STUDIES OF PASTURE RESPONSES TO PARAQUAT

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Summary

In North Island pastures the clover (*Trifolium* spp.) content is often severely suppressed. Trials are described which study the response of these pastures to paraquat in terms of dry matter production, pasture composition changes, relative grass establishment and liveweight gains of young sheep. Strong indications of interactions between paraquat and phosphate fertilizer occurred in the form of dry matter production increases in June, July, August and September. Establishment of oversown ryegrass was improved by spraying and lambs grazing sprayed pasture gained more liveweight than those on the untreated control. The implications of these responses to farm management are discussed.

INTRODUCTION

FUNDAMENTAL to pasture responses from topdressing with phosphorus and potassium is clover (*Trifolium* spp.) nutrition. The effect of the clover component on liveweight gains of young sheep is widely acknowledged.

In North Island districts with reasonable rainfall distribution, clover is often severely suppressed by grasses. Paraquat, through selective activity on grasses, causes clovers to be strengthened. Williams (1967) described trials studying the use of paraquat in pasture improvement, and Palmer (1967) introduced its potential role as a means of preparing pastures for lambs. This paper extends the two previous studies and introduces a wider interpretation of the role of chemicals in pasture management.

RESEARCH METHODS

Six trials, sited in the Waikato, King Country and Central Plateau (North Island) regions, were used to study the response of pastures to paraquat. Of these, "Reporea" and "Pio Pio" were replicated stocking trials, the latter incorporating stocking rate as a second factor. At "Hodderville" I and II pasture frames managed on an alternate mowing/grazing programme were used. The "Arapuni" trial, in its second year (Williams, 1967), and "Pukeatua" were both managed on an alternate mowing/grazing technique whereby the whole trial area was open to grazing except during selected periods for which production data were required.

A brief description of sites is shown in Table 1. Table 2 contains details of treatments and design.

The trials were used to study three factors:

- (1) The relationship between response to superphosphate and paraquat in terms of total dry matter production in the critical periods of pasture supply and demand (June to September).
- (2) Establishment of oversown grasses.
- (3) Livestock responses in terms of liveweight gains of young sheep.

TABLE 1: DESCRIPTION OF SITES

<i>Trial</i>	<i>Type of Farm</i>	<i>Approx. Age of Pasture</i>	<i>Soil Type</i>
Arapuni	Sheep	15 yr	Tirau sandy loam
Pukeatua	Sheep	10 yr	Otorohanga silt loam
Hodderville I and II	Sheep	10-15 yr	Tirau sandy loam
Reporoa	Sheep	5 yr	Taupo sandy silt
Pio Pio	Sheep	20-30 yr	Wairere silt loam

NOTE: Trials are identified by the name of the nearest township.

RESULTS

DRY MATTER PRODUCTION

In the second year of the Arapuni trial, dry matter production in the June/July cut was increased by 44% with spraying at maintenance rates of superphosphate and by 31% at the high rate (Table 3). Production in August/September increased by 21% with paraquat at maintenance phosphate. There was no difference between paraquat and control at the high rate of superphosphate in this cut.

TABLE 3: DRY MATTER PRODUCTION — ARAPUNI (lb/acre)
(Results for second year)

<i>Phosphate (cwt)</i>		<i>Paraquat (oz)</i>	<i>D.M. Production</i>	
			<i>Jun. 2 - Jul. 28</i>	<i>Aug. 14 - Sep. 20</i>
0	....	0	340 bC	1,170 cdBC
		4	310 bc	1,050 dC
Maintenance	....	0	410 bBC	1,260 bcdABC
		4	590 aA	1,530 aA
High	....	0	540 aAB	1,420 abAB
		4	670 aA	1,380 abcABC
CV	....	....	16.9%	13.3%

At Pukeatua, the major difference in the winter cut June 6 to July 24 was between methods of sowing, particularly on sprayed plots (Table 4). There was a significant interaction between sowing and paraquat whereby production was depressed by spraying on broadcast plots but improved slightly over the controls where seed was drilled (670 drill/control, 720 drill/paraquat, 630 broadcast/control and 490 broadcast/paraquat).

