(From the Suez-Canal-University in Ismaelia, the Justus-Liebig-University in Gießen and the University of Agriculture in Vienna)

Potentiality for soil erosion control and improving plant production in arid zones*

5th Communication: Field trials for increasing water efficiency by soil improving agents

By A. GENEAD, H. G. FREDE, D. LÜTKEMÖLLER, H. NEURURER and W. STEINMAYR

(With 6 figures)

Summary

Investigations in the field have been carried out in order to examine the water retention effect of different soil conditioners. Preceding extensive laboratory experiments were necessary by which the evaporation-inhibitory effect of several bituminous emulsions and synthetic polymeres has been proved. The trial site was an irrigation-perimeter (Center-Pivot) on light sandy soil west of Ismaelia in North-Egypt.

Potatoes were cultivated as test crop. The trials were carried out with normal and reduced irrigation.

The results can be summarized as follows:

1. The reduction of irrigation leads throughout to lower water contents in the root-zone, where the water contents of the variants with improving agents were higher than without them.
2. Yield is reduced by lower water-supply, but it was higher when the improving agents were applied, even at a reduced water amount.
3. The economy of the applied water, determined as "water use efficiency", is basically higher at reduced irrigation than at normal irrigation. By application of the soil improving agents it will be increased additionally.
4. The optimal amount of the irrigation depends on the fact whether water is a limited production factor or not.

Key-words: Field trials, soil improving, erosion control, water increasing.

* This project has been financed by Shell International and CMB-Cairo (Chemicals for Modern Building). By these companies the Bituplant products will be commercialized.

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

5. Mitteilung: Feldversuche zur Erhöhung der Wassereffizienz durch Bodenverbesserungsmittel

Zusammenfassung

Es wurden Freilanduntersuchungen mit dem Ziel durchgeführt, die wassersparende Wirkung verschiedener Bodenverbesserungsmittel zu testen. Diesen Freilanduntersuchungen waren umfangreiche Laborexperimente vorangegangen, in denen die evaporationshemmende Wirkung verschiedener Bitumenemulsionen und synthetischer Polymere nachgewiesen worden war. Versuchsstandort war ein Beregnungsperimeter (Center-Pivot) auf einem leichten Sandboden westlich von Ismaelia in Nordägypten. Versuchskultur war die Kartoffel. Die Versuche wurden mit praxisüblicher und reduzierter Bewässerungsmenge durchgeführt.

Die Ergebnisse lassen sich wie folgt zusammenfassen:

1. Die Reduzierung der Wassermenge führt zu durchgehend geringeren Wassergehalten in der Wurzelzone, wobei die Wassergehalte bei Anwendung der Verbesserungsmittel höher waren als ohne.
2. Der Ertrag wird durch ein verringertes Wasserangebot reduziert, bei Anwendung der Bodenverbesserungsmittel jedoch auch bei reduzierter Wassermenge angehoben. Die einzelnen Mittel wirken unterschiedlich.
3. Die Wirtschaftlichkeit des eingesetzten Wassers, bestimmt als water-use-efficiency, ist bei reduzierter Bewässerungsmenge grundsätzlich höher als bei praxisüblicher. Sie wird durch den Einsatz der Bodenverbesserungsmittel nochmals erhöht.
4. Die optimale Höhe der einzusetzenden Wassermenge wird davon bestimmt, ob Wasser zu den knappen Produktionsfaktoren zählt oder nicht.

Schlüsselworte: Feldversuche, Bodenverbesserungsmittel, Bodenerosion, Wassereinsparung.

1. Problem

The importance of different polymeres and bituminous emulsions, as soil conditioners, especially in arid regions, has increased in the last years (VERPLANCK et al. 1990, TAYEL and MATYN 1990). In laboratory tests and guiding field trials it has been proved that by using soil conditioners based on ureapoly-condensate- and polydimethyl-siloxane as well as bituminous emulsions considerable improvements of the stability of the soil structure can be achieved, and danger of wind- and water erosion is reduced clearly (NEURURER et al. 1991 a, 1991 b, 1991 c). Due to the dark colour of the soil surface after the application of bituminous emulsions, the soil temperature is additionally influenced and therefore the possibility is given to place the vegetation period on an earlier date, within reasonable limits.

