SOILS MODIFIED WITH POLYMER EMULSIONS AS SUBSTITUTES FOR POLYETHYLENE SHEET

By R. T. BISHOP*
Revertex (S.A.) (Pty) Limited

Abstract

Observed properties imparted to soils at economical levels by a wide range of different polymer emulsions are discussed. The results of pot experiments are summarised indicating how specifically treated sand can reduce soil moisture evaporation, increase temperatures in wet soils and reduce leaching losses of fertilizers. Early shoot counts from four separate replicated field experiments planted in autumn and winter with modified soil barriers at or below the soil surface showed that less than 25 kg of dry polymer per hectare increased the numbers of shoots by 268%, 47% and 39% in dry land conditions, and by 21% in irrigated cane when compared with the respective control plots.

Introduction

The possibility of using synthetic polymers as soil conditioners is not new. During the late 1940's and early 1950's structure stabilisation of soils had great appeal and at one time more than 100 widely different chemicals were commercially available. By the early 1960's most of these products had disappeared and published research papers decreased from 32 in 1954 to one in 1962.

In 1972 a symposium at Ghent[1] re-stimulated interest in this topic and 23 papers were presented, including two which summarised the reasons for the previous failure of polymers to find commercially useful applications. The failure was financial in that returns failed to justify expenditure, as was the case for using clear polythene film as a mulch in the South African sugar industry. Millard[3] and Rau and Millard[4] showed that a clear polyethylene sheet mulch over the rows of sugar cane planted under cool conditions gave earlier tillering and significant yield increases, as high as 25 ± 3,9 tons cane per hectare. Their conclusions were that the polyethylene mulch prevented moisture loss and increased soil temperatures. It was stated[4] that PE film could have a use in the sugar cane industry if and when the price of polyethylene became more competitive and that a liquid mulch applied as a spray would be ideal. These conclusions added impetus to the local programme of work then in progress on the use of polymer emulsions as soil conditioners.

Materials and methods

Experiment 1

After some preliminary laboratory tests, the value of a thin continuous film of a polymer emulsion as a substitute for clear polyethylene sheeting, was assessed in a randomized block experiment in the field on Natal Estates property. The trial was planted in mid-June, 1975, on a heavy alluvium soil. About 500 kg per hectare of 2% solids emulsion was mechanically foamed to a density of 500 g/litre and sprayed in a band about 20 cm wide over the cane row. As expected, the foam collapsed in about 30 minutes, but disappointingly did not form a continuous clear film on top of the soil, and it did not cause soil temperatures to rise. Other treatments comprised 50 tons of filter cake per hectare on the cane setts, a 5 cm depth of water applied in the furrow at planting, and a 5 cm depth of water applied over the row after planting. Shoot counts were taken 10 weeks after planting, and virtually no rain fell during that period. The trial was subsequently destroyed by fire and therefore no yield results were obtained.

Experiment 2

A number of water based polymer emulsions were selected for testing in the laboratory. These included polyvinyl acetate homopolymers (PVAc), vinyl acetate-2 ethylhexylacrylate copolymers (VAc-2EHA), vinylacetate-butylacrylate copolymers (VAc-BA), vinylacetate-vinyl ester of versatic acid copolymers (VAc-VeoVa), methylmethacrylate-2EHA copolymers (MMA-2EHA), MMA-BA copolymers, styrene-2EHA copolymers, styrene-butadiene carboxylated copolymers (SBR carb.), and styrene-butadiene uncarboxylated copolymers (SBR uncarb.). Briquettes were formed by oven-drying sand-polymer emulsion mixes. Tests included tensile strength, measured by means of a Richards Rupture Tester[5], and water uptake after immersion for four hours. Those emulsions which reduced water entry or imparted a "water holdout" effect were selected for further testing, and the lowest concentrations at which this effect took place were determined. The property of water repellency was assessed by forming depressions in the loose sand (aggregation did not occur at low concentrations) and adding 100 ml of water to give a head of about 25 mm (see Fig. 1). If the full effect was achieved the water remained on the surface and only disappeared after several days due to evaporation.