TABLE 4: MAIN EFFECT MEANS, JUNE-JULY — PUKEATUA
(lb D.M./acre)

Drill/maintenance phosphate	670 b	Drill	700 aA
Drill/high phosphate	730 a	Broadcast	560 bB
Broadcast/m'tnce. phosphate	510 b	Maintenance phosphate	590 a
Broadcast/high phosphate	600 a	High phosphate	670 a
CV at sub-plot level = 22.1%			

TABLE 2: SUMMARY OF TREATMENTS AND DESIGN

Trial	Treatments				Sowing	Design
	Paraquat	Fertilizer		Nitrogen		
		Phosphate				
Arapuni	0, 4 (5/4/66)	0, maintenance (April 1966 and 1967) and high (April '66, Sept. '66 plus main- tenance April '67 and Sept. '67)	—	—	A + M broadcast (6/4/66)	Randomized block, 5 replications. Plots 10ft x 30ft
Pukeatua	0, 4 (8/2/67)	Maintenance and high (8/2/67)	0, 1 & 3 cwt calcium ammonium nitrate (8/2/67)		A + M broadcast at 20 lb per acre; A + M drilled at 10 lb per acre (5 lb in two rows at 30°) (8/2/67)	Factorial, plots 8ft x 25ft
Hodderville I	0, 2 (27/2/67)	Maintenance	—		Nil, A + M drilled at 1½ lb per acre, A + M drilled at 11½ lb plus Wester- wolds ryegrass at 17½ lb per acre drilled at 90° to A + M	Randomized block, 4 replications. Plots 16ft x 100ft

Hodderville II	0, 2 (9/11/66, 9/1/67, 21/2/67)	Maintenance	—	Randomized block, 5 replications. Plots 16ft x 200ft
Reporoa	0, 3 (25/10/66) 0, 2 (13/3/67)	Maintenance	—	Randomized block, 4 replications. Plots $\frac{1}{4}$ acre
Pio Pio	0, 2 (13/11/67)	Maintenance	—	Factorial with two stocking rates 18 and 24 ewe lambs 18/2/67 to 25/3/68. Plots 0.44 acre and 0.56 acre (high and low stocking rate)

- NOTE: 1. Rate of paraquat is in ounces active ingredient per acre.
2. *Maintenance phosphate* is the fertilizer normally applied at each site per acre:
Arapuni — 4 cwt superphosphate
Pukeatua — 5 cwt 30% potassic superphosphate
Hodderville I and II — 3 cwt superphosphate
Reporoa — 6 cwt potassic serpentine superphosphate
Pio Pio — 3 cwt 30% potassic superphosphate.
High phosphate is maintenance plus additional superphosphate equivalent to that applied as maintenance. (e.g. Pukeatua 5 cwt 30% potassic superphosphate + 4 cwt superphosphate = "High").
3. Sowing "A" + "M" is Grasslands 'Ariki' plus 'Manawa' rye-grasses mixed at 3 lb "A" + 1 lb "M".

TABLE 5: MAIN EFFECT MEANS, AUGUST-SEPTEMBER
— PUKEATUA (lb D.M./acre)

Paraquat 0	....	....	....	1,630 bB	Drill ....	....	....	1,760 a
Paraquat 4 oz	....	....	....	1,900 aA	Broadcast ....	....	....	1,770 a
Maintenance phosphate	....	....	....	1,750 a				
High phosphate	....	....	....	1,780 a				

CV at sub-plot level = 14.3%

In the August/September cut there was a 20% response to paraquat (Table 5). Method of sowing and rate of superphosphate had no effect.

In no cut did calcium ammonium nitrate applied on February 8 cause any effect on total dry matter production.

At Hodderville I the main effect of spraying was to increase dry matter production in the early spring cut, August 24 to October 11 (Table 6). Production in the period May 8 to August 14 was not affected by treatments applied.

TABLE 6: MAIN EFFECTS — HODDERVILLE I, 24/8/67 TO 11/10/67
(lb D.M./acre)

No seed	....	....	....	....	....	....	1,530 a
Seed	....	....	....	....	....	....	1,890 a
No Westerwolds	....	....	....	....	....	....	1,980 a
Westerwolds	....	....	....	....	....	....	1,800 a
Paraquat 0	....	....	....	....	....	....	1,670 bA
Paraquat 2 oz	....	....	....	....	....	....	2,110 aA
CV	....	....	....	....	....	....	19.5%

The effect of time of applying 2 oz paraquat on rate of recovery is shown in Table 7 relative to the untreated at Hodderville II. Recovery was most rapid from early January spraying.

TABLE 7: RATE OF RECOVERY FROM 2 OZ PARAQUAT
HODDERVILLE II
(Production for 8 weeks from spraying relative to untreated)

<i>Paraquat Applied</i>	<i>Production</i>
nil	100
2 oz 9/11/66	63
2 oz 9/1/67	88
2 oz 21/2/67	72

PASTURE COMPOSITION

The effect of spraying and oversowing as shown at Arapuni 15 months after treatment was a large reduction in unpalatable and low-producing

grasses [Yorkshire fog (*Holcus lanatus*), sweet vernal (*Anthoxanthus odoratum*) and browntop (*Agrostis tenuis*)] and an increase in ryegrass (*Lolium* spp.) and to a smaller extent white clover (*Trifolium repens*) (Table 8). The fertilizer effect followed the same pattern but to a much smaller degree.

