period (fig. 2). This relation was only found for the loamy sand soil during the first 6 days; then the rate started to decrease (fig. 3). This response is related to the surface area of soil pores which must be larger for the sandy than the loamy sand soil.

Soils treated with Bituplant bituminous emulsions did not only lead to reduced evaporation (fig. 2 and 3, tab. 4), but also reduction became linear throughout the test periods. This result indicates that some of the macro-pores were sealed off. Consequently, retained soil moisture requires prolonged time for evaporation. Such time is conditioned by the degree of sealing off the soil pores, the preliminary distribution of soil pores, and the concentration of the emulsion and its type, as reported by GENEAD (1985).

Apparently, the best bituminous emulsion to be used for sandy soil is 7a, as it reduced evaporation by about 45% (tab. 4). However, the bituminous emulsions 7 and 22, which reduced evaporation by about 34 and 32%, respectively, are considered better than bituminous emulsion 7a. This conclusion is based upon the concentrations and applied rates (1500 l/ha for 7a and 750 l/ha for the other 2 types).

The recommended bituminous emulsion for the loamy sand soil is 7x2, as the reduction of evaporation reached 70%. The concentration and rate of application for such products are 25% and 1500 l/ha, respectively. It can be foreseen that, if such application method will be used for Bituplant 22, the results might be better than those of 7x2.

The results concerning Bituplant 22 and Sarea Evaporation Inhibitor were taken from another test series dealing with the inhibition of evaporation and are presented in table 5. Evaporation data are given after a test period of 7 days (Bituplant 22) and of 6 days (Sarea Evaporation Inhibitor).

In each of the trials evaporation from the treated vessels was less than from the control vessels. But the effectiveness of the products was different. Films are built when at the very moment of breaking single particles of sand and loess are compacted after the product was atomized. Thus, the surface pores are sealed off and evaporation is inhibited. This procedure, however, will differ with the various emulsions. Sometimes, there will not be built any film, because the emulsions ooze away, sometimes the capillary pores will be sealed off at such an extent that evaporation will be considerably reduced.

As shown in table 5, the required standards are met by Bituplant 22, by which evaporation is reduced up to 60%. If capillary saturation occurred, evaporation was not inhibited by Sarea Evaporation Inhibitor. However, if the product had been applied to the dry soil surface and water was added afterwards, evaporation was reduced by more than 50%, as shown in table 5. But it has to be mentioned that, due to the hydrophobe properties of Sarea Evaporation Inhibitor, infiltration was impeded considerably.

It may be assumed that the product was translocated by infiltrating water into the pores, which therefore got sealed off.

Table 5

Evaporation reduced by soil conditioners applied to sand and loess, compared to untreated control (arithmetic mean, measuring repeated 3 times)

Variant	Evaporation in mm control	Evaporation in mm substrate	% of control
Sand			
Bituplant 22,25 %, 1500 l/ha	21,7	8,9**	41,0
Sarea Evap. Inh. 75 l/ha	14,7	7,5**	51,0
Loess			
Bituplant 22,25 %, 1500 l/ha	21,1	12,7**	60,2

** Significance: $P \leq 1$ %

3.2.2 Soil moisture contents and film quality

The results obtained from sandy soil, used for tests, whether a 25% 7-cationic bituminous emulsion should be sprayed on wet or dry soil, reveal that 750 l/ha should be applied to wet soil. Total evaporation from wet and dry sand was 22,71 and 26,68 for 10 days. Therefore, percent reduction of evaporation amounted to 48 and 39, respectively. This result indicates that the bituminous film is somewhat homogeneous and of good spreading potentiality on the wet sand surface.

In conclusion, the characters of soil conditioners should be fully understood. Their formation of films coating the surface soil particles, must involve partial sealing of macropores. This process may be aided by a moderate elasticity of the films. Such films should be anchored beneath the surface soil particles, yet its penetration depth should not be large. The thickness of the conditioner film layer and the degree of sealing off the soil macropores depend on the initial soil moisture content, on the type of material and its rate of application. Sarea Evaporation Inhibitor is suggested to be added to dry soil at a rate of 75 l/ha in 15.000 l of water. Bituplant bituminous emulsions, particulary nr. 22, are recommended to be applied at a rate of 1500 l/ha at a concentration of 25%. Furthermore, the distribution of soil porosity must be considered, in order to understand how soil conditioners should be handled.

Summary

By green-house trials optimal dosages were determined, as 1000 to 3000 l/ha (1500 l/ha, 25%) for Bituplant 22, 100 kg/ha for Sarea Soil Stabilizer and 75 l/ha for Sarea Evaporation Inhibitor. Spraying became much easier and better efficiency was reached, if the products were combined in a tank mixture.

By the use of soil stabilizers not only wind erosion was prevented, but also soil puddling and soil crusting, which meant better penetration of water into the soil. In phytotron trials evaporation was reduced up to 60% by Bituplant 22, and more than 50% by Sarea Evaporation Inhibitor. Product finding has become easier, and specific field trials will be made possible by tests in the green-house and in the phytotron.

Möglichkeiten zur Verhinderung der Bodenerosion und Verbesserung der Pflanzenproduktion in ariden Klimagebieten

2. Mitteilung: Untersuchungen von Bodenfestigern und Verdunstungshemmern im Vegetationshaus und Phytotron.

Zusammenfassung

In Vegetationsversuchen konnten die optimalen Aufwandmengen der Produkte ermittelt werden. Sie betragen für Bituplant 22 1.000 bis 3.000 l/ha (1.500 l/ha, 25%), für Sarea Bodenfestiger 100 kg/ha und für Sarea Verdunstungshemmer 75 l/ha. Tankmischungen zwischen den Produkten verbessern die Verspritzbarkeit und erhöhen die Wirkung. Die bodenstabilisierenden Produkte verhindern nicht nur die Winderosion, sondern setzen auch die Verschlämmung und Verkrustung des Bodens herab. Dadurch kann Wasser besser in den Boden eindringen.

In Klimakammerversuchen zeigte Bituplant 22 eine Herabsetzung der Evaporation bis zu 60% und Sarea Verdunstungshemmer eine solche von mehr als 50%. Vegetationshaus- und Phytotronversuche erleichtern die Produktfindung und ermöglichen gezielte Freilandversuche.

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Anschrift der Verfasser:

Univ.Prof.Dipl.-Ing. Dr. Hans NEURURER, Universität für Bodenkultur, Institut für Pflanzenschutz, Peter-Jordan-Straße 82, A-1180 Wien, Prof. Ali GENEAD, Soils And Water Department, Suez-Canal-University, Ismaelia, Ägypten und Dipl.-Ing. Walter STEINMAYR, Fa. Sarea Ges.m.b.H., Franckstraße 2, A-4020 Linz