NEW DEVELOPMENTS IN THE WEEDKILLER FIELD

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SUMMARY

PRELIMINARY work with erbon, fenac, dalapon/2,4,5-TP mixture, and diquat has indicated that none of these chemicals will have any advantage over dalapon for chemical ploughing techniques of pasture and crop establishment.

Some investigations have been initiated using paraquat and it appears that this is one of the most outstanding herbicides to be developed for some years. Unlike dalapon, it gives extremely rapid suppression of a sward and has no residual toxicity effects in the soil. Pasture species apparently exhibit marked differences in susceptibility to paraquat and these differences frequently change from one time of application to another.

To date much of the experimental work with paraquat is interim only and requires further confirmation. Much more exhaustive work must still be done before an accurate assessment of the chemical can be made.

INTRODUCTION

Since 1954, when dalapon was released, much experimental work has been carried out in an attempt to perfect the technique of "chemical ploughing". However, though dalapon can be used for chemical ploughing with great success under favourable conditions, the method is probably still too unreliable to be recommended with absolute confidence. The main disadvantages of dalapon are its residual toxicity effects and the fact that if economic rates are used, grass species show marked differences in tolerance and no one time of application will give optimum control of all species. Because of this as new herbicides become available they are tested to determine if they are superior to dalapon for sward destruction.

During 1960-61 five relatively new herbicides were evaluated against dalapon in Department of Agriculture trials carried out at Takapu Road Experimental Area and Marton Experimental Area and the results of this work are presented in this paper.

DETAILS OF TRIALS

Eight trials formed a comprehensive series which covered numerous aspects of pasture and crop tolerance to various rates of erbon, fenac, dalapon/2,4,5-TP mixture, diquat, and paraquat. In most of the experiments dalapon and/or dalapon/amitrole mixtures were included as the standard treatment.

Information was first obtained as to which chemicals were sufficiently promising as herbicides to warrant further work. Once this preliminary sorting had been completed, detailed work involving comparison of species tolerance, rates of application, stages of growth, and residual toxicity was conducted to evaluate further the more satisfactory chemicals; to date, much of this work is still interim.

EXPERIMENTAL TECHNIQUE

Initially, in some of the investigations, a logarithmic sprayer was used to give a wide coverage of rates of application. In later more detailed work treatments were applied at a few selected rates to pure sowings of common pasture species to give precise data on species tolerance.

Point analysis was used in some trials to assess accurately differences in treatment effects.

Treatments were replicated and randomised in all trials.

RESULTS

Erbon

Applied at 6 lb and 12 lb a.i. per acre to a mixed low fertility sward Erbon proved to be quite useless as a herbicide. At the high rate of application a small percentage of browntop (*Agrostis tenuis*) was removed, but its main effect was only to scorch the tips of the blades of the herbage and cause a temporary reduction in growth.

Fenac

As a herbicide for general sward destruction this material was also quite ineffective and both rates of 6 lb and 12 lb a.i. per acre which were used on low fertility pasture gave only a slight check to the grass growth. However, the outstanding effect of fenac was that every clover plant was completely eliminated from the sward at both rates of application, and even 18 months after spraying no clover had re-established.

Dalapon/2,4,5-TP mixture

This product, containing 4 lb a.i. per acre of dalapon and $\frac{1}{2}$ lb a.i. per acre of 2,4,5-TP per gallon, proved to be no more effective than equivalent rates of dalapon as a sward killer.

Thompson (1) has shown that the residual effect of this mixture is much more toxic and persistent than dalapon or dalapon/amitrole mixtures and this result was confirmed, oversown grasses and clovers suffering severe damage due to residual toxicity effects.

Diquat

Though most spectacular in its action of scorching off all plant tissue (damage visible within one hour under bright sunny conditions), diquat was found to have only a transient effect on grasses and clovers. Recovery of the herbage was very rapid, being almost complete about two months after spraying in spring.

White clover appears to recover from spraying with diquat more rapidly than grasses, so that the only permanent effect of the chemical is to encourage clover dominance.

The tolerance of turnips, chou moellier, wheat, and maize to diquat was also determined, the crops being sprayed when about 6 in. high (see paraquat section (crop tolerance) for actual heights and stages of growth).

With rates from 1 lb to 0.1 lb a.i. per acre turnips and maize were only temporarily affected by leaf desiccation and recovered at all rates, though they were a little retarded in growth three months after spraying. Wheat was severely stunted at all rates and chou moellier was drastically thinned at rates above 0.5 lb a.i. per acre and very stunted at all rates.

Paraquat

Paraquat, a chemical closely related to diquat, has only recently been released; at present it is available only for experimental purposes.

Preliminary work showed this to be a particularly promising material for use in chemical ploughing. It seemed to be a very good grasskiller and in early September eliminated most of the grasses present in a mixed sward even at a rate of 1 lb a.i. per acre.

