SOIL MODIFICATION WITH COPOLYMER EMULSIONS

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Abstract

The application of a specific copolymer emulsion at a rate of 10 kg dry copolymer per hectare over the crop row had four different beneficial effects on sugarcane. These were better germination, earlier development, more stalks at harvest and greater cane yields. Although 5 kg dry copolymer per hectare significantly increased the number of shoots present three months after treatment, only at a rate of 10 kg did the beneficial effects persist to give statistically greater increases in cane yields at harvest. In addition to conserving soil moisture, the copolymer may also conserve water sensitive soil additives such as fertilizers and herbicides by reducing losses due to leaching.

Introduction

It has been shown (Bishop[1]) that surface sprays of polymer emulsions which impart a water repellent property to soils also have the effects of conserving soil moisture and raising wet soil temperatures. It was shown that 10 kg of dry copolymer per hectare applied in the planting furrow induced earlier tillering and produced an additional 15 tons of cane per hectare, or a 25% yield increase. These results were obtained from four replications of single lines in a field trial on a Clansthal sand (11% clay). Although Millard,[3] and Millard and Rau[4] previously showed clear polyethylene sheet mulches to give similar earlier tillering, and yield increases as high as 25 ± 3,9 tons cane per hectare on heavy soils, neither effect was obtained on sandy soils. Work was therefore continued using surface applications of a specially stabilized styrene-octyl acrylate copolymer emulsion (Reverseal 5), firstly to confirm the observed results on sandy soils; secondly, to assess the magnitude of the effects at several sites with different soils, climatic conditions and times of treatment; and thirdly, to investigate the effects of using different amounts and concentrations of copolymer on final cane and sugar yields.

While most benefit can be obtained by treating plant cane, since the higher population effects are carried over into subsequent ratoons (Bishop[1]), the possibility of improving ratoon crops was also investigated.

As the copolymer dispersion renders the surface film of soil hydrophobic, soluble N fertilizers and herbicides were included in the sprays to determine whether losses through leaching could be reduced.

Materials and methods

Experiment 1

The effects of different placements of the copolymer spray on earlier tillering, final stalk population, and cane and sugar yields on a Clansthal sand were assessed in a randomised block design field experiment with five replications. The earlier tillering in this experiment (39% more tillers in treated plots than in control plots when the crop was four months old), with the control treatment catching up by the ninth month, was reported previously (Bishop[1]). Planting was carried out in May 1976 following good rains and the treatments were:

A. Control
B. 4,4 tons of diluted emulsion (containing 0,75% solids or 33 kg dry copolymer per ha) per hectare sprayed in a band 30 cm wide over the cane row and the soil then lightly compacted (11 g dry/m^2 over row).
C. 3,5 tons of diluted emulsion (containing 0,75% solids or 26 kg dry copolymer per ha) per hectare sprayed over the complete plot without any soil compaction (3 g dry/m^2 overall).
D. 4,4 tons of diluted emulsion (containing 0,75% solids or 33 kg dry copolymer per ha) per hectare sprayed in the furrow and compacted before planting while wet (11 g dry/m^2 in furrow).

All treatments were shallow-planted with a view to obtaining higher soil temperatures around the setts. Nitrogen (90 kg N/ha), potassium (90 kg K/ha) and Temik (20 kg/ha) were applied in the normal way. Some three months of dry weather followed planting and eventually the plots were irrigated. Shoot counts and height measurements were made at regular intervals. At harvest cane yields, numbers and heights of stalks and estimated recoverable sugar (ers) contents were determined. The results are presented in Table 1.

Experiment 2

In a laboratory experiment (not reported here) in which pots were watered 21 days after planting, a significant increase in the germination rates of single eyed setts was recorded in soils which had received the copolymer mulch, compared to control treatments. An observational field trial to test the effectiveness of the copolymer surface mulch in improving germination of early planted cane was conducted at Sezela. In early August 1978 a two hectare block of newly planted cane on a soil of the Williamson series was sprayed with the copolymer emulsion containing 1% solids. The liquid was applied by means of knapsack sprayers in a 30 cm band over the planting row at a rate of 600 ℓ/ha (220 mℓ/m^2 over row). Four months after treatment the germination rates in the treated and untreated areas were compared visually, and by counting the number of shoots in eight randomly selected lines, each 25 m long.

Experiment 3

The effects of applying various amounts of carrier water with the copolymer emulsion on early development of the crop and final cane yields were assessed in a randomised block field experiment with four replications on a Shortlands series soil at Eston. Plots comprising six rows each 8 m long were marked out in a newly planted field of commercial cane and the treatments were applied on the 17 October 1977. All copolymer treatments were applied as a spray in a band 30 cm wide over the row. The concentrations and rates of copolymer applied are given in Table 2. Shoot counts were taken regularly and the number of stalks and cane yields at harvest were recorded. The results are presented in Table 2.

