The Effect of Paraquat on Some Grasses and Other Weeds Commonly Found in Rubber Plantations

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The contact herbicide, Paraquat, 1,1'-dimethyl, 4,4'-bipyridylium-dimethyl sulphate was tested against a number of weeds. Digitaria longiflora, Panicum nodosum, Axonopus compressus *and certain species of* Scleria *were found to be susceptible to the chemical, being controlled by application of 0.4 gal. per acre of Paraquat.* Pueraria phaseoloides *is also susceptible, but* Paspalum conjugatum *and* Mikania scandens, *although initially affected, were found to regenerate quickly after application of Paraquat.*

Against mixed grass populations the volume of application of Paraquat need be no more than 50 gal. per acre, and for optimum effect 0.5 pint of Lissapol N wetting agent should be added to every 50 gal. of spray liquid.

In 1955 some quarternary ammonium compounds were found to show high herbicidal activity (CRONSHEY, 1961). One of these compounds, 'Paraquat' (1,1'-dimethyl, 4,4'-bipyridylium-dimethyl sulphate), has been shown to have considerable promise as a contact herbicide for use in rubber cultivation. It is very soluble in water and is rapidly absorbed by the plant leaf. In the plant it interferes with the oxidation-reduction system and exerts a very rapid and toxic effect; nevertheless the effect is not persistent and regeneration may be rapid.

This paper presents the results of a number of experiments in which Paraquat has been tested against common weeds found in rubber plantations.

EXPERIMENTAL

Experiments were carried out to test the herbicidal effect of Paraquat on certain plant species, and also the influence of wetting-agent concentration and of volume of application on the effectiveness of Paraquat. Lissapol N, a non-ionic wetting agent is recommended for use with Paraquat and has been used as the standard wetter in this work. Details of the experiments are given in *Tables 1* and *3*.

Estimates of the percentage cover before and after spraying, using the point quadrat method (RIEPMA, 1962), for the main species present and also for the total plant population, enabled the respective percentage mortalities to be determined. Estimates of cover in the control plots throughout the course of the experiment enabled adjustments to be made for any increase or decrease due to natural causes (FINNEY, 1952).

RESULTS

The Effect of Paraquat on Various Plant Species

Paspalum conjugatum. Only one trial against *P. conjugatum* (Experiment 1) is recorded in this paper (*Table 2*). Recordings at thirteen days after spraying showed that good control of this grass was obtained with concentrations of Paraquat ranging from 0.4 – 1.0 gal. per acre, but this effect was not persistent and at forty-five days after spraying only a poor measure of control was found. After spraying, the leaf of the *P. conjugatum* is burnt but it appears that the stem may remain unharmed and regeneration can be rapid. Further, unreported work has since confirmed

that *P. conjugatum* is not particularly sensitive to Paraquat.

Axonōpus compressus. Two experiments on *A. compressus* are reported (*Table 2*). In Experiment 3, Paraquat was sprayed against almost a pure stand of *A. compressus*. Recordings at eighteen days after spraying showed that good control was achieved by spraying with 0.6 gal. per acre and above, and recordings at sixty-five days after spraying showed that the effect was rather more persistent than that found with *P. conjugatum*. In Experiment 2, 0.4 gal. per acre of Paraquat was found to give a high level of control at nineteen days after spraying. In this experiment rain fell during the afternoon and night after the spraying but this evidently had no adverse effect. Concentrations of wetting agent varied between these two experiments, but they do not seem to have had a large effect on the results and 0.4 gal. of Paraquat per acre would seem to be an adequate concentration to control *A. compressus*.

Panicum nodosum. The effect of Paraquat on this grass has been recorded in three experiments. In Experiments 5 and 6 rain fell after application, but even so good control was achieved using 0.4 gal. per acre Paraquat. This is confirmed in Experiment 2 and it would seem that 0.4 gal. per acre is an adequate concentration to use against this grass.

Digitaria longiflora. The results of one experiment (Experiment 4) against *D. longiflora* are reported. It can be seen from *Table 2* that a very high measure of control was obtained using 0.4 gal. per acre and this grass appears to be particularly sensitive to Paraquat. The effect was persistent up to seventy-three days after application, and although at this time there was a significant difference in control between the various concentrations of Paraquat, this difference was not sufficient to justify the use of rates above 0.4 gal. per acre.

