

WEED CONTROL UNDER *HEVEA* IN CEYLON WITH HERBICIDE MIXTURES BASED ON MSMA

By

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SUMMARY

Results of seven experiments where the effects of MSMA when used singly and in mixtures with Amitrole, 2, 4-D-amine, sodium chlorate and Dalapon on *Paspalum conjugatum*, *Mikania scandens* and a few other weeds under mature rubber in Ceylon are reported.

High rates of MSMA were required to obtain a good control of *P. conjugatum*. Under mature rubber, mixtures of 0.825 lb MSMA + 0.188 to 0.375 lb Amitrole were found to effectively control *P. conjugatum*. Mixtures of 0.825 to 1.65 lb MSMA + 0.6 to 0.9 lb 2, 4-D-amine were very effective on a mixed growth of *P. conjugatum* and *M. scandens*. In areas with a mixed growth of *P. conjugatum*, *M. scandens*, *Axonopus affinis*, *Borreria hispida*, *Borreria ocymoides* and *Hedyotis auricularia*, mixtures of 0.825 to 1.65 lb MSMA + 0.6 to 0.9 lb 2, 4-D-amine + 4 to 5 lb sodium chlorate or 1 to 2 lb Dalapon were found to control the weeds effectively.

INTRODUCTION

Weeds are considered undesirable for various reasons, mostly connected with decreased economic return from the land. They compete with rubber plants for moisture, light and nutrients, and hinder the field operations such as tapping, spraying and fertilizing. Some weeds contain growth inhibitory substances, which can depress the growth of *Hevea* (Wong, 1964).

The weed flora of rubber plantations, consists mainly of *Paspalum conjugatum* Berg (sour grass), *Axonopus affinis* Chase (carpet grass), *Mikania scandens*, *Borreria ocymoides*, *Borreria hispida* (formerly *Spermacoce latifolia*) and *Hedyotis auricularia* L.

Weed control using sodium arsenite at rates varying from 2 lb to 10 lb/acre per application is widely practised on rubber estates. Three to seven applications per year ensure adequate control. Sodium arsenite is cheap and highly effective on a wide range of weed species, but its high mammalian toxicity presents serious hazards to its use and it cannot be advocated for weed control in certain areas. The use of sodium arsenite would also seriously limit the possibility of intercropping, supplementary cropping and crop substitution on rubber lands. Alternate herbicides are therefore urgently required for weed control under *Hevea* in Ceylon. Such herbicides should have a low mammalian toxicity and be cheap as well as effective. Therefore the choice is limited.

Amitrole (3-amino-1, 2, 4-triazole) was shown by Riepma (1962) to be effective against *P. conjugatum*. However herbicidal action was very slow and high rates were required (Riepma, 1963). Complete kill of the grass was recorded after ten weeks by Headford (1966), using Amitrole at the rate of 1.5 lb/acre.

Attempts made by Headford (1966) to obtain a rapid and lasting control of *Paspalum* with Paraquat + Amitrole or Paraquat + disodium methylarsonate (DSMA) mixtures were unsuccessful. However, when Paraquat was applied two weeks after an initial sub-lethal dose (0.375 lb/acre) of Amitrole T, desiccation was rapid and complete eradication was achieved. Similar results were obtained when Weedazol TL at 1 pint/acre was followed two weeks later by sodium chlorate at 7½ lb/acre (Wong, 1966).

Riepma (1964) obtained good control of perennial grasses including *P. conjugatum* using DSMA. DSMA is an organo-arsenic herbicide with low mammalian toxicity. DSMA has been used in the United States for the selective control of *Digitaria sanguinalis* L. in turnip and recently as a selective post-emergent herbicide to control *Sorghum halepense* (Johnson grass) in cotton (Anon, 1967). A cheaper, safer and even more effective related compound—monosodium acid methane arsonate (MSMA) has been introduced recently. MSMA was found to be more effective when used in mixtures with 2, 4-D (amine), sodium chlorate and Dalapon than when used independently (Anon, 1968).

This paper describes seven experiments in which the effect of MSMA when used singly and in mixtures with Amitrole, Dalapon, sodium chlorate and 2, 4-D (amine) on *P. conjugatum* and a few other common weeds in rubber plantations in Ceylon, were evaluated. The economics of the use of MSMA-based mixtures are also discussed.