Experiment 4

To test the reproducibility of the beneficial effects of a treatment sprayed over the row, ten field trials were laid down on commercial plant cane. The sites differed in soil type, cane variety, altitude, climatic conditions and time of planting. The general procedure followed was to mark out eight plots, each comprising six rows 8 m long on newly planted cane. Four

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randomly selected plots received 2 000 ℓ of copolymer emulsion containing 0,5% solids per hectare (10 kg dry polymer per ha), sprayed from knapsacks in a band 30 cm wide over the row. The other four plots were left as controls. At one site, on a Clansthal sand at Umdloti, two blocks of eight rows each 35 metres long were sprayed with the copolymer emulsion at the same rates from a conventional herbicide applicator unit on a tractor. The rows in the itermediate blocks were sprayed with water to serve as controls. At regular intervals the shoot populations at all sites were recorded. Yield results were obtained at only four of the sites.

Experiment 5

To see if the beneficial effects of a copolymer mulch could be imparted to ratoon crops, an area made up of 16 rows each 25 m long in a six-week old third ratoon crop was pegged out on the 31/6/77. Two plots of four lines each were sprayed with 3 600 ℓ of the copolymer emulsion containing 0,5% solids per ha (18 kg dry polymer per ha or 6 g/m² over the row). The remaining two plots were left as controls. Shoot counts were taken immediately after treatment and at regular intervals thereafter to monitor changes in population.

Experiment 6

Because the mechanism of the copolymer mulch is to create a thin surface layer of hydrophobic soil particles, the possibility of incorporating soluble materials in the spray in order to restrict leaching losses, has been suggested previously (Bishop[1]). The rate of release can be accurately controlled by adding varying levels of any soluble salt (Bishop[2]).

To assess the effects of a copolymer mulch alone, and with different rates of N fertilizer dissolved in it, a field experiment with maize was conducted on an Avalon series soil at Dundee. Planting took place on 11 October 1977 after 1 000 kg of superphosphate (8,3% P) and 230 kg of KCl per ha were broadcast and disced into the soil. The variety of maize was Cedara No. 6144. Three rates of ammonium sulphate containing 21% N were top dressed over the rows of maize. The liquid treatments were sprayed in a band 30 cm wide over the rows. Details are given in Table 3. The ear leaf samples were

TABLE 1

Plant populations, height measurements and yield data for Experiment 1 (means of 5 replications)

Treatments	Shoot counts per hectare × 10³				Height measurements (in cm)		Yield		Yield
	1976		1977	At harvest	1977	At harvest	tons cane per ha	ers % cane	ters/ha
	17/9	7/10	19/1	14/9/77	19/1	14/9/77	14/9/77		
A. Control	60	94	198	116	89	190	95	14,9	14,2
% of Control	100%	100%	100%	100%	100%	100%	100%	100%	100%
B. Surface row only polymer	73†	131†	206	122	97*	193	107	15,3	16,5
% of Control	122%	139%	104%	105%	109%	102%	113%	103%	116%
C. Surface complete cover polymer	69*	131†	196	120	98†	190	99	15,1	15,1
% of Control	115%	139%	99%	104%	110%	100%	104%	101%	106%
D. Polymer in row at planting	60	103	181	114	85	192	95	14,9	14,2
% of Control	100%	110%	91%	98%	96%	101%	100%	100%	100%
C.V. (%)	13,4	14,8	11,8	5,8	7,4	5,0	11,2	2,9	12,5
5%	8	16	43	9	6	14,0	14,4	0,58	2,42
1%	11	22	58	12	8	20,0	19,7	0,79	3,30

* Statistically significant at the 5% level. † Statistically significant at the 1% level.