To determine its potentiality further experiments were carried out and the results of this work are described below.

(i) Residual Toxicity Effects

Row sowings were made of white clover, lucerne, red clover, subterranean clover, wheat, maize, turnips, and chou moellier, but immediately before drilling the seed into cultivated ground paraquat was applied at rates varying from 0.2 lb to 3.6 lb a.i. per acre.

At no stage of growth was there ever any difference between the sprayed and unsprayed rows, either in density or vigour of plants, showing that there had been no residual toxicity effects up to 3.6 lb a.i. per acre of paraquat.

(ii) Crop Tolerance

Rates of paraquat ranging from 0.45 lb to 0.04 lb a.i. per acre were applied to rows of:

Crop	No. of true leaves	Height (in.)
Turnips	6	6-8
Chou moellier	2-3	4
Wheat	3	8-10
Maize	4-5	4-5

The initial effect was to cause scorching and chlorosis of much of the foliage of the crops. Only the turnips recovered from spraying at all rates and even they were somewhat retarded in growth four months after application. Maize was killed at rates above 0.2 lb a.i. per acre, but below this rate plants recovered well and the only effect of spraying noted after two months was a slight retardation of flowering compared with unsprayed maize. Chou moellier was very stunted at all rates and drastically thinned with rates above 0.2 lb a.i. per acre. Wheat was almost entirely eliminated at all rates.

(iii) Legume Tolerance

Young plants of lucerne and white, red, and subterranean clovers sown in early November and sprayed five, seven, and nine weeks after sowing in a dry season showed marked susceptibility to paraquat applied at rates ranging from 0.2 lb to 3.6 lb a.i. per acre.

Lucerne was the most susceptible species, severe damage being sustained even at the lightest rate and the majority of plants were killed at rates in excess of 0.4 lb a.i. per acre. White, red, and subterranean clovers followed in order of susceptibility, but the tolerance range was small, most plants being eliminated at or about the 0.9 lb a.i. per acre rate.

Indications were that plants became increasingly tolerant with maturity.

In addition to the above work on newly established plants, paraquat was also applied to well established white clover in a two-year-old sward. Rates of paraquat used were 0.45, 0.9, and 1.8 lb a.i. per acre, applied in late December and again in late March.

At both times of application the clovers were quickly defoliated, but recovery of the surviving plants was rapid.

Assessments made three months after spraying gave differences in white clover content which reflect the intensity of damage caused to white clover by the three rates of paraquat (see table 1).

Dalapon at 3.7 lb and 7.4 lb a.i. per acre was also applied to the sward and a comparison with paraquat shows that the two high rates and the two low rates of the chemicals caused similar amounts of damage to the clover.

TABLE 1—TOLERANCE OF MATURE WHITE CLOVER

Results of point analysis—cover hits per 100 points

Treatments lb a.i. per acre		White clover	
		Sprayed 21/12/60 Assessment 15/3/61	Sprayed 21/3/61* Assessment 6/6/61
Control	---	24 d B	28
Paraquat 0.45	---	82 a A	60
0.9	---	76 ab A	38
1.8	---	61 bc A	18
Dalapon 3.7	---	73 abc A	44
7.4	---	55 c A	14

* Data not yet statistically analysed.

(iv) Grass Tolerance

To ascertain the tolerance of some of the more common grass species to herbicides separate blocks of perennial ryegrass (*Lolium perenne*), cocksfoot (*Dactylis glomerata*), browntop, Chewings fescue (*Festuca rubra* var. *fallax*) and Yorkshire fog (*Holcus lanatus*) were sown and at the time of

application of the chemicals had been well established for three years. The tolerance of these grasses to 0.45, 0.9, and 1.8 lb a.i. per acre of paraquat compared with 3.7 and 7.4 lb a.i. per acre of dalapon was determined for two times of the year (late December and late March) and some information on the susceptibility of *Poa trivialis* was also obtained, since it was a major volunteer in the perennial ryegrass block.

Table 2 gives the results of assessments made by point analysis three months after spraying.

Perennial Ryegrass

Applied in December and March, paraquat 0.45 lb a.i. per acre had a negligible effect on perennial ryegrass, but the 0.9 and 1.8 lb a.i. per acre rates had increasingly severe effects. The high rates of dalapon and paraquat both gave similar control of perennial ryegrass, but the control given by dalapon 3.7 lb a.i. per acre was less effective than that given by paraquat 0.9 lb a.i. per acre.

Cocksfoot

In December, the high rates of dalapon and paraquat both eliminated cocksfoot from the sward almost entirely, and dalapon 3.7 lb a.i. per acre and paraquat 0.9 lb a.i. per acre also gave fairly satisfactory results by reducing the amounts of cocksfoot by 75 per cent. However, 0.45 lb a.i. per acre of paraquat was insufficient to cause really serious damage.