MATERIALS AND METHODS

The trials were conducted on a Boralu series soil on Malaboda Estate, in the Kalutara District, where the average annual rainfall is 160 in. Details of the experiments and the treatments applied are given in Table 1. Experiments 1, 2 and 3 were sited in areas where *P. conjugatum* was dominant, evenly distributed and growing vigorously, while experiments 4 and 5 were sited in areas with a mixed growth of *P. conjugatum* and *M. scandens*. Experiments 6 and 7 were sited in areas with a mixed growth of *P. conjugatum*, *M. scandens*, *A. affinis*, *B. ocyroides*, *B. hispida* and *H. auricularia*. All the trials were sited in mature rubber areas, the plot size being 0.005 acre arranged between the rubber tree rows. The chemicals were sprayed with a Hortensia sprayer fitted with a 078 polijet nozzle, at a volume rate of 50 gal per acre. Sodium arsenite was however sprayed at the normal volume rate of 80 gal/acre. A surfactant was added to the spray at a uniform rate of 1 fl oz per 5 gal of water. In all cases only commercial formulations of the herbicides were used. The trade name and the percentage of active chemicals are given in Table 2.

TABLE 1
SUMMARY OF EXPERIMENTS

Experiment No.	Design	Treatments (lb/acre)	Dominant weed species
1	Randomised block, three replicates	0.825 MSMA 1.65 " " 2.475 " " 0.825 " + 0.375 amino triazole 1.65 " + 0.375 " " 2.475 " + 0.375 " " 0.825 " + 1.7 Dalapon 1.65 " + " " 2.475 " + " " 0.825 " + 5 sodium chlorate 1.65 " + " " 2.475 " + " " 2 sodium arsenite 10 " "	Mainly <i>P. conjugatum</i> 95%
2	Factorial 3 ² , three replicates	0.413 MSMA + 0.188 amino triazole 0.413 " + 0.375 " " 0.413 " + 0.563 " " 0.825 " + 0.188 " " 0.825 " + 0.375 " " 0.825 " + 0.563 " " 1.238 " + 0.188 " " 1.238 " + 0.375 " " 1.238 " + 0.563 " "	Mainly <i>P. conjugatum</i> 95%

SUMMARY OF EXPERIMENTS (cont.)

Experiment No.	Design	Treatments (lb/acre)	Dominant weed species
3	Randomised block, four replicates	0.375 amino triazole 0.750 " " 1.130 " " 0.825 MSMA + 0.375 amino triazole 1.65 " + 0.375 " "	Mainly <i>P. conjugatum</i> 95%
4	Randomised block, three replicates	0.825 " + 0.45 2, 4-D 0.825 " + 0.90 " 1.65 " + 0.45 " 1.65 " + 0.90 " 0.825 " + 0.188 amino triazole 0.825 " + 0.375 " 1.65 " + 0.188 " 1.65 " + 0.375 "	Mainly <i>P. conjugatum</i> 40% and <i>M. scandens</i> 47%
5	Factorial 3 ^a	0.825 MSMA + 0.45 2, 4-D 1.65 " + 0.45 " 2.46 " + 0.45 " 0.825 " + 0.90 " 1.65 " + 0.90 " 2.46 " + 0.90 " 0.825 " + 1.35 " 1.65 " + 1.35 " 2.46 " + 1.35 "	Mainly <i>P. conjugatum</i> (44%) and <i>M. scandens</i> (50%)
6	Randomised block, three replicates	0.825 " + 0.90 2, 4-D + 2.55 Dalapon 1.65 " + 0.90 " + 2.55 " 0.825 " + 0.90 " + 5 sodium chlorate 1.65 " + 0.90 " + 5 sodium chlorate 0.825 " + 0.375 amino triazole + 2.55 Dalapon 1.65 " + 0.375 amino triazole + 2.55 Dalapon 0.825 " + 0.375 amino triazole + 5 sodium chlorate 1.65 " + 0.375 amino triazole + 5 sodium chlorate 10 sodium arsenite	<i>P. conjugatum</i> (30%) <i>M. scandens</i> (30%) <i>A. affinis</i> 10% <i>B. hispida</i> (10%) <i>H. auricularia</i> (10%) <i>B. acymoides</i> (8%) Others (2%)
7	Split plot, two replicates	0.45 2, 4-D + 0.85 Dalapon 0.45 " + 1.6 " 0.45 " + 2.55 " 0.45 " + 2.0 sodium chlorate 0.45 " + 4.0 " " 0.45 " + 6.0 " " 0.9 " + 0.85 Dalapon " 0.9 " + 1.6 " 0.9 " + 2.55 " 0.9 " + 2.0 sodium chlorate 0.9 " + 4.0 " " 0.9 " + 6.0 " " 0.825 MSMA was added to all the mixtures before spraying	<i>M. scandens</i> (40%) <i>P. conjugatum</i> (25%) <i>A. affinis</i> (10%) <i>B. hispida</i> (10%) <i>H. auricularia</i> (8%) <i>B. acymoides</i> (5%) Others (2%)