TABLE 2

Plant populations and yield data for Experiment 3 (means of 4 replications)

Treatments	Shoot counts × 10³/ha			Yield (tons cane/ha)
	14/12/77	27/1/78	8/12/78	8/12/78
A. Control	104	144	114	94,6
% of Control	100%	100%	100%	100%
B. 1 500 ℓ/ha at 0,5% solids (7,5 kg dry/ha)	103	176†	116	97,3
% of Control	99%	122%	102%	103%
C. 1 000 ℓ/ha at 0,5% solids (5,0 kg dry/ha)	108	178†	110	91,1
% of Control	104%	124%	97%	96%
D. 1 000 ℓ/ha at 0,75% solids (7,5 kg dry/ha)	103	156*	119	101,4
% of Control	99%	108%	104%	107%
E. 1 000 ℓ/ha at 1,0% solids (10 kg dry/ha)	121*	176†	127	107,5*
% of Control	116%	122%	111%	114%
F. 500 ℓ/ha at 1,0% solids (5 kg dry/ha)	112	172†	123	103,4
% of Control	108%	119%	108%	109%
G. 500 ℓ/ha at 2,0% solids (10 kg dry/ha)	109	186†	116	92,7
% of Control	105%	129%	102%	98%
C.V. (%)	15,6	6,8	9,3	7,8
5%	17	12	16	11,2
1%	24	16	22	15,2

* Statistically significant at the 5% level † Statistically significant at the 1% level

TABLE 3
Leaf N % values and maize yields in Experiment 6 (means of 3 replications)

Treatments	Leaf N%	Cob counts × 10^3/ha	Grain yields tons/ha at 12,5% H_2O	Cob + grain tons/ha	Stover yields tons/ha	Total plant yields tons/ha
				Not corrected for moisture contents		
A. *Control — split dressing*						
(i) 25 kg N/ha over row at plant + 25 kg N/ha at 6 weeks	2,66	58,0	6,987	8,396	7,976	16,372
(ii) 50 kg N/ha over row at plant + 50 kg N/ha at 6 weeks	2,79	61,4	7,831	9,530	8,507	18,037
(iii) 75 kg N/ha over row at plant + 75 kg N/ha at 6 weeks	2,90	61,7	7,652	9,298	8,630	17,928
B. *Liquid fertilizer — one application at planting*						
(i) 50 kg N/ha in 2 000 ℓ/ha of copolymer at 0,5% solids over row	2,40	57,6	6,738	8,180	7,280	15,460
(ii) 100 kg N/ha in 2 000 ℓ/ha of copolymer at 0,5% solids over row	2,76	63,8	7,614	9,203	7,270	16,483
(iii) 150 kg N/ha in 2 000 ℓ/ha of copolymer at 0,5% solids over row	3,18†	64,5*	8,081	9,587*	10,430	20,287
C. *Mulch — fertilizer split as in A*						
(i) 2 000 ℓ/ha of copolymer at 0,5% solids over row . . .	2,50	59,3	6,606	8,262	7,567	15,829
(ii) 2 000 ℓ/ha of copolymer at 0,5% solids over row . .	2,66	63,5	7,687	9,284	8,712	17,996
(iii) 2 000 ℓ/ha of copolymer at 0,5% solids over row . .	2,86	68,3†	8,166*	9,898*	10,061	19,959
C.V. (%)	8,63	6,3	9,4	8,9	22,5	14,3
LSD 5%	0,39	6,5	1,158	1,323	2,910	4,111
1%	0,52	8,6	1,544	1,764	4,151	5,480

TABLE 4
Mean ratings of different pre-emergent herbicide treatments in Experiment 8b

Treatments: Herbicides	Rates in ℓ or kg/ha	Ratings for 4 replications: 1	2	3	4	Means	Interpretation
A. Atrazine + water	3,25 + 336,75 . . .	6	8	8	3	6,25	Moderate effect
B. Atrazine + water + Reverseal 5	3,25 + 326,75 + 10 . .	5	2	5	2	3,50	Just acceptable
C. Eptam incorporated: Atrazine + water surface spray	4,00: 3,25 + 336,75 . .	2	6	2	2	3,00	Satisfactory
D. Eptam incorporated: Atrazine + water + Reverseal 5 surface spray	4,00: 3,25 + 326,75 + 10	1	1	1	1	1,00	Complete control
E. Gesagram + water	4,00 + 336,00 . . .	2	3	2	4	2,75	Satisfactory
F. Atrazine + Lasso + water	3,25 + 5,00 + 331,75 .	1	5	5	1	3,00	Satisfactory
G. Gardomil + water	3,50 + 336,50 . . .	7	9	9	9	8,50	Checked
H. Control	—	9	9	9	9	9,00	No effect

taken at tasseling for nutrient analysis. The cobs + grain and the whole plants were harvested and their mass determined on 16 May 1978. The ratio of grain mass to cob mass and the moisture content of the grain were determined from representative samples taken from each plot. The mass of dry grain was determined using the shelling factor, and then adjusted to 12,5% moisture.

Experiment 7

An experiment was conducted to test the effect of a copolymer mulch containing N fertilizer on the sucrose content of cane.