TABLE 2—INDIVIDUAL SPECIES TOLERANCE

Results of point analysis per cent survival (Control = 100)

(a) Sprayed 21/12/60. Assessment 15/3/61.

Treatments lb a.i. per acre	Perennial ryegrass	Cocksfoot	Browntop	Chewings fescue	Yorkshire fog
Control	100 a A	100 a A	100 a A	100 a A	100 a A
Paraquat					
0.45	111 a A	66 a B	61 b B	51 b AB	44 b B
0.9	63 b AB	25 b BC	20 c C	15 c CD	16 cd C
1.8	30 c B	3 c C	12 c C	4 c D	6 d C
Dalapon					
3.7	81 ab A	25 b BC	30 c C	40 b BC	29 bc BC
7.4	30 c B	0*	13 c D	9 c C	10 cd C

(b) Sprayed 21/3/61. Assessment 6/6/61†

Treatments lb a.i. per acre	Perennial ryegrass	Cocksfoot	Browntop	Chewings fescue	Yorkshire fog
Control	100	100	100	100	100
Paraquat					
0.45	78	36	83	77	4
0.9	54	21	82	42	5
1.8	30	3	58	18	Trace
Dalapon					
3.7	78	49	18	23	12
7.4	35	15	2	8	9

* Not included in the analysis.

† Data not yet statistically analysed.

Cocksfoot was much more susceptible to paraquat at 0.45 lb a.i. per acre in March than in December. However, it was more tolerant of dalapon in March than in December. Only the high rate of paraquat gave really excellent suppression in March, but the results obtained with dalapon at 7.4 lb a.i. per acre and paraquat at 0.9 lb a.i. per acre were satisfactory.

Browntop

Browntop was markedly more tolerant of paraquat in March than in December, the high rate in March giving no better control than the low rate in December.

In contrast to paraquat dalapon was more effective in March than in December; in March, both rates of dalapon were much superior to any rate of paraquat.

Chewings Fescue

Extremely good control of Chewings fescue was given by 0.45 and 0.9 lb a.i per acre of paraquat applied in December, but these rates applied in March were much less effective.

Only the high rate of dalapon gave consistently good control at both times of application.

Yorkshire Fog

Both materials at all rates applied in March gave very good suppression of Yorkshire fog, but in December, only the high rates of dalapon and paraquat gave good control.

Poa Trivialis

Poa trivialis was eliminated at all rates of application of both chemicals made in December, and apparently only the two lowest rates of paraquat did not give complete control in March.

Because only quite small amounts of the species were present in the sward, results are not given in Table 2 as relative figures; actual cover hits are given in Table 3.

TABLE 3—TOLERANCE OF *POA TRIVIALIS*
Results of point analysis—cover hits per 100 points

Treatments				Sprayed 21/12/60	Sprayed 21/3/61
lb a.i. per acre				Assessed 15/3/61	Assessed 6/6/61
Control	---	---	---	23	18
Paraquat	0.45	---	---	Trace	7
	0.9	---	---	---	3
	1.8	---	---	Trace	---
Dalapon	3.7	---	---	1	---
	7.4	---	---	---	---

TABLE 4—SPECIES TOLERANCE TO PARAQUAT

Results of point analysis.
Mean tolerance of species over all rates (Control = 100).

	Perennial ryegrass	Cocksfoot	Browntop	Chewings fescue	Yorkshire fog
Sprayed 21/12/60	68	31	31	23	22
Assessed 15/3/61					
Sprayed 21/3/61	54	20	74	46	3
Assessed 6/6/61					

Browntop and Chewings fescue were more tolerant in autumn than in summer, but in contrast Yorkshire fog showed a decrease in tolerance in autumn when it was a most susceptible species.

Of the three high fertility grasses *Poa trivialis* was very susceptible to paraquat at both times (see Table 3), perennial ryegrass was most resistant, and cocksfoot was intermediate in tolerance.

TABLE 5—SPECIES TOLERANCE TO DALAPON

Results of point analysis.

Mean tolerance of species over both rates (Control = 100).

		<i>Perennial ryegrass</i>	<i>Cocksfoot</i>	<i>Browntop</i>	<i>Chewings fescue</i>	<i>Yorkshire fog</i>
Sprayed 21/12/60	---	56	12	22	25	20
Assessed 15/3/61						
Sprayed 21/3/61	---	56	32	10	16	10
Assessed 6/6/61						

Browntop, Chewings fescue, and Yorkshire fog were fairly similar in tolerance to dalapon, but the chemical was more effective on the grasses in autumn than in summer.

The order of susceptibility of the three high fertility grasses was the same as for paraquat. However, cocksfoot was much more tolerant of dalapon in autumn than in summer, which was the reverse of the effect of paraquat.