TABLE 2

<i>Chemical name</i>	<i>Commercial name</i>	<i>Percentage active chemical</i>
1. MSMA (monosodium acid methane arsonate)	Weedfree 55 M	66%
2. Amitrole (3, amino-1, 2, 4-triazole)	Weedazol	27.8% Amitrole and 24.1% ammonium thiocyanate
3. 2, 4-D (amine salt of 2, 4-dichlorophenoxyacetic acid)	Shell weedkiller 'D'	50%
4. Dalapon (Na, salt of 2, 2-dichloropropionic acid)	Gramavein	85% Dalapon
5. Sodium chlorate	Atlacide	100% sodium chlorate
6. Sodium arsenite	Sodium arsenite	100% sodium arsenite

The effects of treatments on *P. conjugatum* and other weeds were recorded as visual estimates of percentage control relative to unsprayed plots, on a scale from 0 (no effect) to 100 (complete kill). A repetition of the application was judged to be necessary at the stage of 50% regrowth.

The percentages were transformed into their inverse sin ($\theta = \sin^{-1} \sqrt{P}$) to normalise the distribution.

RESULTS

Effect of chemicals on Paspalum (Experiments 1, 2 and 3)

MSMA: Results are presented in Table 3. The first visible sign of MSMA toxicity was a brownish discolouration of leaves which was observed on the seventh day after spraying. There was a significant increase in the control of weeds with increase in concentration of MSMA. At the 0.825 lb/acre and 1.65 lb/acre levels, the control improved with time up to the third week and thereafter decreased, whereas at 2.475 lb/acre, the kill was more rapid and reached a maximum of 85%, and this degree of control persisted up to the sixth week. At all levels the effect declined rather rapidly after the sixth week. Repeat application was adjudged necessary at the end of the 8th, 10th and 12th weeks for plots that received 0.825 lb, 1.65 lb and 2.475 lb/acre respectively.

TABLE 3

EFFECT OF MSMA AND MIXTURES OF MSMA, AMITROLE, DALAPON OR SODIUM CHLORATE
ON THE CONTROL OF *P. CONJUGATUM*

Treatments : lb/acre	Weeks after first treatment												
	Observed percentage control						Transformed values						
	1	2	3	6	9	12	1	2	3	6	9	12	
0.825 MSMA	40	57	63	60	43	33	39.2	49.2	52.5	50.8	41.0	35.1	
1.65 "	57	70	75	62	53	43	49.1	56.8	60.0	51.9	46.7	41.0	
2.475 "	80	85	80	77	60	50	63.4	67.2	63.4	61.3	50.8	45.0	
0.825 MSMA + 0.375 Amitrole	33	63	73	97	100	87	60	35.1	52.5	58.7	80.0	70.0	68.9
1.65 " + 0.375 "	67	70	78	100	100	88	57	54.9	56.8	62.0	90.0	90.0	70.1
2.475 " + 0.375 "	73	83	78	100	100	85	60	58.9	66.7	62.0	90.0	90.0	67.2
0.825 " + 1.7 Dalapon	33	53	65	73	50	40	35.1	46.7	53.7	58.7	45.0	39.2	
1.65 " + 1.7 "	67	70	78	82	67	57	54.9	56.8	62.0	64.9	54.9	49.0	
2.475 " + 1.7 "	67	70	70	82	73	65	54.9	56.8	56.8	64.9	58.7	53.7	
0.825 " + 5 sodium chlorate	77	77	73	65	53	43	61.3	61.2	58.7	53.7	46.7	41.0	
1.65 " + 5 " "	77	73	75	73	60	50	61.3	58.7	60.0	58.7	50.8	45.0	
2.475 " + 5 " "	80	80	82	78	63	53	63.4	63.4	64.9	62.0	52.5	46.7	
2 sodium arsenite	90	88	80	68	45	35	71.6	69.7	63.4	55.6	42.1	36.2	
10 " "	95	98	95	92	87	85	40	77.1	81.9	77.1	73.6	68.9	67.2
							L.S.D.	10.7	7.5	8.4	10.4	10.1	10.5

Amitrole: Results are presented in Table 4. The action of Amitrole on *Paspalum* was extremely slow. However there was an appreciable increase in the control of this grass with increase in concentration.

TABLE 4

EFFECT OF AMITROLE AND MSMA + AMITROLE MIXTURES
ON *P. CONJUGATUM*

Treatments : lb/acre	Weeks after first application								
	Observed percentage control				Transformed values				
	1	3	5	7	1	3	5	7	
0.375 Amitrole	00	10	20	43	00	18.4	26.6	41.0	
0.750 Amitrole	00	10	30	53	00	18.4	33.2	46.7	
1.130 Amitrole	00	20	43	66	00	26.6	41.0	54.3	
0.825 MSMA + 0.375 Amitrole	50	81	89	90	45.0	66.2	70.6	71.6	
1.650 MSMA + 0.375 Amitrole	60	86	91	93	50.8	68.1	72.5	74.7	
					L.S.D.	00	2.7	6.2	8.3

MSMA + Amitrole: Results are presented in Table 5. Except the mixture containing the lowest level of MSMA, viz. 0.413 lb and lowest level of Amitrole, viz. 0.188 lb, all other combinations gave excellent control of 80% and more. This was observed from the sixth week till the end of the 18th week. It is remarkable that plots that received 0.413 lb MSMA + 0.188 lb Amitrole mixture reached 50% regrowth stage only at the end of the 16th week. However, the maximum control achieved by this mixture is only 83% as against almost complete eradication of this grass with the other mixtures.