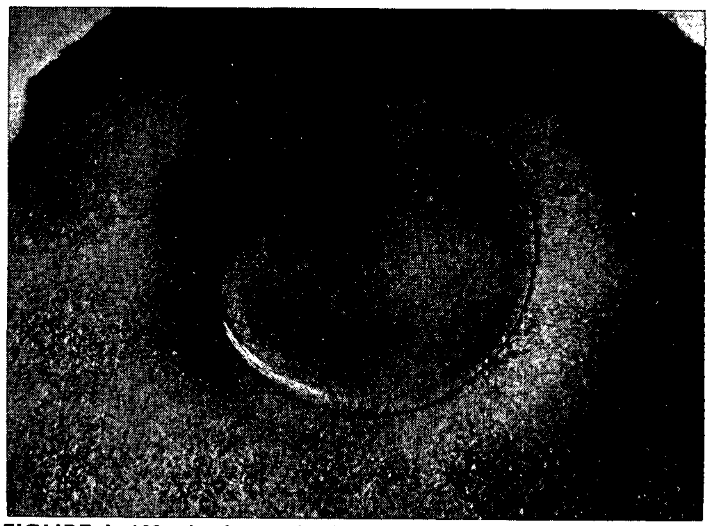

FIGURE 1 100 cc's of water held in a depression in loose single grained free flowing polymer treated sand.

Experiment 3

If water repellency is to be a useful characteristic, it must develop in soil as well as in sand. A styrene-2EHA surfactant stabilized copolymer containing 0,2% solids was used as the slurry medium on a marine sand, a Clansthal sand and a heavy black alluvium soil containing 40% clay. Water repellency of the treated soils were observed.

Experiment 4

It was of interest to determine whether or not a layer of water repellent soil had any effect on the movement of water vapour in a soil profile. An alluvium (41% clay), a Balmoral soil (15% clay), a Clansthal sand (7% clay) and a marine sand (0% clay) were used in this experiment. Six 200 g samples

* Postgraduate material for submission to the University of Natal, Department of Soil Science.

of each soil were placed in 280 ml plastic containers. On the surface of the soil in three out of each set of six pots was poured 10 ml of 1% surfactant stabilized styrene-acrylic emulsion, and 10 ml of water was added to the remaining three pots in each set. All cups were then weighed before placing them in a room where the temperature was controlled at 25°C and the relative humidity at 50%. The pots were weighed at regular intervals to determine evaporation losses. When constant weight was attained 30 ml of water was added to each pot and the drying procedure was repeated.

Experiment 5

To determine whether or not the effect of a water repellent layer of soil would affect plant growth, an experiment was conducted with maize growing in marine sand. Four pots were treated with the polymer as described for Experiment 4, and four pots were untreated controls.

Experiment 6

To study the effects of treatment with a polymer on soil temperature, four 5-litre containers were filled with Clansthal sand, and a thermometer was placed in each container so that its bulb was 20 mm below the surface of the soil. Surfactant stabilized styrene-2EHA copolymer containing 0,5% solids was dripped onto the surface of the soil in two containers until the soil was just completely wet. Equivalent amounts of water were added to the other two containers, and all four were left to dry in the sun for a week. One litre of water was poured onto the soil surface in each bucket, and temperatures were recorded daily at 9 a.m. to 3 p.m.

Experiment 7

The possibility that the property of water repellency could be used to advantage by effecting the slow release of fertilizer compounds in the soil was considered. It was decided to dissolve fertilizer material in a polymer emulsion to determine whether or not, when applied to the soil, the mixture would "protect" the fertilizer from rapid leaching. As an example of the technique used in this experiment, 3 g of urea and 3 g of potassium chloride were dissolved in 99 g of water, and then 1 g of a 50% solids surfactant-stabilized styrene-2EHA copolymer emulsion was added. Four ml of this solution were poured over the surface of 200 g of marine sand contained in each of three 280 ml plastic cups, whilst another three similar cups received the same treatment excluding the polymer emulsion. The cups full of soil were then dried, holes were pricked in the bases, and measured quantities of water were repeatedly used to leach through the soil. The electrical conductivities of the successive leachates were measured.