(v) Weed Tolerance

Information on the susceptibility of weeds to paraquat compared with dalapon was obtained in association with the grass tolerance work.

For both times of application it was found three months after spraying that the areas to which dalapon had been applied contained a much greater cover of flatweeds (mainly *Crepis capillaris*, *Cerastium glomeratum*, *Taraxacum officinale*, and *Hypochaeris radicata*) than the paraquat sprayed areas.

TABLE 6—WEED TOLERANCE IN ESTABLISHED PASTURE

Results of point analysis—cover hits per 100 points

<i>Treatments</i> <i>lb a.i. per acre</i>		<i>Sprayed 21/12/60</i> <i>Assessed 15/3/61</i>	<i>Sprayed 21/3/61</i> <i>Assessed 6/6/61*</i>
Control	---	13 b A	13
Paraquat 0.45	---	12 b A	22
0.9	---	12 b A	29
1.8	---	9 b A	47
Dalapon 3.7	---	30 a A	57
7.4	---	31 a A	82

* Data not yet statistically analysed.

Weeds on the dalapon sprayed areas were large and spreading compared with the small plants on the paraquat areas.

For the December application which was followed by very dry weather, weed content on the unsprayed and paraquat sprayed areas was similar three months after application, but fewer weeds were present where paraquat had been used.

Good growing conditions prevailed following the March applications of paraquat and three months after spraying weeds were more prevalent where paraquat had been applied than on the unsprayed areas, the higher rates of chemical having a greater weed content.

Presumably the original weeds present in the pasture before spraying were either killed or very severely retarded in growth by the paraquat. The result of this would be that re-establishment of weeds would be relatively slow when dry conditions followed spraying as in December 1960, but quicker under good growing conditions such as those following spraying in March 1961.

Dalapon had apparently little effect on the weeds and so rapid growth occurred when interplant competition was removed.

DISCUSSION

Of the five chemicals tested (erbon, fenac, dalapon/2,4,5-TP mixture, diquat, and paraquat) paraquat was found to be the most efficient herbicide and should prove valuable for chemical ploughing; the other four materials are probably of no practical use for this technique.

Erbon at the rates used (6 lb and 12 lb a.i. per acre) was ineffective for sward destruction. However, had high rates been used, better results could possibly have been achieved.

Fenac at 6 lb and 12 lb a.i. per acre also entirely failed to control grasses, but was most effective in eliminating clovers for many months. It would appear that where total destruction of clover is required, such as in some playing greens, fenac could be used with lasting effect. For this work it seems to be more efficient than the commonly used 2,4,5-T.

Dalapon/2,4,5-TP mixture was found to be no more effective than dalapon at equivalent rates and because of its increased residual toxicity effects compared with dalapon, the chemical cannot be recommended for chemical ploughing work.

Diquat will probably be of great value as a crop desiccant, but has no value as a weedkiller suitable for chemical ploughing because of its only transient effect on the herbage. Applied to a mixed sward, diquat appears to encourage clover dominance and may be a useful chemical to use to improve the clover content of a sward.

Paraquat appears to be a most promising herbicide, but many more experiments must be conducted before it can be recommended for general use.

To date, its apparent **advantages** over dalapon are:

1. Lack of residual toxicity effects, thus enabling seed to be sown immediately after spraying. This allows the maximum time for the establishment of the sown seed.
2. Rapid uptake, particularly on grasses, which means that there is less likelihood of rainfall reducing its herbicidal effect.
3. Rapid action, which reduces the delay in pasture or crop establishment.
4. It gives a cleaner and less weedy seedbed than dalapon. Apparent **disadvantages** compared with dalapon are:

- (i) It seems that because of the very rapid destruction of the foliage paraquat may not move throughout the whole plant, particularly in rhizomatous grasses and regrowth may soon follow. If this happens, a second application could be necessary.
- (ii) A wetting agent must be used for application.
- (iii) Apparently inferior control of browntop is given in autumn.

Unless better results are obtained in future work with paraquat in autumn, dalapon is to be preferred for spraying low fertility browntop dominant swards.

As for dalapon, time of application of paraquat appears to be very important in determining the efficiency of the chemical. Grass species show marked differences in susceptibility to paraquat and these differences usually differ from one time of application to another. Species tolerance to dalapon and paraquat also appears to be quite independent; that is increased tolerance of a species to paraquat at one time does not mean that it is more tolerant of dalapon at that time.

Rates of application for effective control of species have not yet been precisely determined, but 1 lb a.i. per acre should prove quite adequate for most pasture renovation if the optimum time of application is determined. For most crop establishment work, 2 lb a.i. per acre will probably be necessary.

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Reference

1. Thompson, A. Proc. 13th N.Z. Weed Control Conf. 1960. pp. 95-101.