SOME FACTORS AFFECTING THE PERSISTENCE OF PICLORAM IN THE SOIL

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Summary

The residual effect of picloram in some New Zealand soils on the growth of white (*Trifolium repens*), red (*T. pratense*) and subterranean clover (*T. subterraneum*), both in field and pot assays are described. Data on the effect of rainfall, vegetation cover, rate of application and soil type on the disappearance of picloram are discussed. Results are presented on the movement of picloram through the soil and the relative sensitivity of the three clover species is considered. The relative importance of the various factors which play a role in determining the rate of disappearance of picloram from the soil is evaluated.

INTRODUCTION

SINCE ITS DISCOVERY, picloram has proved to be an extremely active herbicide, controlling a wide range of annual and perennial broadleaf and woody weeds (Moffat, 1965, 1966; Mason, 1965, 1966). The outstanding features of picloram as a herbicide are its high activity at low dosages, its mobility and residual activity within plants, and its long-lasting effectiveness via the soil. Most members of the families Leguminosae and Solanaceae are extremely sensitive to picloram and, because of their importance in the agricultural economy of New Zealand, harmful side-effects from its use must be kept to a minimum. Determination of the rate of disappearance of picloram from the soil under field conditions is necessary to establish the minimum withholding period required before susceptible crops can be introduced following treatment.

Factors known to affect the persistence of picloram in the soil include, soil type, rainfall, organic matter, rate of application (Herr, *et al.*, 1966; Goring, *et al.*, 1965), microbiological activity and ultra-violet light (Wiltse, pers. comm.). This paper presents data on the disappearance of picloram from soils studied at various sites in New Zealand using white (*Trifolium repens*), red (*T. pratense*) and subterranean clover *T. subterraneum* as the test species in qualitative bio-assay technique. Information is also presented on the varietal susceptibility of these clovers to picloram and its movement in the soil.

EXPERIMENTAL

The field sites selected were essentially level. The cultivated site was rotary-hoed to a depth of 6 in. graded and rolled to a uniform well compacted seedbed. Prior to the final working, the area was fumigated with methyl bromide at 1 lb/100 sq. ft five weeks prior to treatment. Apart from clover, a high degree of weed control was obtained, the few remaining weeds being controlled by hand hoeing. All treatments were applied as a water-soluble salt formulation to plots 31 ft × 7 ft, using an Oxford Precision Sprayer applying 32 gal of spray per acre.

Treatments were replicated five or six times with untreated buffer strips between plots being at least 6 ft wide. All rates are expressed as lb of active ingredient per acre.

Soil cores 1.75 in. in diameter were taken at random on the various treated plots to a depth of 6 in. These were divided into two sections—0 to 3 in. and 3 to 6 in. The separate soil cores were broken up and placed in 3 in. waxed paper pots. White clover, red clover and subterranean clover were surface sown either alone or in mixture on the thoroughly mixed soil and lightly covered with river washed fine gravel. The pots were placed in a cold frame and carefully watered overhead as soil conditions demanded. On some field sites clover was oversown at the time of sampling. On the bare soil area this was done with a Planet Junior seeder and on the pasture sites the seed was introduced into a groove $\frac{1}{4}$ to $\frac{1}{2}$ in. deep cut into the turf. The pasture was kept mown to reduce plant competition until the clover was clearly established. Observations were made for clover survival and vigour 4 to 6 weeks after sowing, this being sufficient time to allow full development of any of the characteristic picloram symptoms, or to allow death of the seedlings to occur. Qualitative ratings were made on a 0 to 5 scale by three or more independent observers using the following classification:

- 0—No establishment—the seedlings germinated and died.
- 1—20% establishment with severe foliage symptoms and severely stunted growth.
- 2—50% establishment showing marked symptoms and reduction in growth.
- 3—100% establishment showing moderate symptoms with some reduction in growth.
- 4—100% establishment showing slight symptoms with no apparent reduction in growth.
- 5—Normal growth with no visible symptoms.