Scleria spp. In Experiment 6, *Scleria* spp., mainly *Scleria laevis* and *Scleria sumatrensis*, occurring in a mixed stand with *P. nodosum* and other weeds, were shown to be very sensitive to Paraquat. A high level of control was obtained using 0.2 gal. per acre, the effect persisting up to sixty-one days after application.

Mikania scandens. In Experiment 5 a good measure of control over this weed, recorded at twenty-five days after application, was obtained using 0.4 gal. per acre Paraquat. However, although the leaves of the *Mikania* may have been killed, regeneration was rapid and at sixty-two days after application the experimental plots were practically overgrown with the plant. Control of *P. nodosum* in this experiment is better than that recorded in Experiment 2; nevertheless recovery was very rapid and this may well have been due to the presence of the *M. scandens* which, scrambling over the grass, would intercept quite a large proportion of the spray liquid.

Pueraria phaseoloides. Subsidiary observations on *P. phaseoloides*, occurring in mixed stand with *P. conjugatum* in Experiment 1, showed that it was very sensitive to Paraquat. Persistent control, up to forty-five days after spraying, was obtained using 0.4 gal. per acre and it is of interest to note that no regeneration of the *Pueraria* could be recorded in this experiment, whereas *P. conjugatum* regenerated quite vigorously.

Miscellaneous weed species. In all of the above experiments a variety of weed species was present in mixture with the main species under test. Use of the point quadrat method enabled recordings to be done for each species present in the population and this was done where necessary. In Experiment 4 *Cynodon dactylon* was found to be quite sensitive to 0.4 gal. per acre of Paraquat, while in Experiment 5 *Lygodium flexuosum* and other ferns showed some resistance, poor control being obtained even with 0.8 gal. per acre, although this may have been partially due to interception of the spray liquid by *M. scandens*.

In Experiment 1, *Eleusine indica* and *Paspalum scrobiculatum* were present as secondary weeds, and recordings (not shown) indicated that these grasses may show some resistance to Paraquat. Further work is needed, however, before this can be confirmed.

The Effect of Lissapol N Concentration, and Volume of Application, on the Effectiveness of Paraquat

In *Table 3* details are given of three experiments carried out to study the effect of concentration of wetting agent, and volume of application, on the effectiveness of Paraquat against miscellaneous weed species.

In recordings carried out in Experiment 7 (*Table 4*), data suggest that the most favourable Lissapol N concentration for control of *P. nodosum* is 0.2 pint per 50 gal., although some interaction between Lissapol and Paraquat concentrations occurs. At 0.5 gal. of Paraquat per acre, differences in results for the various Lissapol N concentrations were not shown to be significant, whereas when using 0.25 gal. of Paraquat per acre 0.2 pint of Lissapol N per acre gave optimum control. In the same experiment it appeared that 0.1 pint of Lissapol N per 50 gal. of water gave the best effect with *Mimosa pudica*, when using 0.25 gal. or 0.5 gal. per acre of Paraquat. This experiment confirmed that *P. nodosum* and *M. pudica* may easily be controlled by Paraquat, and the addition of 0.1 or 0.2 pint Lissapol seems to increase its effectiveness.

In Experiment 8 (*Table 5*) three concentrations of Lissapol and three concentrations of Paraquat were tested in an area where *Scleria* species, mainly *Scleria hebecarpa*, were the main weeds. A mixture of other species was also present and the effect of the herbicide on general weed control as well as on that of *Scleria* has been estimated. It can be seen that the mean percentage kill of *Scleria* was extremely high and was not influenced by the different Paraquat concentrations or by Lissapol concentrations. This confirms the data given above in showing that *Scleria* species are very sensitive to Paraquat (Experiment 6). For general weed control the addition of Lissapol N at 0.5 pint in 50 gal. tended to increase the effect of Paraquat. Three weeks after spraying, the mean results for 0.5 pint Lissapol were significantly superior to that of the control (no Lissapol) at the 5% level. Two months after spraying, there was only a non-significant indication that 0.5 pint Lissapol N was acting beneficially on the activity of Paraquat.