TABLE 8: PASTURE COMPOSITION BY POINT ANALYSIS
— ARAPUNI, 24/9/67

("Cover" hits per 50 points)

<i>Paraquat</i>	<i>Phosphate</i>	<i>Ryegrass</i>	<i>White Clover</i>	<i>Total Unpalatable and Low-producing Grass</i>
0	0	24	8	23
0	maintenance	24	14	19
0	high	31	10	12
4	0	30	12	3
4	maintenance	34	13	4
4	high	33	13	2

The effect of 2 oz of paraquat on pasture composition two months after spraying at Pio Pio was to cause a similar reduction in unpalatable and low-producing grasses, a marked increase in clover but little difference in ryegrass (Table 9).

TABLE 9: PASTURE COMPOSITION BY POINT ANALYSIS
— PIO PIO, 12/2/68

("Total" hits per 100 points)

<i>Paraquat</i>	<i>Ryegrass</i>	<i>Clover*</i>	<i>Yorkshire Fog</i>	<i>Browntop</i>
0	43	25	81	24
2 oz	34	63	12	8

* Mostly *T. repens*, some *T. subterraneum*.

At Hodderville II the optimum time of applying 2 oz paraquat in terms of increasing clover content and reducing unpalatable and low-producing grasses was January 9 (Table 10).

Herbage dissection analysis data were obtained for Pukeatua and Hodderville I (Tables 11 and 12). Grass establishment was improved by spraying at both trials. At Hodderville I, cross drilling with Grasslands '4707' (Westerwolds) ryegrass resulted in a higher proportion of total ryegrass and a reduction in *Poa* species.

Unpalatable and low-producing grasses were reduced by spraying at Pukeatua. Drilling improved ryegrass establishment on sprayed plots but the resultant stronger ryegrass suppressed clover.

TABLE 10: PASTURE COMPOSITION BY POINT ANALYSIS
— HODDERVILLE II, 20/7/67
("Cover" hits per 50 points)

	<i>Paraquat</i>	<i>Ryegrass</i>	<i>Clover</i>	<i>Unpalatable and Low-producing Grasses</i>
0		11	8	14
2 oz 9/11/66		7	11	13
2 oz 9/1/67		11	20	4
2 oz 21/2/67		8	15	4

TABLE 11: HERBAGE DISSECTION ANALYSIS — HODDERVILLE I
(% dry weight October 11, 1967; lb D.M./acre Aug. 24 to Oct. 11
in parenthesis)

	<i>Ryegrass</i>	<i>Clover</i>	<i>Poa Species</i>	<i>Unpalatable and Low-producing Grasses</i>
No seed	37 (570)	16 (240)	27 (410)	21 (320)
Seed	46 (870)	12 (230)	25 (470)	17 (320)
No Westerwolds	40 (790)	13 (260)	32 (630)	15 (300)
Westerwolds	52 (940)	11 (200)	18 (320)	18 (320)
No paraquat	37 (620)	14 (230)	20 (330)	29 (480)
2 oz paraquat	55 (1120)	10 (210)	30 (630)	4 (80)

TABLE 12: HERBAGE DISSECTION ANALYSIS — PUKEATUA
(% dry weight February 13, 1968, Maintenance phosphate only;
lb D.M./acre Jan. 4 to Feb. 13 in parenthesis)

<i>Paraquat</i>	<i>Sowing</i>	<i>Ryegrass</i>	<i>Clover</i>	<i>Other Grasses*</i>
0	Drill	26 (380)	38 (560)	36 (530)
0	Broadcast	29 (410)	35 (500)	35 (500)
4 oz	Drill	54 (710)	28 (360)	15 (200)
4 oz	Broadcast	38 (550)	35 (650)	15 (220)

* Unpalatable and low-producing grasses as above plus *Poa* species and trace of *P. dilatatum*.

LAMB LIVEWEIGHT CHANGES

At Reporoa, lambs stocked at 24 per acre gained 1 lb per head more liveweight each week for 10 weeks December 15 to February 28 on paraquat treated pasture than on the control (Table 13).

The main effect on liveweight at Pio Pio was due to spraying (8.9 lb) rather than stocking rate (5.6 lb) (Table 14).

Neither effect reached significance, owing largely to poor performance of two high stocked plots, one of each chemical treatment. The stocking rate factor will be removed from this trial for the winter so as to effect a period of uniformity.

TABLE 13: LAMB LIVEWEIGHT CHANGES — REPOROA

(lb per lamb)

<i>Date</i>	<i>Control</i>	<i>Paraquat</i>
Dec. 15, 1967	49.1	48.9
Jan. 12, 1968	61.3	65.0
Feb. 9, 1968	72.2	78.7
Feb. 28, 1968	75.8	85.6
Total gain Dec. 15 to Feb. 28	26.7 bB	36.7 aA
S.E. per lamb = 4.3 lb		

TABLE 14: MAIN EFFECT MEANS — PIO PIO

	<i>Liveweight Gain (lb)</i> <i>18/12/67 to 25/3/68</i>
Paraquat 0	11.1 a
Paraquat 2 oz	20.0 a
	8.9 as effect of spraying
Low stocking rate (18 lambs/acre)	18.3 a
High stocking rate (24 lambs/acre)	12.7 a
	5.6 as effect of stocking rate.
S.E. per lamb = 4.5 lb.	