An important effect of the soil-improving agents tested by NEURURER et al. 1991 a, 1991 b and 1991 c, is the reduction of the unproductive part of the total evaporation. Trials under controlled climatic conditions in the phytotron revealed, that after spraying a suitable bituminous emulsion on the soil surface the evaporation could be reduced by more than 50 %. This indicates the importance of soil improving agents in those regions, where water is a limited and therefore expensive production factor. The present investigations were carried

out in order to verify the water-saving-effects obtained in the laboratory and under practical conditions in the field. A large-scale trial was realized in the north-west of Egypt.

2. Material and methods

The trials were carried out in Salhea, about 30 km west of Ismaelia. Irrigation was done by Center-Pivot sprinklers. The test plots were arranged under a sprinkler (fig. 1 and 2).

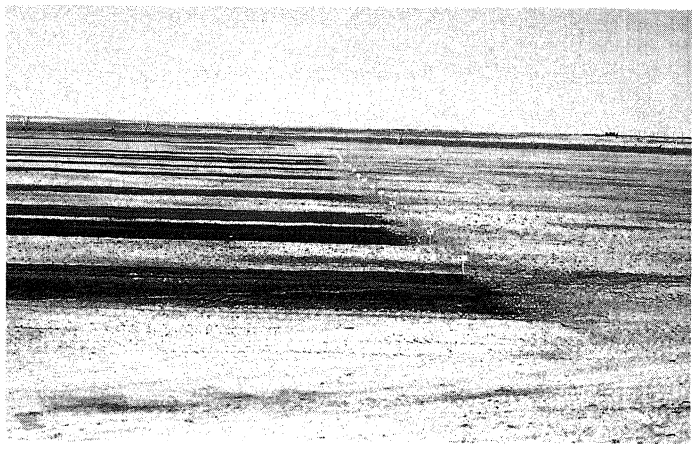

Fig. 1: Laying-out of the potato-trial under Center-Pivot sprinkler

Fig. 2: Potatoes in the middle of growing season.

The coarse-sandy soil of the test area (table 1) in Salhea is representative for the soils in this region. It is characterised by the low contents of silt and clay and the low CEC-values.

The unfavourable distribution of particle size with a clear maximum in the coarse-sand fraction causes the low amount of plant-available water of about 12 vol.% (0.1—15 bar). Due to this low storage capacity irrigation in very short intervals is necessary.

The trial was layed out at the beginning of October 1990.

Harvest was done 118 days after sowing, and irrigation was stopped 8 days

before harvest. The trial was carried out with three replications and a plot size of 9 × 131 m each. From the single plots 9 × 111 m were intended for harvest-determination and strips of 10 m width for water-content determination.

Table 1

Distribution of particle-size and water-content suction-force relation of the trial site

Depth	particle size distribution in % 2000—200	200—63	63—2	<2 µm	pH
10—20 cm	60.5	26.4	9.8	3.3	7.9
20—40 cm	65.3	16.2	12.2	6.3	7.9
40—60 cm	79.7	6.8	1.6	11.9	8.6

Depth	water content at matrix-suction head 0.05	0.1	0.3	0.6	1.0	15 bar
0—20 cm	17.5	15.0	13.0	3.0	7.3	3.1 vol.%
20—40 cm	16.3	15.3	13.3	7.7	6.5	3.0 vol.%

After the potatoes had been planted, the soil conditioners were sprayed in the following quantities (origin and composition of the products and application technique are described by NEURURER et al. 1991 a respectively 1991 c):

1. untreated
2. 1 500 kg/ha Bituplant
3. 1 000 kg/ha Bituplant + 30 kg/ha Sarea Evaporation Inhibitor
4. 150 kg/ha Sarea Soil Stabilizer + 80 kg/ha Sarea Evaporation Inhibitor

Irrigation was in two variants:

1. normal irrigation = 389 mm total amount = 100 %
2. reduced irrigation = 239 mm total amount = 61 %.

The amount of normal irrigation depended on the potential evapotranspiration under consideration of the necessary leaching quantity, the amount of the reduced irrigation was chosen assuming that the particular soil improving agent would bring the expected saving effect concerning evaporation. Therefore irrigation was reduced by about 40 % in comparison to the control.

3. Results and discussion

The field trials should reveal, whether a reduction of the water-consumption and a higher efficiency of the applied water can be reached by the applied soil improving agents.

The volumetric water-contents during the vegetation period (fig. 3) indicate that the water supply for potatoes was different in the variants but a typical water-stress could not be noticed. In all variants the water contents ranged between 11 and 20 vol.%. Compared with the water-content suction-head relation, matric-suctions of less than 0.6 bar can be derived for the whole time of the trial. That means that potatoes disposed of easy plant-available water during the whole vegetation period. In all variants the water contents of reduced irrigation lay below the contents of normal irrigation. A comparison of the different soil improving agents showed, that the water contents in the variants Bituplant and Bituplant + Sarea Evaporation Inhibitor were higher than in the other variants.