In December 1977, four 1,5 hectare randomly located blocks of newly planted cane received 2 000 ℓ/ha of water containing 10 kg of dry copolymer and 380 kg of sulphate of ammonia. Soil analyses indicated that the soil contained adequate P and K. The liquid was sprayed in bands 60 cm wide over the planting furrows. Application was made with a conventional spray unit on a tractor. Four other interspersed blocks of the same size were top dressed 8 weeks later with equivalent amounts of dry ammonium sulphate in the conventional manner and left as controls. The site was at Glendale and the soil was of the Shortlands series. The field was flat and the crop received regular supplementary irrigation from overhead sprinklers. A chemical cane ripener was applied at a rate of 0,4 kg acid equivalent per hectare over all blocks prior to harvest. Representative cane samples taken from each block at harvest (mid December 1978) were analysed in the local mill laboratory for sucrose and fibre contents and juice purity. The total yield from the eight blocks was 1 097 tons or 91,4 tons/ha.

Experiment 8

To test the effect of the copolymer emulsion on the length of effectiveness of herbicides, several field trials were laid down. Two of these are considered here.

8A This trial was conducted on a Milkwood series soil at Mount Edgecombe in early September 1978. The blend being applied commercially consisted of 2-4-D (3 ℓ/ha), paraquat (2 ℓ/ha) and Lasso (5 ℓ/ha) in 600 ℓ of water per ha. Two plots, each comprising six rows of newly planted cane, were sprayed with the herbicide mixture. The two remaining plots were sprayed with the same mixture, but the diluent was 600 ℓ of the copolymer emulsion containing 0,5% solids per ha.

The two treatments were applied simultaneously by knapsack sprayers, with the two operators walking at the same speed. The herbicides were sprayed as a full cover treatment.

8B In another trial four replications of a randomised block experiment were laid out on an Avalon series soil at Dundee on 7 November 1978. The plots comprised six lines of newly planted maize seeds, each 18 m long. The different herbicide treatments applied, as an overall spray from knapsack sprayers, are given in Table 4. Weed growth was assessed from time to time using the European Weed Research Council (EWRC) scoring system of 1 to 9, where 1 = complete control, 4 = just acceptable, 5 = just unacceptable and 9 = no effect. The results obtained on 26 February 1979 are recorded in Table 4.

Results and discussion

The results in Table 1 tend to confirm those previously reported by Bishop.[1] The effects due to the surface polymer treatments for the "row only" and for the "overall" polymer treatments respectively, were as follows:

(i) earlier tillering; 22% and 15% more shoots than control at three months of age (statistically significant)

(ii) more stalks at harvest; 5,1% or 6 000/ha and 3,5% or 4 000/ha more than control (not statistically significant)

(iii) greater cane yields; 12,6% or 12 tons/ha and 4,2% or 4 tons/ha more than control (not statistically significant)

(iv) more estimated recoverable sugar (ers) % cane; 2,7% and 1,3% more than control (not statistically significant).

When the treatment was applied over the row only, the increased yield in terms of tons ers/ha was almost significant at the 5% level. The larger responses to the treatment applied on the row only, relative to the overall spray, were not statistically significant, but could have been due to a greater amount of copolymer applied per unit area of soil over the crop row (Bishop[2]), and also to the destruction of the treated barrier by mechanical weeding in the interrows of the overall treatment.

The mean shoot counts in the plots treated with the copolymer mulch (203×10^3/ha) were 193% of those in control plots (105×10^3/ha) four months after treatment in Experiment 2. The control plots required extensive "gapping up" whereas the copolymer mulch plots did not.

The results of Experiment 3 given in Table 2 show that treatment with copolymer had little effect on most counts (except treatment E) after two months, but highly significant effects after 3½ months. By the time of harvest no statistically significant effects on population remained. The object of the experiment was to compare different volume rates of application, and the difference between the yields obtained following treatments E and G was statistically significant. Apparently 10 kg dry polymer applied in 1 000 ℓ of water per hectare was more effective than the same amount applied in 500 ℓ/ha. Higher volumes of water did not appear to enhance the effects of lesser amounts of polymer.

In Experiment 4 it was noted that at only one of the 10 sites did the copolymer treatment fail to induce earlier tillering. The reason for the one failure is not clear but low concentration of copolymer plus bad soil tilth may have been responsible. Although higher cane yields were obtained at three of the four sites harvested (2,5; 4,4 and 13,8 tons/ha), only at the site on a Williamson series soil were the increases in stalk populations (17 000/ha or 7%) and cane yields (13,8 tons or 15,0%) at the time of harvest statistically significant. It is possible that better yield responses would have been obtained had the copolymer been applied at higher concentrations.