The influence of volume of application and of concentration of Lissapol N on the effect of Paraquat against *A. compressus* was tested in Experiment 9 (*Table 6*). There was no significant difference between the two volumes of application, although spraying at 100 gal. per acre gave a rather better effect than at 50 gal. per acre.

Significantly better control of the *A. compressus* was obtained using 0.5 gal. per acre of Paraquat than 0.25 gal. per acre, both at eighteen and at sixty-four days after application.

The effects of Paraquat on *A. compressus* are clearly influenced by the Lissapol concentrations. Where Paraquat was applied at 0.25 gal. per acre, the addition of 0.5 pint Lissapol per 50 gallons water showed the best results for both volumes of water application and at both recordings. With 0.50 gallons per acre Paraquat, there is no general upward trend in results with increasing amounts of Lissapol.

CONCLUSIONS

The contact herbicide Paraquat can be classed as generally effective against a wide range of weeds, but the above work has confirmed that weeds vary in their susceptibility to this chemical.

Digitaria longiflora, *Panicum nodosum*, and the *Scleria* species have been shown to be very susceptible and may easily be controlled by an application of 0.4 gal. per acre of Paraquat. The grass *Axonopus compressus* is not quite so susceptible, although controllable by 0.4 gal. per acre or Paraquat, but the very similar grass, *Paspalum conjugatum*, has been shown to regenerate quickly after spraying and can be said to show some degree of resistance. Incidental observations in the different experiments suggest that *Cynodon dactylon* is susceptible to Paraquat, but that *Paspalum scrobiculatum* and *Eleusine indica* may show

marked resistance to Paraquat. More work is required, however, before this can be confirmed.

The leguminous creeper *Pueraria phaseoloides*, commonly used as a cover plant in the inter-row areas, has been shown to be very susceptible to Paraquat, while the leguminous weed *Mimosa pudica* can be controlled by the application of 0.5 gal. per acre of Paraquat.

Paraquat was initially effective against *Mikania scandens*, but regeneration was rapid. The experiments also demonstrated that in a mixed stand of weeds the *M. scandens* present may intercept a large proportion of the spray liquid and so minimise its effect against the other weed species present. This interception can cut down the effect of Paraquat so markedly that in field problems it would be better to eliminate the *M. scandens* first by an application of 2 lb per acre of a 2,4-D formulation before spraying with Paraquat.

The experiments showed that the concentration of wetting agent, Lissapol N, may appreciably affect the control obtained by Paraquat, and when dealing with a mixed weed population it would seem safest to add 0.5 pint of Lissapol N per 50 gal. of spray liquid.

The one trial (Experiment 9) carried out to test the influence of volume of application on the effectiveness of Paraquat cannot be said to be conclusive by itself, but when considered together with other information (RIEPMA, 1962) it can be concluded that 50 gal. per acre is a suitable volume of application against mixed grass populations.

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TABLE 1. EFFECT OF PARAQUAT ON DIFFERENT PLANT SPECIES. EXPERIMENTAL DETAILS

All experiments were laid out as 5 × 5 Latin squares with five treatments, using plots of 1/200 acre.
Volume of application 50 gal. per acre

Experiment No. *	Site	Weed species present	Date of spraying	Conc. of Lissapol N, pints/50 gal. spray liquid	Conc. of Paraquat, gal./acre
1 (13/61)	Vacant area in the open	*Paspalum conjugatum* with even scattering of *Pueraria phaseoloides*, Other spp.: *Paspalum scrobiculatum* and *Eleusine indica*	17.5.61	1	0, 0.4, 0.6, 0.8, 1.0
2 (14/61)	Inter-row areas of young rubber, no shade	*Panicum nodosum* and *Axonopus compressus*	11.5.61	1	0, 0.4, 0.6, 0.8, 1.0
3 (25/61)	Inter-row areas of young rubber, no shade	*Axonopus compressus*	22.8.61	0.5	0, 0.4, 0.6, 0.8, 1.0
4 (26/61)	Vacant area in the open	Main weed-*Digitaria longiflora*, with *Cynodon dactylon* as secondary weed.	27.10.61	0.5	0, 0.4, 0.6, 0.8, 1.0
5 (34/61)	Inter-row areas of 3-year -old rubber, little shade	*Panicum nodosum* and *Mikania scandens*. Other sp.: *Lygodium flexuosum*	11.8.61	0.1	0, 0.4, 0.6, 0.8, 1.0
6 (74/61)	In partial shade under mature rubber	*Panicum nodosum*, *Scleria laevis* and *Scleria sumatrensis*	9.12.61	0.5	0, 0.2, 0.4, 0.6, 0.8

* R.R.I.M. experiment number in parenthesis.