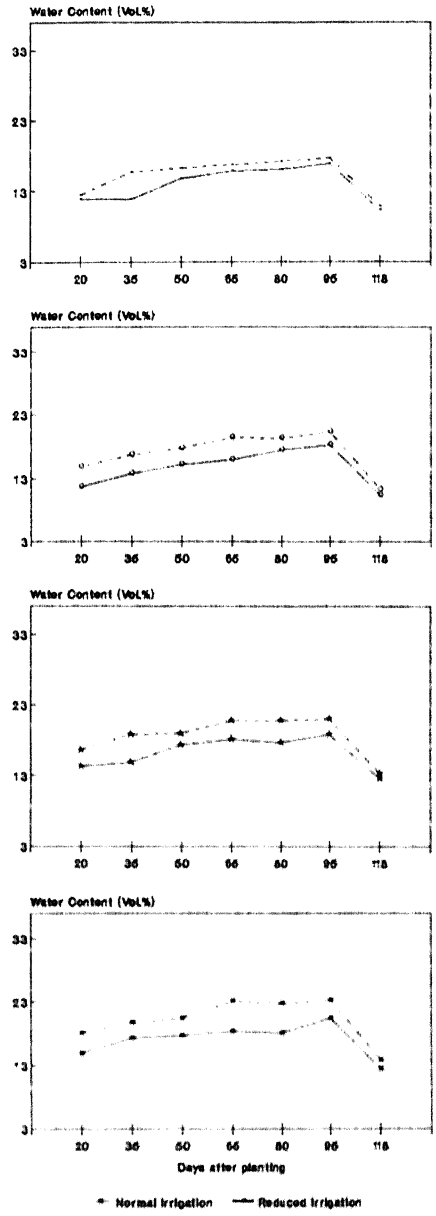

Fig. 3: Water contents during growing season under potatoes with different irrigation and mulch treatments (depth = 20 cm)

Control without Mulch Treatment

Sarea Soil Stabilizer+
Sarea Evaporation Inhibitor

Bituplant

Bituplant+
Sarea Evaporation Inhibitor

Table 2 shows the yield development of potatoes depending on the irrigation amount and the applied soil improving agents at three times.

The yield determinations referring to the single plant have shown that the fresh mass yield at normal irrigation was basically higher than at reduced irrigation. This statement can be made for all variants. All soil improving agents brought yield increases in comparison to the control (fig. 4). Also by reduced irrigation and by use of soil improving agents the yields are higher than without using soil improving agents and normal irrigation. The highest total yield is

Table 2

Development of tuber fresh weights during growing season for different treatments

Treatments	irrigation	Tuber fresh weight/plant (g) after 50	80	118 days
Control	normal	127	646	900
	reduced	117	406	779
Sa. Soil-Stab.	normal	147	857	1451
+ Sa.-Ret.-Prod.	reduced	140	633	956
Bituplant	normal	200	1056	1751
	reduced	173	818	1244
Bituplant	normal	244	1093	1818
+ Sa.-Ret.-Prod.	reduced	191	905	1300

reached with Bituplant + Sarea Evaporation Inhibitor, equally the highest yield-difference between normal and reduced irrigation. It can be noticed, that the differences between the yields at normal and reduced irrigation were very high only at the end of the vegetations period. As the water contents between the variants showed no significant differences, it has to be assumed that the differences have been achieved by different distribution of the total evaporation. It is supposed that by application of soil improving agents there is more transpiration and without them more evaporation from soil surface.

Figure 5 shows the potato yields at time of harvest in kg/ha. The shown tendencies for the single plants continued clearly. By application of soil improving agents basically higher yields can be achieved than without.

At normal irrigation there are statistically significant differences provable for all products in comparison to the control and within the products between Bituplant and Bituplant + Sarea Evaporation Inhibitor on one side, and Sarea Soil Stabilizer + Sarea Evaporation Inhibitor on the other side. At reduced irrigation the comparisons between the single variants and the control are statistically significant. A comparison of the products shows that only the differences between the variants Bituplant and Bituplant + Sarea Evaporation Inhibitor are significant. It is assumed that at reduced irrigation level the full efficiency of the products was not reached due to the limited amount of water.