Experiment 8

The effects of the procedures followed in Experiment 7 on plant growth, were studied in a subsequent experiment. Eight five-litre pots with suitable drainage holes in their bases were filled with marine sand, and four maize seeds were planted in each pot. To four of the pots 5g of 3-2-1 (22) fertilizer mixture was added, and the remaining four pots received 5g of the same fertilizer dissolved in 150g of a 0,8% solids surfactant-stabilized styrene-2EHA copolymer emulsion. The sand was allowed to dry before watering commenced. At each watering, sufficient water was added so that some leachate was obtained. When the plants were sufficiently developed they were harvested, weighed, dried and analysed for N, P and K contents. Four more maize seeds were then planted in each pot and the above procedures were again followed. The process was repeated until five crops of young maize plants had been harvested. No additional fertilizer was added at any stage.

Experiment 9

It seemed possible that the property of water repellency which treatment with a copolymer imparted to a sand could be used to "deflect" water towards plant seeds and young root systems. To assess this possibility an experiment was conducted on a Clansthal sand at Mount Edgecombe in July 1975. Four replications of four treatments, each comprising 18 m of cane row, were laid down. One treatment (A) was a control and the others were :

B: furrows sprayed with 5 000 litres per hectare of a styrene-2EHA emulsion containing 0,4% solids two weeks prior to planting.

C: furrows sprayed with 5 000 litres per hectare of a styrene-2EHA emulsion containing 0,4% solids immediately before planting.

D: furrows lined with a 1 mm layer of pre-treated marine sand.

Treatment D is illustrated in Fig. 2. Stalk counts and height measurements were carried out both in the plant and first ratoon crops, and the plant cane yields were determined when the crop was 14 months old.

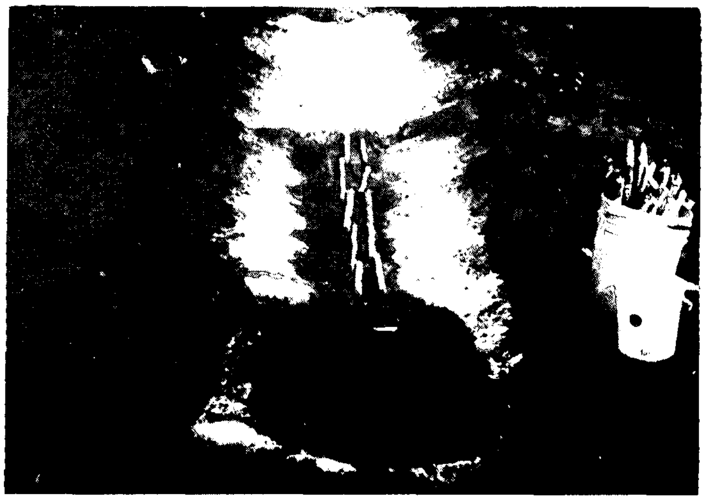

FIGURE 2 A wide, shallow furrow lined with pretreated water repellent marine sand to increase effective rainfall reaching the cane setts.

Experiment 10

The results of Experiment 9 were sufficiently encouraging that an advantage in addition to water "deflection" might be postulated. A further experiment, comprising five replications of a randomized block design, was therefore laid down at Mount Edgecombe in May, 1976, following good rains a few days previously. The treatments were :

A: Control.

B: 4,4 tons/ha of styrene-2EHA, containing 0,75% solids, sprayed in a band 30 cm wide over the cane row, and lightly compacted.

C: 3,5 tons/ha of styrene-2EHA, containing 0,75% solids, sprayed over the complete plot without any compaction.

D: 4,4 tons/ha of styrene-2EHA, containing 0,75% solids, sprayed in the furrow before planting, compacted and planted while wet.

All treatments were shallow-planted with a view to obtaining increased soil temperature and reduced soil moisture loss. Urea and muriate of potash were applied at a rate of 150 kg/ha each in the furrow, and Temik at 20 kg/ha was applied later. Several weeks of dry weather followed planting and eventually the plots were irrigated. Shoot counts and height measurements were taken.