For practical purposes, a mean rating of 4 or above indicates that a normal bulk of leaf and stem tissue of clover had developed.

RESULTS AND DISCUSSION

VEGETATION

Two identical trials were laid adjacent to each other in September 1966, on a free-draining soil classified as a New Plymouth silt loam—one on a weed-free cultivated soil and the other on a vigorous well-established perennial ryegrass/white clover pasture. At the time of treatment, the height of the pasture varied from 4 to 6 in. Samples were collected at various time intervals and subterranean clover oversown on both trials.

Ratings of clover vigour in soil samples from the 0 to 3 in. soil zone and for clover sown in the field were made 4, 8, 12, 16 and 21 weeks after treatment (Table 1).

Depression of clover establishment and vigour was much more severe on bare soil compared with that under pasture cover. With the sampled soil, clover establishment and vigour were not significantly different from the untreated control 4 weeks after treatment with up to 0.25 lb

TABLE 1: EFFECT OF VEGETATION COVER ON PICLORAM RESIDUES IN SOIL

Treatment (lb)	4 wk. (2.57 in.)	8 wk. (9.81 in.)	12 wk. (14.54 in.)	16 wk. (19.63 in.)	21 wk. (24.92 in.)
BARE SOIL—SAMPLE DEPTH 0 TO 3 IN.					
Untreated control	... * (—) 4.1aA	(4.7) 4.4aA	(5.0) 3.9aA	(5.0) 3.1abAB	4.1abAB
Picloram 0.0625	... (—) 1.6bcB	(4.0) 2.8bAB	(5.0) 3.5abAB	(5.0) 2.6abcdABCD	4.1abAB
Picloram 0.125	... (—) 1.8bB	(3.4) 2.6bcBC	(5.0) 2.5cC	(5.0) 2.1deDE	4.1abAB
Picloram 0.25	... (—) 1.0 bcdB	(3.0) 2.0bcdBCD	(5.0) 2.2cdCD	(5.0) 3.1abAB	3.6cBCD
Picloram 0.5	... (—) 0.2 dB	(2.2) 1.2dCD	(5.0) 1.8dD	(5.0) 3.1abAB	3.2deDE
Picloram 1.0	... (—) 0.2dCB	(1.3) 0.8eD	(5.0) 1.4eE	(5.0) 1.6eE	2.8efE
CV	... 12.1%	6.4%	2.3%	3.3%	2.0%
PASTURE—SAMPLE DEPTH 0 TO 3 IN.					
Untreated control	... (5.0) 4.3aA	(5.0) 3.6abAB	(5.0) 3.8aA	3.7aA	4.1abAB
Picloram 0.0625	... (4.5) 3.9abABC	(4.7) 3.6abAB	(5.0) 3.7abAB	4.1aA	4.1abAB
Picloram 0.125	... (4.8) 3.8 abcdABCD	(4.4) 3.8aA	(5.0) 3.4abcdABC	3.7aA	4.0abcABC
Picloram 0.25	... (2.9) 3.9abcABC	(4.3) 3.5abcdABC	(5.0) 3.7abAB	3.7aA	3.6dBCD
Picloram 0.5	... (1.3) 2.8abcde	(4.1) 2.6eDE	(5.0) 3.2bcde	3.5aA	3.2deDE
Picloram 1.0	... (0) 1.1fE	(4.1) 2.2eE	(5.0) 2.4fE	3.2aA	2.8efE
CV	... 7.1%	2.6%	2.4%	2.7%	1.4%

* (—) Establishment and vigour of oversown clover at field site.

picloram on pasture, whereas a considerably longer period (16 weeks), was required on bare soil. A similar result was apparent with oversowing but in this case the clover suppression was of a shorter duration.

In this trial fumigation prior to treatment may still have had some residual effect on microbial activity in the early trial stages. Compared with the bare soil, the greatly reduced clover suppression in the pasture site is most probably due to the much lower concentration of picloram present in the soil. This would primarily in turn be due to interception of the spray by the foliage and also the uptake of the chemical from the soil by the root system of tolerant species, in this case grasses. Studies using radioisotope-labelled picloram clearly indicate that soils containing living plant roots are considerably more active in deactivating picloram than bare soil (Meikle *et al.*, 1966).