TABLE 5

EFFECT OF MIXTURES OF MSMA AND AMITROLE EACH AT THREE LEVELS ON THE CONTROL OF
P. CONJUGATUM

Treatments : lb/acre	Weeks after first treatment										
	Observed percentage control					Transformed values					
	2	6	10	14	18	2	6	10	14	18	
0.413 MSMA + 0.188 Amitrole	60	83	88	65	47	50.8	65.7	69.7	53.7	43.3	
0.413 „ + 0.375 „	50	90	98	90	88	45.0	71.6	81.9	71.6	69.7	
0.413 „ + 0.563 „	53	87	98	90	92	46.7	68.9	81.9	71.6	73.6	
0.825 „ + 0.188 „	73	87	95	87	85	58.7	68.9	77.1	68.9	67.2	
0.825 „ + 0.375 „	70	87	98	93	85	56.8	68.9	81.9	74.7	67.2	
0.825 „ + 0.563 „	60	93	100	95	93	50.8	74.7	90.0	77.1	74.7	
1.238 „ + 0.188 „	73	87	97	82	75	58.7	68.9	80.0	64.9	60.0	
1.238 „ + 0.375 „	77	87	100	93	88	61.3	68.9	90.0	74.7	69.7	
1.238 „ + 0.563 „	77	87	100	92	93	61.3	68.9	90.0	73.6	74.7	
						L.S.D.	17.5	7.4	7.7	6.0	17.9

Effect on a mixed growth of Paspalum and Mikania (Experiments 4 and 5)

Results are presented in Tables 6 and 7. It was observed that MSMA + 2, 4-D mixtures were superior to MSMA + Amitrole mixtures from the third week till the end of the experiments, the maximum control achieved by the former being 90% as against 57% by the latter. When MSMA at 0.825, 1.65 and 2.47 lb/acre were tested in combination with 0.45, 0.90 and 1.35 lb 2, 4-D, there was no significant difference in effect between the different mixtures.

TABLE 6

EFFECT OF MIXTURES OF MSMA AND AMITROLE OR 2, 4-D EACH AT TWO LEVELS ON THE CONTROL OF
P. CONJUGATUM AND *M. SCANDENS*

Weeks after treatment						
Treatments: lb/acre	Observed percentage control			Transformed values		
	3	6	9	3	6	9
0.825 MSMA + 0.45 2, 4-D	70	67	63	56.8	54.9	52.5
0.825 „ + 0.90 „	67	63	67	54.9	52.5	54.9
1.65 „ + 0.45 „	73	73	80	58.7	58.7	63.4
1.65 „ + 0.90 „	73	73	80	58.7	58.7	63.4
0.825 „ + 0.188 Amitrole	33	37	43	35.1	37.5	41.0
0.825 „ + 0.375 „	40	43	47	39.2	41.0	43.3
1.65 „ + 0.188 „	33	30	30	35.1	33.2	33.2
1.65 „ + 0.375 „	40	37	37	39.2	37.5	37.5
	L.S.D.			18.3	15.1	19.4

TABLE 7

EFFECT OF MIXTURES OF MSMA AND 2, 4-D EACH AT THREE LEVELS ON THE CONTROL OF
P. CONJUGATUM AND *M. SCANDENS*

Weeks after first treatment														
Treatments : lb/acre	Observed percentage control						Transformed values							
	1	2	4	6	8	10	12	1	2	4	6	8	10	12
0.825 MSMA + 0.45 2, 4-D	77	83	89	96	90	88	88	61.3	65.7	70.6	78.5	71.6	69.7	69.7
1.65 MSMA + 0.45 2, 4-D	88	90	95	96	92	85	85	69.7	71.6	77.1	78.5	73.6	67.2	67.2
2.46 MSMA + 0.45 2, 4-D	91	98	100	99	98	93	95	72.5	81.9	90.0	84.3	81.9	74.7	77.1
0.825 MSMA + 0.9 2, 4-D	83	92	95	96	94	93	94	65.7	73.6	77.1	78.5	75.8	74.7	75.8
1.65 MSMA + 0.9 2, 4-D	83	88	95	95	92	85	85	65.7	69.7	77.1	77.1	73.6	67.2	67.2
2.46 MSMA + 0.9 2-4-D	90	99	99	99	98	98	99	71.6	84.3	84.3	84.3	81.9	81.9	84.3
0.825 MSMA + 1.35 2, 4-D	88	90	94	94	93	88	85	69.7	71.6	75.8	75.8	74.7	76.9	76.7
1.65 MSMA + 1.35 2, 4-D	80	92	95	96	93	90	87	63.4	73.6	77.1	78.5	74.7	71.6	68.9
2.46 MSMA + 1.35 2, 4-D	92	98	99	99	98	98	98	73.6	81.9	84.3	84.3	81.9	81.9	81.9
	L.S.D.						9.5	7.6	8.3	4.6	5.3	10.5	9.9	