Experiment 11

Five replications of a randomized block design were planted with sugarcane on an Oakleaf sand under overhead irrigation in June, 1976, at Glendale to determine whether or not several treatments could profitably be carried out at the time of planting. The treatments were:

A: Normal planting. Six litres of 2,4-D per hectare on the row only. Top dressing with 300 kg urea and 250 kg muriate of potash per hectare three months after planting.

B: A mixture of 62 kg styrene-2EHA polymer containing 50% solids and six litres of 2,4-D in 4 000 litres of water per hectare sprayed in a band 20 cm wide over the cane row after planting. Top dressing as in A.

C: A mixture of 300 kg urea and 250 kg muriate of potash dissolved in 2 600 litres of water, combined with 62 kg of polymer emulsion, watered in a narrow band over the cane setts at planting. Herbicide treatment as in A.

D: The same treatment as C, but application made three months after planting.

E: A mixture of 300 kg urea, 250 kg muriate of potash, 6 litres of 2,4-D and 62 kg of polymer diluted to 4 000 litres with water, applied per hectare in a band 20 cm wide over the cane row after planting.

Irrigation was started one week after planting. Shoot counts, height measurements and leaf samples were taken at intervals.

Results and discussion

The results of Experiment 1 are shown in Table 1. Although the filter cake treatment gave the highest shoot counts, the polymer treatment was encouragingly better than control.

TABLE 1

Sugar cane shoot counts taken ten weeks after planting Experiment 1 in winter on an alluvium soil at Natal Estates

Treatments	Shoot counts/ hectare x 10^3				Means
	Replications				
	1	2	3	4	
A. Standard planting	39	18	17	3	19
B. Filter cake 50 tons/hectare	77	60	63	60	65
C. Polymer foam at 10 kilograms dry polymer/hectare	61	72	27	44	51
D. 5 cm water over row after planting	25	37	24	14	25
E. 5 cm water in furrow at planting	59	60	13	44	44
C of V %	28,8				
LSD 5%	12				
1%	17				

In Experiment 2 widely differing results were obtained for the different types of emulsions. For example, sand aggregated with polyvinylalcohol stabilised PVAc homopolymers had tensile strengths of 2 000 millibars and absorbed as much as 30% water, whereas a surfactant stabilised SBR carboxylated copolymer emulsion imparted zero tensile strength and took up much less water (16%). Generally, homopolymers free of surfactants gave good sand aggregation but poor water repellency, whereas briquettes formed from surfactant-stabilised copolymers had the opposite properties. These observations tend to confirm the work of Rigole and De Bisschop[6], who suggested that the surface tension of the emulsion engenders the ability to form "wedges" between sand grains. However, the results of Experiment 2 indicate that type of stabiliser rather than surface tension seems to be important, and a single emulsion was produced which matched the aggregating power and the water repellency of the best single emulsions. The lowest concentrations of copolymer at which different emulsions could cause water repellency in a sand were investigated. As the amounts were reduced, the treated sand no longer formed aggregates, but dried out as a free flowing single grained material which surprisingly still possessed the water repellent characteristics. While a number of emulsions imparted absolute water repellency at 0,019% dry polymer on sand (added as 0,1% solids emulsions), at 0,009% polymer on sand only three of the treated sand samples held water for more than 30 minutes and only one of these successfully passed a seven-day test. The three promising samples were characterised as having low average polymer particle sizes (less an 0,5 micron). From surface area considerations it seems safe to assume that if a polymer emulsion exhibits the ability to impart water repellency to sand then the smaller the particle size, the more efficiently will it be able to coat the whole sand grain. It would appear that unless the sand grains are completely coated then the water repellency is not permanent. That the repellent effect is one of surface tension is easily demonstrated by adding surfactant to the water which immediately causes it to penetrate the sand.