DISCUSSION OF RESULTS

The main responses of pastures to paraquat are shown graphically in Fig. 1 where the "productive level" (dry matter, grass establishment, live-weight changes) for the control is reduced to 100.

BIOLOGICAL RESULTS

(a) Fertilizer/Spraying Interaction

In reviewing the results obtained, it must be noted that in none of the phosphate by paraquat trials was spraying treated in isolation of over-sowing.

The 44% increase in winter dry matter production at Arapuni on sprayed plots indicates something more than improved grass establishment alone. At Pukeatua, drilling caused higher dry matter production in the first winter cut owing to better grass establishment. However, despite this, the only factor causing any difference in the later cut was paraquat.

Jackman (1960) explains competition between plants for nutrients on the basis of differing Cation Exchange Capacities (CEC) of the roots of each plant. Clovers (high CEC) are weak competitors for phosphorus and potassium. The effect of paraquat is to cause an immediate phase of clover dominance. The more efficient use of maintenance rates of super-phosphate as shown in these trials could be explained at least in part

Fig. 1: Responses to paraquat (relative to untreated pastures = 100)

by the greater competitive ability of clovers during this phase. Production in the later winter/early spring period would be the result of increased nitrogen fixation by the more vigorous clover.

(b) Grass Establishment

Establishment of oversown grasses was markedly improved by spraying. Drilling caused more rapid establishment and a higher proportion of ryegrass than did broadcasting.

Cullen (1966) showed a response from paraquat in establishment of cocksfoot on unploughable hill country of the South Island, more especially in dense browntop swards than on sparse fescue-tussock (*Festuca novae-zelandiae*). Clover establishment was not materially assisted by spraying in Cullen's work.

In the higher summer rainfall districts of the North Island, improved establishment of grasses through spraying is obviously due to removal of competition from the originally dense sward. Further work should investigate relative establishment of oversown clovers in these districts.

(c) Lamb Liveweights

At Reporoa, repeated spraying with paraquat (3 oz 25/10/66, 2 oz 13/3/67, 2 oz 15/11/67) has resulted in a pure species pasture, white clover from November 1967 to February 1968. The control pasture has been subjected to grazing pressure (up to 200 ewes per acre) which would not be practical on the majority of farms. Thus both treatments have caused the maximum change possible through each system and as such can be compared one to the other on this basis.

The Pio Pio trial is an example of the response of lower intensities of treatment. The effect of changes in pasture composition brought about by paraquat was to increase liveweight gains in favour of the sprayed plots.

From January to March the trial area was under serious drought conditions, yet the effect of stocking rate was less than that of paraquat.

Two further effects of spraying observed in the Pio Pio trial were complete control of Scotch thistle (*Cirsium lanceolatum*), in the rosette stage at spraying, and improved palatability of the pasture to young stock.

IMPLICATIONS OF RESULTS TO FARM MANAGEMENT

The districts in which the trials were located have as the main factor limiting farm production the seasonability of pasture growth, and in particular the deficit of supply over demand from June to September. The main response to paraquat in terms of pasture growth occurred in this period. Improved establishment of oversown grasses by spraying with paraquat suggests that special purpose grasses such as Grasslands 'Paroa Italian' ryegrass or the new Grasslands 4707 (Westerwolds) ryegrass (Barclay and Vartha, 1966) could be economically grown to help overcome this deficit.

The trial studying time of applying paraquat in relation to biological results showed the necessity of matching spraying to the period of maximum pasture growth. As rate of growth determines the time at which a pasture may be withdrawn from the grazing rotation, interpreting biological effects to meet farm management requirements is a simple matter of deduction.

Lamb liveweight effects as shown at Reporoa and Pio Pio have direct application in lamb production. Current animal research (G. K. Hight, pers. comm.) is showing that ewe fertility is strongly related to hogget liveweight. Hight has shown that ewe hoggets which reach 75 lb liveweight in the oestrous season show oestrous activity. Furthermore, those showing cyclic behaviour as hoggets had a higher percentage of lambs born as two-tooths (23%) compared with those which did not show oestrus as hoggets.

Control of annual weeds could be incorporated into a programme using paraquat, at the same time reducing the unpalatable and low-producing grasses.

The work described in this paper indicates a broader interpretation to the use of herbicides in pasture farming, a development which is expected to play a greater part in increasing pastoral production.

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