Effect on a mixed growth of Paspalum, Mikania, Axonopus, Borreria, Hedyotis and a few other weeds (Experiments 6 and 7)

Results are presented in Tables 8 and 9. At the end of one week after treatment, MSMA + 2, 4-D + sodium chlorate mixtures caused severe scorching of most of the weeds. The effect increased until a maximum control of 94% was achieved at the end of the sixth week. MSMA + 2, 4-D + Dalapon mixtures achieved a control of 93% and 97% at the end of the fourth and the sixth week, respectively. But, MSMA + Amitrole + Dalapon and MSMA + Amitrole + sodium chlorate mixtures were not so effective as the other mixtures and a repeat spraying was found to be necessary at the end of the fourth week. In the last experiment, there was no significant difference in effect between treatments till the end of the experiment, except the mixture containing 2 lb sodium chlorate, the effect of which is comparatively lower than that of the mixture containing 4 and 6 lb of sodium chlorate.

TABLE 8

EFFECT OF MSMA, 2, 4-D, AMITROLE, DALAPON OR SODIUM CHLORATE MIXTURES ON THE CONTROL OF WEEDS

Treatments : lb/acre	Weeks after first treatment									
	Observed percentage control					Transformed values				
	2	3	4	6	8	2	3	4	6	8
0.825 MSMA + 0.9 2, 4-D + 1.7 Dalapon	67	72	87	90	91	54.9	58.1	68.9	71.2	72.5
1.650 " + 0.9 " + 1.7 "	77	83	93	97	95	61.3	65.7	74.7	80.0	77.1
0.825 " + 0.9 " + 5 sodium chlorate	85	88	92	94	85	67.2	69.7	73.6	75.8	67.2
1.650 " + 0.9 " + 5 "	87	87	90	93	92	68.9	68.9	71.6	74.7	72.5
0.825 " + 0.375 Amitrole + 1.7 Dalapon	43	48	57	41	39	41.0	43.9	49.0	39.8	38.7
1.650 " + 0.375 " + 1.7 Dalapon	47	53	57	38	37	43.3	46.7	49.0	38.1	37.5
0.825 " + 0.375 " + 5 sod. chlorate	68	60	50	18	07	55.6	50.8	45.0	25.1	15.3
1.650 " + 0.375 " + 5 "	75	58	50	17	10	60.0	44.4	45.0	24.1	18.4
10 sodium arsenite	95	98	95	92	90	71.1	81.9	77.1	73.6	71.6
						L.S.D. 7.6 5.1 10.0 13.4 15.6				

TABLE 9

EFFECT OF MSMA, 2, 4-D AND EITHER SODIUM CHLORATE OR DALAPON MIXTURES ON THE CONTROL OF WEEDS

Treatments : lb/acre	Weeks after first treatment									
	Observed percentage control					Transformed values				
	2	3	4	6	8	2	3	4	6	8
0.825 MSMA + 0.45 2, 4-D + 0.85 Dalapon	50	68	65	78	83	45.0	55.6	53.7	62.0	66.7
" + " + 1.60 Dalapon	55	70	65	78	83	47.9	56.8	53.8	62.0	66.7
" + " + 2.55 Dalapon	65	75	83	78	88	53.7	60.0	65.7	62.0	69.7
" + " + 2.0 sod. chlorate	88	88	78	75	80	69.7	69.7	62.0	60.0	63.4
" + " + 4.0 sod. chlorate	88	94	83	85	90	69.7	75.8	65.7	67.2	71.6
" + " + 6.0 sod. chlorate	90	90	90	85	88	71.6	71.6	71.6	67.2	69.7
" + 0.9 2, 4-D + 0.85 Dalapon	78	93	83	83	94	62.0	74.7	65.7	65.7	75.5
" + " + 1.60 Dalapon	88	95	93	93	95	69.7	77.1	74.7	74.7	77.1
" + " + 2.55 Dalapon	90	93	93	90	93	71.6	74.7	74.7	71.6	74.7
" + " + 2.0 sod. chlorate	68	73	60	65	75	55.6	58.7	50.8	53.7	60.0
" + " + 4.0 sod. chlorate	94	97	97	90	90	75.8	80.0	80.0	71.6	71.6
" + " + 6.0 sod. chlorate	95	97	97	90	95	77.1	80.0	80.0	71.6	77.1
						L.S.D. 31.7 32.4 24.6 23.8 16.1				

DISCUSSION

The main criteria in the selection of herbicides are effectiveness of weed control, cost and phytotoxicity to the crop.