The test with soils in Experiment 3 showed that, after drying and gently crushing to remove aggregation the Clansthal soil showed excellent water repellency, but only held out water for approximately 15 minutes. The heavy black soil showed no sign of water repellency. However, after increasing the concentration of the slurry medium to 1,0% solids followed by drying and crushing the black soil then showed excellent water repellency, but also for only approximately 15 minutes. Concentrations of polymer at 2,0% and 5,0% were then tried with no improvement over the 1,0%. It was concluded that while the water repellency effect can be imparted to all soils, the ability to give absolute water holdout is limited to sands devoid of clay. It is presumed that the clay fractions absorb water and swell, thus disturbing the packing and allowing the water to gradually channel through.

The evaporation test in Experiment 4 indicated that there were no differences in the rates of evaporation of the original 10 g of liquid added to the four soil types. However, even at the first readings, taken 24 hours after the first 30 g of water were added, marked reductions in evaporation losses were noted in those soils having received polymer. At 96 hours the percentages of this water remaining in the treated and untreated soils were respectively for the alluvium 63% and 18%, the Balmoral clay 74% and 9%, the Clansthal sand 60% and 8% and the marine sand 40% and 5%.

In Experiment 5 the four replications of pots with a polymer emulsion treated sand sprinkled onto the surfaces yielded 38% more dry matter in the young maize plants than did the controls which received the same amount of water.

Although no temperature differences were noted in Experiment 6 at 9 a.m. each day, at 3 p.m. on sunny days the temperature in the control pots was 28°C, and in the pots with polymer modified soil on the surface it was 32°C. When the pots had dried out completely no differences were recorded at either time. The magnitude of this difference is considerably less than the 9°C advantage reported by Millard[3] at 4 cm depth beneath a clear polyethylene sheet. This ability of the modified soil layer to "switch off" the heating effect when surface soil moisture becomes limiting could be an advantage over polyethylene sheeting.

The concentrations of salts in the initial leachates in Experiment 7 were significantly less from the fertilizer treatments containing polymer than from the controls. For example, after three leachings the total amount of salts removed from the polymer-containing fertilizer was only 49% of the amount from the controls. After the fourth leaching the conductivity readings for the control treatment was virtually nil, whereas in the polymer-containing treatments this point was only reached after 14 leachings.

The advantage of this nutrient retention to crops was illustrated in Experiment 8, where the young maize plant yields were greater in the polymer emulsion treatments than those in the control treatment in four of the five croppings, while the N and K contents for every crop were consistently better. The final total improved recovery of added fertilizer compared with control was 32% N, 20% P and 29% K.

The results from the field trial at Mount Edgecombe (Experiment 9) are shown in Table 2. The data from a single line trial can only be interpreted tentatively, but the early shoot and height measurements are considered to be meaningful because at that stage the edge effects must have been minimal. From the time of the earliest shoot counts the polymer emulsion treated plots showed marked increases in numbers over the control plots. Not only were there more shoots, but they were also consistently taller, and although only one treatment gave a statistically significantly higher yield at the 5% level, the results indicate that the treatment could be commercially remunerative. Furthermore, the improvement in plant crop performance with the emulsified polymer seems to be carrying through to the first ratoon, but as was the case with the polyethylene sheet work[4], this effect may disappear before harvest.

Experiment 10 has yet to be harvested but the shoot counts and height measurements obtained so far are given in Table 3. In contrast with the previous two field experiments, the polymer treatments here showed little increase in tillering rate in the first three months. However, in the fourth month, September, soon after the first spring rains had fallen, a significant increase in the number of shoots in the row-only treatment occurred. At a later stage this also happened in the complete-cover polymer treatment plots. Since Rau and Millard[4] obtained poorer earlier tillering in sandy soils due, they concluded, to poorer heat transfer than occurred in heavy soils, it may be that the polymerised emulsion can be more effective than a polyethylene sheet mulch. This could be due to better heat transfer as the insulating layer is an integral part of the soil profile. Again in accordance with earlier findings[4], where earlier tillering occurred in treated plots, the superiority in number of shoots was almost lost by January, but at this time there were still significant height advantages of some 10% over control. It can be assumed that, as with polyethylene sheet, the advantages over the control treatment will gradually disappear with age, but economic returns could be realized if the crop is harvested at about 14 months of age.