TABLE 2. THE EFFECT OF PARAQUAT ON VARIOUS SPECIES AND ON GENERAL WEED CONTROL

Experiment No.*	Time of recording (days after application)	Species	Mean % mortality					s.e. of means
			Paraquat conc. in gal. per acre					
			0.2	0.4	0.6	0.8	1.0	
1 (13/61)	13	*Paspalum conjugatum*	—	76.6	78.4	87.9	92.3	± 4.55
	45		—	28.2	47.9	64.9	67.6	± 8.94
	13	*Pueraria phaseoloides*	—	96.5	98.4	98.7	100.0	± 1.338
	45		—	98.2	98.6	100.0	91.8	± 4.017
2 (14/61)	19	*Panicum nodosum*	—	94.5	93.5	98.4	97.9	± 1.184
	38		—	50.4	44.5	67.8	69.3	± 6.748
	19	*Axonopus compressus*	—	88.7	75.9	86.0	98.9	± 8.068
	38		—	51.9	48.9	69.2	93.2	± 11.267
3 (25/61)	18	*Axonopus compressus*	—	68.12	78.36	87.3	82.4	± 4.864
	65		—	46.1	63.3	75.4	68.1	± 6.264
4 (26/61)	31	*Digitaria longiflora*	—	99.5	99.2	100.0	99.9	± 0.251
	73		—	94.6	97.4	99.1	99.9	± 1.179
	31	Mixed stand	—	95.6	90.8	98.2	98.9	± 2.715
	73		—	89.2	75.7	92.3	97.8	± 5.394
5 (34/61)	25	*Mikania scandens*	—	90.1	87.5	88.6	95.2	± 4.578
		Panicum nodosum	—	95.8	86.5	90.8	98.0	± 3.991
		Mixed stand	—	63.3	68.8	75.7	88.0	± 7.842
	62	Mixed stand	—	5.0	22.8	16.4	36.9	± 9.804
6 (74/61)	25	*Panicum nodosum*	35.7	61.7	74.0	85.3	—	± 6.301
	61		26.6	12.4	25.8	38.0	—	± 10.585
	25	*Scleria spp.*	85.0	90.9	83.9	97.4	—	± 6.654
	61		89.0	94.5	95.8	99.6	—	± 2.518
	25	Mixed stand	37.7	54.6	66.2	80.0	—	± 4.680
	61		30.3	11.0	14.7	38.1	—	± 8.689

* R.R.I.M. experiment number in parenthesis.

TABLE 3. EFFECT OF LISSAPOL N CONCENTRATION AND VOLUME OF APPLICATION ON EFFECTIVENESS OF PARAQUAT. EXPERIMENTAL DETAILS

All experiments were laid out in plots of 1/200 acre

Experiment No.*	Design	Site	Weed species present	Date of spraying	Volume of application, gal. per acre	Conc. of Lissapol N, pints per 50 gal.	Conc. of Paraquat, gal. per acre
7 (21/61)	Two (5 × 5) Latin squares intermixed by rows. 4 concs. Lissapol 2 concs. Paraquat 2 controls	Inter-row areas of young rubber—no shade	*Panicum nodosum* and *Mimosa pudica*. Other species, *Axonopus compressus* and *Ischaemum aristatum*	8.6.61	50	0, 0.1, 0.2, 0.5	0.25, 0.50
8 (41/61)	Youden square 13×4	In partial shade under mature rubber	*Scleria hebecarpa* and other *Scleria* spp.	17.10.61	50	0, 0.1, 0.2, 0.5	0.4, 0.6, 0.8
9 (44/61)	Youden square 13×4	Inter-row areas of young rubber—no shade	*Axonopus compressus*	21.8.61	50 and 100	0, 0.2, 0.5	0.25, 0.50

* R.R.I.M. experiment number in parenthesis.