Effectiveness: The dosages evaluated were carefully selected so as to keep them within reasonable economic limits for use under *Hevea*. Within this range there was a linear response to MSMA when it was sprayed alone on *P. conjugatum*. MSMA at the highest level exhibited better control and the duration of control was also longer. From this it is evident that if MSMA is used alone, high rates will be required to obtain a good kill of weeds. MSMA + Amitrole mixtures were superior to both MSMA + Dalapon and MSMA + sodium chlorate mixture in controlling *P. conjugatum*. The period of control lasted for about 20 weeks in most of the plots and complete eradication of *P. conjugatum* was also achieved in some plots. From Experiment 2 it is evident that with a mixture of 0.413 lb of MSMA and 0.188 lb of Amitrole an excellent control of *P. conjugatum* could be obtained for about 10 weeks and a repeat spraying may be necessary only at the end of 16 weeks. The mode of action of MSMA is quite different from that of Amitrole. MSMA, although it is a contact herbicide, is translocated within the plant. It takes about seven days to show symptoms of phytotoxicity. In contrast Amitrole as evident from Experiment 3, which confirms the finding of Riepma (1962), is very slow in action, and with 1.13 lb Amitrole a control of 66% was achieved only after a lapse of about seven weeks. Amitrole although a slow acting herbicide it is freely translocated within the plant and moves readily in the phloem to regions of meristematic activity. Chlorosis was seen to varying extents in affected weeds. The emerging leaves were yellow due to lack of chlorophyll. Hall *et al.* (1954) showed that this was due to inhibition of development of chloroplasts. Rogers (1957) indicated that Amitrole prevents the developments of normal plastids from proplastids. When affected by Amitrole, *Paspalum*, which has a high content of anthocyanin in its young leaves, displayed its pink colour, in the absence of chlorophyll. It seems probable that the two chemicals MSMA and Amitrole are complementary herbicides and their mode of action on *P. conjugatum* appears to be in agreement with the findings of Headford (1966) on the control of this grass by the technique of split herbicide action.

MSMA + Amitrole mixtures are however not as effective as MSMA + 2, 4-D mixture on a mixed growth of *P. conjugatum* and *M. scandens*. This obviously is due to the fact that 2, 4-D is more effective on dicotyledenous weeds than Amitrole, and MSMA, perhaps exhibits selective toxicity to grasses but not to dicotyledenous weeds. An excellent control of 88% was observed even at the end of 12 weeks with the lowest levels of MSMA and 2, 4-D, and in most cases (Experiment 5) complete eradication of *P. conjugatum* and *M. scandens* was achieved.

In situations where there is a mixed growth of *A. affinis*, *B. hispida*, *B. ocymoides*, *P. conjugatum* and *M. scandens*, addition of either sodium chlorate or Dalapon

was found to be necessary (observation trial — not reported here). This is confirmed in Experiments 6 and 7. Here again, 2, 4-D in the presence of MSMA and either sodium chlorate or Dalapon is superior to Amitrole in the presence of the same chemicals (statistically significant). As explained earlier, this obviously is due to the presence of a dicotylenous weed, *Mikania*. MSMA + 2, 4-D + sodium chlorate mixture gave an excellent control of over 85% at the end of two weeks (Experiment 6). In contrast, MSMA + 2, 4-D + Dalapon mixtures did not attain this degree of control (over 85%) until the end of the fourth week. This probably is due to the presence of Dalapon, in the mixture, which being a translocated chemical, does not act so fast as sodium chlorate. Sodium chlorate in the presence of MSMA and 2, 4-D was found to be superior to Dalapon in the presence of the same chemicals (statistically significant) until the end of the third week. From the end of the fourth week till the end of the sixth week, there was no difference in effect between the two mixtures. At the end of the eighth week, the effect of Dalapon mixture was superior to that of the sodium chlorate mixture (statistically significant). However this has not been confirmed in Experiment 7. A possible explanation for this is that the proportion of *Mikania* in the plots in Experiment 7 is higher than that in Experiment 6, and hence the control of *Mikania* by 2, 4-D in the mixture, would have given a higher percentage of overall control, at a stage earlier than expected. The mixture with the lowest level of Dalapon has given control comparable with that of the highest level. But sodium chlorate at the lowest level has not given the same degree of control as the higher level. However, the control effected by 4 lb and 6 lb of sodium chlorate in the mixture is comparable.