While in the control and using Sarea Soil Stabilizer + Sarea Evaporation Inhib-

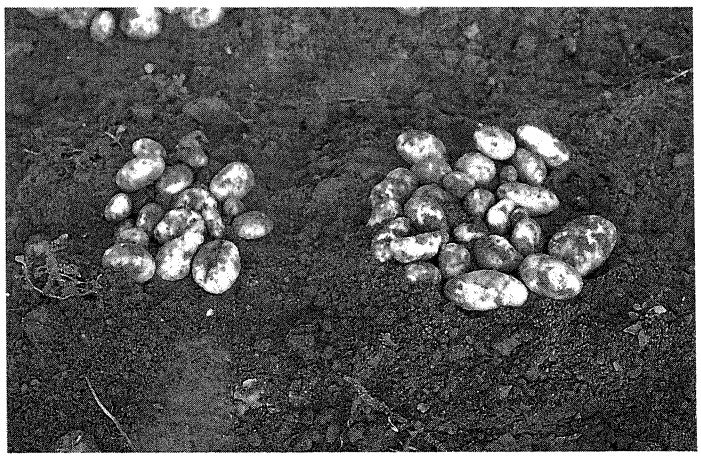

Fig. 4: Yield of tubers of two potato plants; left — untreated, right — treated

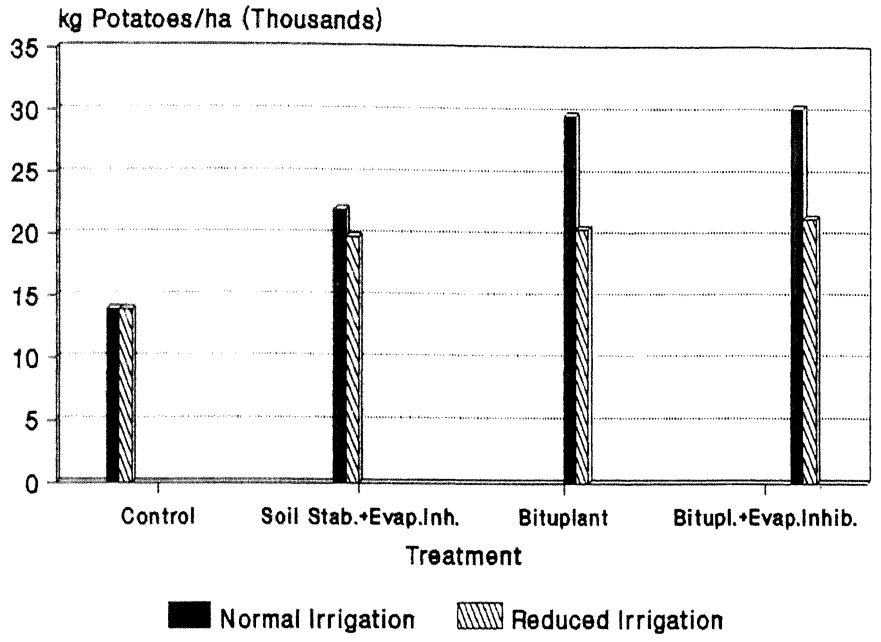

Fig. 5: Potato yield at two irrigation levels with different mulch treatment

itor no differences between reduced and normal irrigation are provable, these differences between Bituplant and Bituplant+Sarea Evaporation Inhibitor are sure. If total yield as single valuation factor is used for assessing the efficiency of the products, Bituplant and Bituplant+Sarea Evaporation Inhibitor can be evaluated equally.