It can probably be safely concluded that the polymer in the interrows is having little effect since the responses in the row only treatments are of the same magnitude. With row widths of 1,36 m this implies that 7,3 kg of dry polymer per hectare is sufficient. The one aspect of these results which is difficult to explain is why the infurrow treatment, unlike that in the previous trial on the same site, is worse than control. The main differences between the treatments here and the wet treatments used in the previous trial were that firstly, the wet treated soil was compacted, and secondly, this was a May plant as opposed to an August plant. These two factors could have resulted in a hard impervious layer forming under the setts in the prolonged dry spell after planting, and could hardly have been conducive to root development or penetration.

TABLE 2

Shoot counts, height measurements and final cane yield of sugar cane in Experiment 9

Treatments	PLANT CROP									
	Mean Shoot Counts x 10^3 per hectare				Yield	Mean Stalk Heights in mm				
	11/9 1975	11/11 1975	17/12 1975	25/2 1976	Harvest weights 19/9/1976 tons/hectare	11/9 1975	11/11 1975	17/12 1975	25/2 1976	Sticks at Harvest 19/9/1976 mm
A. Normal Planting	22	48	153	137	60,2	—	140	189	586	1 450
% of Control	100	100	100	100	100		100	100	100	100
B. Furrows sprayed with 0,4% solids emulsion and air dried for 2 weeks	30*	59**	194	202	75,2*	—	161**	232**	682*	1 738
% of Control	137	123	127	147	125		115	123	116	120
C. Furrows sprayed with 0,4% solids emulsion and planted immediately	26	66**	204	171	71,5	—	147	216**	703**	1 602
% of Control	118	138	134	125	119		105	114	120	111
D. Furrows lined with pre-treated marine sand	33**	59**	192	172	69,7	—	159**	221**	664*	1 661
% of Control	149	123	126	126	116		114	117	113	115
C of V%	25	11	30	34	17		8	7	11	On Composite Samples
LSD 5%	7	7	59	62	14,6		13	16	75	
1%	10	10	82	85	20,2		18	22	103	
First Ratoon										
	7/10 1976	14/12 1976	7/2 1977			7/10 1976	14/12 1976	7/2 1977		
A.	82	258	182			—	249	845		
% of Control	100	100	100				100	100		
B.	115**	308**	203			—	277	900*		
% of Control	140	119	112				111	107		
C.	104*	300*	216			—	269	942**		
% of Control	127	116	119				108	112		
D.	103*	300*	204			—	277	923**		
% of Control	125	116	112				111	109		
C of V%	17,4	10,6	22,3				10,5	5,6		
5%	19	32	48				29	53		
1%	25	44	66				40	73		

The experiment designed to compare comprehensive treatments at Glendale (Experiment 11) has also yet to be harvested. The results to date have shown the following:

(i) As in all previous trials a wide band of dilute polymer emulsion resulted in a significant increase in shoot counts (21% more than control) from 3 months until the 6th month (December). This was most significant in Treatment E, indicating that the early application of fertilizer is beneficial.

(ii) Leaf analyses at 8 months showed no statistically significant differences between plots receiving N, K and polymer at planting and those receiving N and K at 3 months. The levels were 1,66% N and 1,59% K, but because there were no plots receiving N and K only at planting it cannot definitely be said that the polymer reduced losses by leaching.

(iii) No obvious differences between the efficiencies of the herbicide could be noted, however, subsequent inter-row treatment of weeds was still essential.

It would seem that the presence of polymer still holds promise in eliminating the need to topdress fertilizer at 3 months, but although earlier tillering, compaction over the row and reduced leaching losses or herbicide might reduce weed growth in the row, it does not eliminate the need for subsequent inter-row weeding.

General Discussion

Because soils treated with certain polymer emulsions lose less moisture due to evaporation than do untreated soils, and because the temperatures of wet treated soil increased relative to those in untreated soil, the mulching materials are of agricultural interest for crops which tiller under wet conditions when the temperatures are low.