An important feature that is evident from all the experiments described above is that none of the chemicals under investigation exhibited antagonism in the mixture. They could be easily mixed with each other without any loss of potency. The effect appears to be entirely additive.

Cost: There is considerable variation in the degree of weed control desired by estates, as well as a natural variation in flora, soil and moisture conditions. These variations make a general estimate of cost effectiveness of the treatments difficult. Based on the experiments described a rough estimate of the cost effectiveness of some of the promising treatments compared to sodium arsenite is given in Table 10.

Under mature rubber, assuming that three applications per year are required with MSMA mixtures, and if three out of the four mixtures are used, the cost per sprayed acre would vary from Rs. 51.84 to Rs. 83.61. When sodium arsenite is used, assuming that seven applications are necessary with 2 lb and three applications with 10 lb of sodium arsenite, the cost per sprayed acre would vary from Rs. 52.85 to Rs. 53.85. The maximum cost that may be incurred with MSMA mixtures is not likely to exceed Rs. 83.61. Under normal conditions, where weeds are controlled regularly, it may not be necessary to use higher concentrations of the mixture.

TABLE 10
COST COMPARISON OF EFFECTIVE TREATMENTS

Chemicals	Dosage: a.i.: lb/acre	Equivalent commercial formulation	Cost of chemicals Rs.	*Cost of labour Rs.	Cost per sprayed acre per application Rs.	Cost per sprayed acre Rs.
MSMA + Amitrole	0.825 + 0.188 to 0.375	1 pint containing 6.6 lb. a.i./gallon $\frac{1}{2}$ to 1 pint Weedazol T. (27.8% amitrole and 24.1% ammonium thiocyanate)	** 6.25 *** 5.00 to 10.00	3.30	14.55 to 19.55	51.84 to 83.61
MSMA + 2, 4-D	0.825 to 1.65 + 0.6 to 0.9	1 to 2 pint - 6.6 lb a.i./gallon 1 to $1\frac{1}{2}$ pint with an a.e. of 5 lb/gallon	6.25 to 12.50 **** 3.88 to 5.82	3.30	13.43 to 21.62	
MSMA + 2, 4-D + sodium chlorate	0.825 to 1.65 + 0.6 to 0.9 + 4 to 5	1 to 2 pint — 6.6 lb a.i./gallon 1 to $1\frac{1}{2}$ pint — 5 lb a.e./gallon 4 to 5 lb sodium chlorate	6.25 to 12.50 3.88 to 5.82 ** 5.80 to 7.25	3.30	19.23 to 28.87	
MSMA + 2, 4-D + Dalapon	0.825 to 1.65 + 0.6 to 0.9 + 0.85 to 1.7	1 to 2 pint — 6.6 lb a.i./gallon 1 to $1\frac{1}{2}$ pint — 5 lb a.e./gallon 1 to 2 lb — 85% Dalapon	6.25 to 12.50 3.88 to 5.82 **** 5.75 — 11.50	3.30	19.18 to 33.12	
Sodium arsenite	2	2 lb sodium arsenite	** 2.60	4.95	7.55	52.85 to 53.85
Sodium arsenite	10	10 lb sodium arsenite	13.00	4.95	17.95	

* Labour costs are compiled at an average of Rs. 3/30 to spray 50 gallons/acre

** Information obtained from Messrs. Harrisons & Crosfield Ltd.

*** Information obtained from Messrs. Mackwoods Ltd.

**** Information obtained from Messrs. Lankem Ceylon Ltd.

But on the other hand, in a situation where only *Paspalum* and *Mikania* are present, and if two out of the three applications are given with MSMA + 2, 4-D mixture a saving of Rs. 5.80 could be achieved. In this instance the addition of sodium chlorate to the mixture is considered unwarranted. Moreover, when using sodium arsenite, allowance will have to be made for the additional cost that may be incurred, in the preparation of arsenite (stock solution), providing medical treatment and protective clothing for the workers.

Phytotoxicity to rubber: No damage to the bark or retardation of growth of rubber plants has been observed at the levels investigated, during the course of these experiments. However these conclusions are based on one year's observations and the long term effects of the regular use of these herbicides on growth and yield of rubber still remain to be determined.

CONCLUSIONS

On the basis of the results of experiments outlined above it appears that MSMA-based mixtures are effective on a wide range of weed species and are cheap. Depending on the weed species that should be controlled, four types of mixtures could be identified.