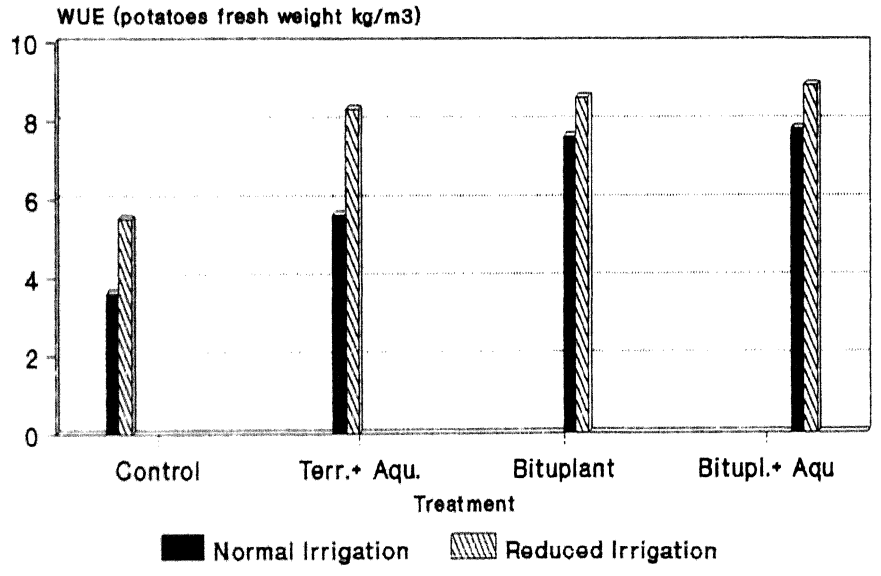

Fig. 6: Water Use Efficiency at two irrigation levels with different mulch treatment

This succession of the products and variants changes, when the applied water amount is estimated too. This is done by using the water use efficiency (WUE), the quotient out of the harvested fresh mass in kg and the water consumption in m^3 (fig. 6). Now all variants of reduced irrigation show higher values than the normally irrigated variants. These differences are statistically significant in the control and Sarea Soil Stabilizer + Sarea Evaporation Inhibitor, but not for Bituplant and Bituplant + Sarea Evaporation Inhibitor. In all three treatment variants reduced irrigation has an equally high WUE, the differences are not secured. At normal irrigation the WUE of Bituplant and Bituplant + Sarea Evaporation Inhibitor is still very high, but decreases in Sarea Soil Stabilizer + Sarea Evaporation Inhibitor and the control significantly.

Evaluation of the results has to be done under two different aspects: once under the aspect of yield and for the second under the aspect of economy of the applied water. If yield is of main interest, an optimal (normal) water supply should be aimed and the use of Bituplant or Bituplant + Sarea Evaporation Inhibitor is promising significant yield increase which will not be so high by the use of Sarea Soil Stabilizer and Sarea Evaporation Inhibitor.

If the applied water is a limiting production factor, weighting has to be as follows: Reduction of the water amount results in a significant higher economy for all three examined soil improving agents equally.

In order to achieve a combination of maximal yield and high economy for the applied water, this can be realized by a normal irrigation amount depending on the evaporation demand of the atmosphere in connection with the soil improving agents Bituplant or Bituplant + Sarea Evaporation Inhibitor.

Acknowledgement

We should like to thank very much the companies of Shell International, CMB — Cairo and Sarea-Nestlé for their continous support of the project.

References

NEURURER, H., A. GENEAD and W. STEINMAYR, 1991 a: Potentiality for soil erosion control and improving plant production in arid zones. 1st Communication: Laboratory and electron microscopic investigations of soil stabilizers and evaporation inhibitors. Die Bodenkultur *42*, 101—112.

NEURURER, H., A. GENEAD and W. STEINMAYR, 1991 b: Potentiality for soil erosion control and improving plant production in arid zones. 2nd Communication: Greenhouse and phytotron investigations of soil stabilizers and evaporation inhibitors. Die Bodenkultur *42*, 199—208.

NEURURER, H. and A. GENEAD, 1991 c: Potentiality for soil erosion control and improving plant production in arid zones. 3rd Communication: Technique of application of soil and evaporation inhibitors and investigations of the environmental behaviour of these substances. Die Bodenkultur *42*, 295—306.

TAYEL, M. Y. and M. A. MATYN, 1990: Effect of soil heaping and the location of bitumen mulch on groundnut growth. Soil Technology *3*, 173—182.

VERPLANCK, H., M. DE BODT and A. A. AL-JALOUD, 1990: Effect of synthetic polymers on water use efficiency for crop production on sandy soils in Saudi Arabia. Soil Technology *3*, 45—55.

(Manuskript eingelangt am 15. November 1991, angenommen am 2. Dezember 1991)

Anschrift der Verfasser:

Prof. Dr. Ali GENEAD, Suez Canal University, Soils and Water Department, Ismaelia, Ägypten; Prof. Dr. Hans-Georg FREDE und Dipl.-Ing. Dorothe LÜTKEMÖLLER, Institut für Landeskultur, Justus-Liebig-Universität, Gießen, Deutschland; Univ.-Prof. Dipl.-Ing. Dr. Hans NEURURER, Universität für Bodenkultur, Institut für Pflanzenschutz, Peter-Jordan-Straße 82, A-1180 Wien und Dipl.-Ing. Walter STEINMAYR, Fa. Sarea Ges. m. b. H., Franckstraße 2, A-4020 Linz