RAINFALL

A comparison of assessments for clover vigour following treatment of picloram on two free-draining soils under differing rainfall regimes is presented in Table 2.

TABLE 2: INACTIVATION OF PICLORAM AT TWO SITES, UNDER CONTRASTING RAINFALL CONDITIONS
(Sample Depth 0 to 3 in.)

<i>Treatment (lb)</i>	<i>Waimakariri Silt Loam Weeks after Treatment</i>		<i>New Plymouth Silt Loam Weeks after Treatment</i>	
	12 (5.84*)	21 (9.84*)	12 (14.54*)	21 (24.92*)
Picloram 0.0625	2.7	3.1	3.7	4.1
Picloram 0.125	2.1	2.6	3.4	4.0
Picloram 0.25	1.8	2.6	3.7	3.6
Picloram 0.5	1.2	2.2	3.2	3.2
Picloram 1.0	0.6	0.9	2.4	2.8
Untreated	3.5	3.2	3.8	4.1

*Accumulated rainfall (in.) after treatment.

Both soil types are described as free-draining silt loams. Pasture cover was somewhat more dense on the Taranaki soil, which certainly contributed to the increased rate of disappearance of picloram. Nevertheless, results clearly suggest that rainfall has a marked influence on the rate of disappearance of picloram from the surface layer of the soil.

MOVEMENT IN SOIL

Assessment of clover vigour for 0 to 3 in. and 3 to 6 in. soil samples taken at intervals from pasture on a Taranaki soil following treatment with picloram are presented in Table 3.

The results indicate fairly rapid downward movement of picloram through the soil profile on a free-draining soil under the conditions of moderate to high rainfall. Twenty-one weeks after treatment, 2 lb of picloram was giving no significant clover depression in the 0 to 3 in. layer, while there was still a noticeable effect at the 3 to 6 in. level. The 4 lb rate gave marked suppression at both soil levels, with the effect being most severe in the lower region. This trend was also evident for lower rates, that is, down to 0.25 lb, but with complete

TABLE 3: MOVEMENT OF PICLORAM THROUGH SOIL PROFILE

Treatment (lb)	Sample Depth (in.)	Weeks after Treatment			
		9 (13.39*)	13 (15.41*)	17 (22.71*)	21 (22.86*)
		Clover Growth			
Picloram 2.0	0-3	2.1	1.9	3.4	4.0
	3-6	2.0	1.3	2.5	3.3
Picloram 4.0	0-3	1.7	1.3	2.6	3.2
	3-6	1.2	0.2	1.4	2.3
Untreated control	0-3	3.6	3.5	4.2	4.1
	3-6	4.4	3.2	4.2	4.3

*Accumulated rainfall (in.) after treatment.

recovery of plant growth achieved within a shorter time. Movement downwards through the soil appears more variable in treatments with 0.0625 lb and 0.125 lb of picloram, probably because of the reduced soil contamination from the interception by the pasture foliage at these low rates. Further studies are required on the rate and pattern of movement of picloram in the subsoil region of various soil types.

RATE OF APPLICATION

The results presented in Table 1 indicate that the period required for the disappearance of picloram from the surface zone of the soil increases with higher rates. There is some doubt as to whether the rate of disappearance of picloram is directly proportional to its concentration in the soil (Goring *et al.*, 1965). Alternatively, there may be a similar rate of disappearance but a lag period follows prior to degradation of all concentrations and this lag period increases with higher concentrations (Grover, 1967).

SOIL TYPE

The characteristics of the soil type are influenced by inter-related factors such as parent material, rainfall, soil temperature, nature of plant cover, and topography. As these factors vary with the site, only broad conclusions can be drawn as to the effect of soil type on the rate of disappearance of picloram. Details of mechanical analyses and pH of the soil types in the present study are listed in Table 4.