- I. MSMA (0.825 lb to 1.65 lb) + Amitrole (0.188 lb to 0.375 lb)
- II. MSMA (0.825 to 1.65 lb) + 2, 4-D (amine) (0.6 to 0.9 lb)
- III. MSMA (0.825 to 1.65 lb) + 2, 4-D (amine) (0.6 to 0.9 lb) + sodium chlorate (4 to 5 lb)
- IV. MSMA (0.825 to 1.65 lb) + 2, 4-D (amine) (0.6 to 0.9 lb) + Dalapon (0.85 to 1.70 lb)

Mixture I could be used in a situation where *P. conjugatum* is solely dominant, Mixture II on a mixed growth of *P. conjugatum* and *M. scandens* and Mixtures III and IV on a mixed growth of *P. conjugatum*, *M. scandens*, *A. affinis*, *B. hispida*, *B. ocymoides*, *H. auricularia* and other weeds. The dosage of the components of these mixtures will depend on the height and density of the weed population and the conditions of growth — open or shade. In open non-shaded areas where the weeds are strong and thick, then obviously higher rates are necessary. Nevertheless, to ensure effective use of these mixtures a correct appraisal of the weed situation and spray programme must be made.

The long term effects of the regular use of MSMA mixtures on weed successions, growth and yield of rubber still remain to be determined. Herbicides proving effective on small-sized experimental plots will have to undergo further testing and development. These will have to be tested for the method, time of application, and also the influence of climatic and edaphic factors on their performance. It is also essential to undertake large scale trials on one to two-acre plots, preferably on commercial estates, to study their performance and any problems that may arise when they are used on a field scale. Therefore, the use of MSMA-based mixtures on commercial estates can now be suggested, but on an experimental basis.

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QUESTIONS AND ANSWERS

- Question : (1) Does MSMA or any of the mixtures mentioned contain pre-emergent properties ?
(2) Could you detail a suitable mixture to eradicate a field of grasses and *Mikania*, on an estate having a rainfall of over 200" per year ? (Anon).

Answer : (1) No, MSMA is a post-emergent contact herbicide.
(2) MSMA + 2, 4-D + sodium chlorate mixture could be used. The concentration of the components of this mixture will depend on the height and density of the weed growth.

- Question : Does *Mikania* retard the growth of immature rubber to any significant extent ? If not, will it be sufficient if strip-weeding is done without eradicating it ? (Anon).

Answer : It was reported that the roots of *Mikania* produces certain toxic chemical substances which were identified as phenolic compounds, which depress the growth of young rubber plants.

- Question : (1) Has it been conclusively established that weeds inhibit yields?
(2) If the answer to (1) is yes, can more generous applications of fertilizers compensate for such loss ? (Mr. M. Forster).

Answer : (1) No extensive data are available on the depression of yield of rubber by weed competition. However it has been established that certain weeds cause the reduction of girthing of young rubber trees ; this postpones the time at which the trees reach tappable size and therefore reduce early return on invested capital.
(2) It should be possible; this is being investigated at the moment.

- Question : (1) Will spraying of planting rows with sodium arsenite, three to four times a year cause :—
(a) any significant damage to feeder roots in the top soil in mature and/or immature rubber ?
(b) any drop in yield ?
(2) Can MSMA be used successfully during periods of rain ? (Mr. M. N. Sadanandan).

Answer : (1) (a) Sodium arsenite is a highly toxic contact herbicide. Hence, if a high concentration of this chemical comes in contact with the feeder roots of rubber, it might cause damage to the feeder roots.
(b) Since sodium arsenite is inactivated on contact with the soil, it is not likely to cause any drop in yield.
(2) MSMA-based mixtures could be used in all weather conditions except when heavy rain, liable to cause a washout, falls within two to three hours after spraying.

- Question : Rainfall in the rubber areas vary from 150"—200" a year. There is therefore hardly any competition for water. So why spend hard earned foreign exchange on imported weedicides ? What is the loss of crop due to weeds and translated into rupees ? What is the gain per acre in profit by the application of weedicides ? Loss from soil erosion too must be considered. (Mr. B. Warusavitane and Mr. M. L. M. Salgado).

Answer : Weeds, not only compete for moisture, but for nutrients as well. They also hinder various field operations such as tapping, fertilizing and spraying. Moreover, the economic advantages of employing herbicides for the control of weeds has been generally recognised. This has a special value for tropical agriculture in that the soil cultivation along the planting rows, which has now been superseded by spraying with herbicides, was liable to result in rapid oxidation of soil organic matter, loss of soil structure and erosion. On the other hand, weeds which are killed by herbicides, but not removed, give protection to the soil, improve structure and facilitate the incorporation of fertilizers.

At the same time, it is emphasized that we do not encourage clean weeding of rubber estates. Clean weeding for the sake of having a clean-weeded condition on a rubber estate, is by and large a thing of the past. We would encourage producers to adopt a rational attitude towards the type of vegetation that is generally regarded as weeds. Even in mature rubber areas, what should be considered is weed eradication in planting strips and not overall eradication.