Although spraying in Experiment 5 took place in late June when conditions were very dry, and although no rain fell subsequently, a highly statistically significant increase in the number of new shoots occurred within four weeks of treatment. In the six months following application the rate of new shoot development was 2,5 times faster in the treated rows than in the controls, giving rise to 62%, or 56×10^3, more shoots per hectare. In summer the same copolymer treatment when applied to a 12-week old ratoon crop, with 80×10^3 shoots per hectare, failed to increase the rate of new shoot development. Further field trials are obviously necessary to establish the real value of this treatment.

The grain yields obtained in Experiment 6 appear in Table 3, and show that only one treatment gave a statistically significant increase in yield when compared with 50 kg N/ha applied in two doses. This was the treatment with 2 000 ℓ of copolymer emulsion mulch per ha and 150 kg N/ha applied in two doses. A comparison of treatments A, B and C indicates that no statistically significant responses were obtained due to the copolymer mulch itself.

The levels of sucrose, purity and ers % in canes from those blocks of Experiment 7 which received the liquid N-copolymer mulch treatment at planting were all statistically higher (1% level) than those in canes from the control blocks. The relative concentrations in treated versus control canes were for sucrose, 14,8% versus 13,4%; purity, 85,6% versus 84,1% and ers % cane, 12,6% versus 11,4%. If all plots had yielded the average amount of 91,4 tons cane/ha this would represent 1,1 tons ers more per hectare due to treatment with copolymer and nitrogen. Further experimentation will be required to determine whether the increased sucrose yields were due to the moisture conserving or N conserving effects of the copolymer, or a combination of both; and also whether the role of the ripener was important.

The difference in weed control achieved by the two treatments applied in Experiment 8A, 10 weeks after application, is illustrated in Figure 1. The blocks treated with the standard herbicide application showed strong weed growth, once the expected period of control expired. Although the interrows of the whole experiment were accidentally mechanically weeded

FIGURE 1 Differences in weed control of a herbicide treatment alone (to the right of the marked post) and in combination with the copolymer emulsion (to the left of the marker).

12 weeks after treatment, the blocks which received the herbicide plus copolymer continued to exhibit good control of weeds in the rows until full canopy.

The assessments of weed growth in Experiment 8B some 16 weeks after the different herbicides were applied are presented in Table 4. The copolymer increased the effectiveness of those herbicides to which it was added. The absence of weeds from plots treated with Eptam + Atrazine + Reverseal confirmed the results of Experiment 8A. However, although several further field experiments showed similar beneficial effects to those described above, others failed to enhance the performance of the herbicides. When rainfall patterns were investigated it was found that the improved effect of the modified herbicides occurred when rainfall exceeded 300 mm in the 2 to 14 weeks following treatment, whereas those showing no improvements received less than 200 mm during a comparable period.

General discussion

A copolymer emulsion mulch can reduce evaporation from the soil. There is some evidence (Table 2) that the effect increases with the amount of copolymer applied, and amounts per hectare greater than those already tested may be warranted. If there were a carry-over effect of the higher stalk populations into the ratoon crops, the treatments would be more economically attractive. Factors, other than the rate of copolymer application, which affect the magnitude of the yield response, are the type of soil and the time of application. It would seem that soils with the higher moisture holding capacities would give the greatest yield increases per unit mass of copolymer applied. Although time of year is not critical for the earlier tillering effect to take place, the crop must be at a certain stage of development for it to occur.

Crops other than sugar cane will most likely benefit from the effects of reduced evaporation if economic considerations permit reasonable amounts to be applied.

In addition to conserving soil moisture, the copolymer emulsion can also conserve water soluble chemicals by reducing leaching losses. However, the rate of release is critical — it must be sufficiently slow to reduce leaching losses, but sufficiently fast to ensure optimum effectiveness. A concentration of soluble fertilizers greater than 30% is recommended for maize and sugarcane (Bishop[2]).

Conclusions

The results presented in this paper suggest that several beneficial effects are possible with a spray containing water, soluble fertilizers, herbicides and a copolymer emulsion. Either a single overall spray, with preferentially more liquid falling over the planting line could be applied, or alternatively, two blends from a compartmented tank could be sprayed with water, herbicide and copolymer being applied overall, and water, fertilizer and copolymer only over the row. The potential benefits could include:

(i) better germination and earlier tillering
(ii) greater plant yields
(iii) higher stalk sucrose content and juice purity
(iv) reduced number of weedings due to the longer-lasting effects of herbicides
(v) the need for only one application of fertilizer because of lower leaching losses
(vi) reduced fuel and labour costs
(vii) reduced wind and water erosion of soil.

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