The observed results are similar to those obtained by previous workers with clear polyethylene sheet mulch, and it therefore seems reasonable to assume that best yield results will be obtained on the heavier soil types when these are planted between April and September, or wherever cold wet soil conditions occur.

The additional possible benefits of polymer emulsions compared to polyethylene sheeting, such as not increasing temperatures in dry soils, increasing the efficiency of fertilizer and other water soluble materials, the easier penetration of shoots, and the faster and easier application of the materials should make them worth while investigating further. The possible advantage of increasing rainfall effectiveness by means of water repellent barriers which direct the precipitation towards the cane setts should not be ignored.

Regarding application in the field there seems no doubt that, because the whole process depends on wetting of the soil, the more liquid applied per hectare, the better the results will be. The carting of this water is an obvious disadavantage, but adequate wetting in a row-only treatment can be achieved with 1 000 litres per hectare of a 0,4% solids emulsion. Furthermore, work on the foaming technique, more efficient sprayers and different techniques of soil preparation may reduce the volumes of water required even further.

One aspect not yet studied is the effect of placing such barriers at depth in sand to reduce moisture losses through drainage. Such barriers would certainly be easier to place than the asphalt types previously described by Sumner and Gilfillan[7].

Conclusions

There are indications that polymer emulsions could be economically feasible for extensive agricultural applications. However, much work still needs to be done in the field. For example, the technique might be useful for ratoons cut in winter; it could be useful when planting at other times besides winter; the effect of soil type is likely to be important; the principles might apply to grain crops as well as sugarcane; and the slow release of fertilizer nutrients needs further investigation.

Acknowledgements

Company Directors and staff of Revertex (S.A.) (Pty) Limited; Dr. G. D. Thompson, Director of the S.A.S.A. Experiment Station and his staff; Professor M. E. Sumner, Department of Soil Science, Natal University; Mr. P. Bullock, General Manager of Glendale Sugar Company and Mr. S. Rau, Agronomist at Natal Estates.

REFERENCES:

1. Anon (1972) Proc Symposium of Fundamentals of Soil Conditioning — Ghent University. Volume 1.
2. Prasad, R., Rajale, G. B. and Lakhdive, B.A. (1973). Nitrification retarders and slow release nitrogen fertilizers. Indian Agricultural Research Institute Division of Agronomy, New Delhi, India.
3. Millard, E. W. (1974). Plastic mulching of sugar cane. SASTA Proc **48**, 53-57.
4. Rau, S. and Millard, E. W. (1975). Further studies on the use of a polyethylene mulch in the growing of sugar cane. SASTA Proc **49**, 182-186.
5. Richards, L. A. (1953). Modulus of rupture as an index of crusting of soils. Soil Science Soc Amer **17**, 321-322.
6. Rigole, W. and De Bisschop, F. (1972). The formation of adhesive links between granular particles by means of emulsions. Proc Symposium of the Fundamentals of Soil Conditioning — Ghent 939-954.
7. Sumner, M. E. and Gilfillan, E. C. (1971). Asphalt barriers to improve productivity of sandy soils — a preliminary assessment. SASTA Proc **45**, 165-168.

TABLE 3

Mean shoot counts and height measurements of shallow planted sugarcane with various anti-dehydration treatments in Experiment 10

Treatments	Shoot counts per hectare x 10^3						Height measurements (in mm)	
	1976					1977	1976	1977
	12/8	25/8	17/9	7/10	3/12	19/1	6/12	19/1
A. Control	34	39	60	94	242	198	371	889
% of Control	100	100	100	100	100	100	100	100
B. Surface row only polymer	31	37	73**	131**	282*	206	410*	968*
% of Control	91	95	122	139	117	104	111	109
C. Surface complete cover polymer	36	41	69*	131**	272	196	416**	979**
% of Control	106	105	115	139	112	99	112	110
D. Polymer in furrow at planting	33	38	60	103	216	181	356	851
% of Control	97	97	100	110	89	91	96	96
C of V%	14,1	12,0	13,4	14,8	16,5	11,8	9,2	7,4
LSD 5%	4	4	8	16	35	43	31	62
1%	5	5	11	22	47	58	42	84