TABLE 4. EXPERIMENT 7. PERCENTAGE CONTROL OF PANICUM NODOSUM AND MIMOSA PUDICA AS AFFECTED BY VARIATION IN PARAQUAT AND LISSAPOL N CONCENTRATION

Recorded at 19 days after application

Species	*Panicum nodosum*					*Mimosa pudica*				
Lissapol, pints per 50 gal / Paraquat, gal. per acre	0	0.1	0.2	0.5	Mean	0	0.1	0.2	0.5	Mean
0.25	92.3	93.8	96.5	91.1	93.4	81.2	95.5	93.0	85.5	88.8
0.50	96.1	97.6	98.7	98.6	97.7	92.7	98.9	92.8	94.8	94.8
Mean	94.2	95.7	97.6	94.8		86.9	97.2	92.9	90.2	
s.e. of diff. between means of Paraquat conc.				± 0.602				± 2.00		
s.e. of diff. between means of Lissapol conc.				± 0.852				± 2.83		
s.e. of diff. between Paraquat × Lissapol means.				± 1.205				± 3.99		

TABLE 5. EXPERIMENT 8. PERCENTAGE CONTROL OF SCLERIA AND OTHER SPECIES AS AFFECTED BY VARIATION IN PARAQUAT AND LISSAPOL N CONCENTRATION

	Percentage control of *Scleria* spp										Percentage control of general ground cover									
	22 days after application					61 days after application					22 days after application					61 days after application				
Lissapol, pints per 50 gal. / Paraquat, gal. per acre	0	0.1	0.2	0.5	Mean	0	0.1	0.2	0.5	Mean	0	0.1	0.2	0.5	Mean	0	0.1	0.2	0.5	Mean
0.4	99.1	96.7	98.9	98.7	98.4	95.8	90.6	95.9	93.8	94.0	88.5	90.5	92.8	92.7	91.2	73.4	64.6	72.2	82.3	73.1
0.6	96.8	99.2	94.2	99.2	97.4	96.0	93.0	95.7	94.5	94.8	92.2	90.7	92.5	96.3	92.9	73.6	98.8	80.8	80.7	78.5
0.8	98.5	98.6	98.2	98.6	98.5	91.3	95.8	88.6	90.8	91.7	92.9	92.6	92.2	98.5	94.0	79.7	81.2	79.2	85.5	81.4
Mean	98.1	98.2	97.1	98.8		94.3	93.2	93.4	93.1		91.2	91.3	92.5	95.8		75.6	74.9	77.4	82.8	
s.e. of diff. between Paraquat × Lissapol means.	± 2.20					± 4.50					± 3.39					± 7.15				
s.e. of diff. between means of Lissapol conc.	± 1.27					± 2.60					± 1.96					± 4.13				
s.e. of diff. between means of Paraquat conc.	± 1.10					± 2.25					± 1.69					± 3.58				

TABLE 6. EXPERIMENT 9. PERCENTAGE CONTROL OF AXONOPUS COMPRESSUS AS AFFECTED BY VARIATION IN PARAQUAT AND LISSAPOL N CONCENTRATION

Time of recording	Volume of application, gal. per acre	Lissapol, pints per 50 gal. / Paraquat, gal. per acre	0	0.2	0.5	Mean
18 days after application	50	0.25	44.7	54.4	65.1	54.7
		0.50	78.7	87.4	80.6	82.2
	100	0.25	70.4	63.2	80.2	71.3
		0.50	84.0	70.6	82.2	78.9
		Mean	69.7	68.9	82.0	
64 days after application	50	0.25	6.8	6.9	26.6	13.4
		0.50	39.2	56.3	43.0	46.2
	100	0.25	12.8	12.1	38.8	21.2
		0.50	37.7	40.9	71.8	50.1
		Mean	24.1	29.1	45.0	

	18 days after application	64 days after application
s.e. of diff. between Paraquat × Lissapol × vol. of application	± 9.52	± 12.2
s.e. of diff. between means of Lissapol conc.	± 4.76	± 6.10
s.e. of diff. between means of volumes of application	± 3.89	± 4.98
s.e. of diff. between means of Paraquat conc.	± 3.89	± 4.98