TABLE 4: MECHANICAL ANALYSES % AND pH OF SOILS SAMPLED IN SURVEY

Soil Type	Mechanical Analysis %			pH
	Clay	Silt	Sand	
New Plymouth black loam	 27	18	55	5.9
Rotomahana shallow sandy loam	12	25	63	5.8
Waimakariri silt loam	 18	29	53	5.9
Oxford mottled silt loam	 28	40	32	5.4

With the exception of the Oxford clay loam, all were comparatively free-draining soils. A similar rate of disappearance of picloram was observed under comparable rainfall. However, dissipation of residues from the surface zone has been slower under lower rainfall and on the heavy clay. The greatest sorption of picloram is observed on soils containing a high percentage of organic matter and for acidic soils. Maximum sorption of picloram is reached only slowly by high organic soils (Hamaker *et al.*, 1966).

CLOVER SENSITIVITY

White, red and subterranean clover were sown on a pasture soil treated three months previously with various rates of picloram. Each treatment was replicated four times. Plants were harvested after 12 weeks. Germination percentage and dry weights of harvested tops for red, white and subterranean clover growing under varying rates of picloram are presented in Table 5.

The 0.25 lb rate of picloram on subterranean clover was the only treatment to give a significant depression in yield. At the time of harvest, leaf cupping symptoms of picloram were visible only on subterranean clover at the two highest rates. Although this trial was of only an exploratory nature it does support field plot observations from over-drilling the three species that subterranean clover is much more sensitive to picloram than white and red clover. White and red clover exhibit a similar degree of sensitivity to picloram.

CONCLUSIONS

The results in the present study deal with the top 6 in. layer of the soil. The root systems of the major New Zealand pasture legumes, with the exception of lucerne, are mainly confined to this upper layer. This is supported by the normal growth of oversown clover observed in the field while growth suppression has continued in soil from the 3 to 6 in. layer taken from the same site. Normal establishment of clovers is more rapid when seed is oversown on pasture. This is the usual method of clover introduction on areas treated for the control of brush weeds. Picloram residues at the lower level (3 to 6 in.) appear to be of practical significance only where rates above 0.5 lb are applied or when cultivation is carried out which may redistribute the chemical into the root zone of the establishing legume. The present results support field experience under similar conditions that the use of low rates of picloram, up to 0.125 lb per acre, for crop and pasture weed control presents little hazard to establishing clovers sown at the normal time following utilization of the crop or in the autumn following a spring application.

Soil residues for higher rates, 0.5 to 3 lb per acre, used for brush weed control take longer to dissipate. Although such dosages may be applied topically to brush weeds, the rate actually reaching the soil to present a potential residue hazard may be considerably less. In dense stands of brush weeds this may be as low as 10% (Merkle *et al.*, 1966). Undoubtedly, considerable variation will occur in the speed of dissipation of picloram used at brush killing dosages, although practical field experience indicates that clover can be successfully established in some such areas 12 to 15 months after treatment.

This work of a qualitative nature supports the evidence that plant cover, rainfall, rate of application and soil type all have an important

TABLE 5: VARIETAL SENSITIVITY—WHITE, RED AND SUBTERRANEAN CLOVER

<i>Treatment (lb)</i>	<i>White Clover</i>				<i>Red Clover</i>				<i>Subterranean Clover</i>			
	0	0.0625	0.125	0.25	0	0.0625	0.125	0.25	0	0.0625	0.125	0.25
Germination (%)	84	83	75	78	67	66	58	63	77	92	82	70
Dry wt. tops (g)	1.23	1.52	1.37	0.99	1.19	1.23	0.80	1.42	1.42	1.51	0.82	0.55
Relative	100	124	111	81	100	104	68	73	100	106	58	39
LSD 5%	0.67				0.67				0.64			

effect on the rate of disappearance of picloram from the soil. These factors all influence microbial activity which almost certainly has an important effect on picloram loss, although the actual mode of micro-organism degradation has not yet been clearly defined. Further studies are now required to establish conclusive data measuring the effect of picloram on pasture production.

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