NEW DEVELOPMENTS WITH LINURON

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Summary

This paper reports and discusses the results of further trials with linuron-treated crops, with onions, wheat and maize. Testing for linuron residues in asparagus is also discussed. While applications of 0.5 lb a.i. per acre of linuron at the 2-leaf stage of Pukekohe-grown onions can be recommended, the timing of the initial application to crops grown elsewhere requires further investigation. For wheat, rates of 3 to 6 oz a.i. per acre, depending on the weeds present, are suggested for trials for early application at the 2- to 4-leaf stage. Mixtures incorporating mecoprop for example are necessary for the control of thistle (*Cirsium* spp.). In maize the control of barnyard grass (*Echinochloa crus-galli*) is enhanced by the addition of 0.5% v/v of non-ionic surfactant (100% active ingredient).

INTRODUCTION

THE USE of linuron in potato crops is discussed in another paper presented to this Conference (Sumich, 1966). Linuron at rates of 0.5 to 2 lb (all rates in active ingredient per acre) whether pre- or post-emergence has been accepted by growers for weed control in carrots and parsnip crops. Soil type and growth determine actual rates used. Other crops for which linuron appears to be a likely candidate at rates of 0.5 to 1.0 lb include leeks and celery after transplanting and post-emergence asparagus beds. Previously (Sumich, 1963), linuron was suggested for pre-emergence treatment of field beans and post-emergence in peas. Although trials indicated that these treatments caused no significant yield decreases because of the lack of twofold tolerance, the recommendation has been discarded.

ONIONS

Weed control in onions has been the subject of three papers at recent Conferences (Thompson, 1961; Patterson, 1962; Thompson, 1962) and in nearly all the trials discussed an endeavour was made to maintain a wide spectrum of weed control over periods of up to six months by means of a single application of weedkiller. This is beyond the capacity of any selective herbicide so far developed. In Pukekohe where some 800 to 900 acres of onions are grown annually, it is found that pre-emergence applications of chlorpropham/CDAA or chlorpropham/diquat require to be followed by several successive applications of sulphuric acid, depending on the seasonal conditions. Observational trials carried out during 1964 indicated that linuron gave satisfactory weed control with crop tolerance equal to that of sulphuric acid.

In 1965 it was decided to conduct a yield trial in which standard treatments were compared with linuron applied both at pre- and

post-emergence stages of growth, followed by subsequent further applications. It was hoped that the trial could produce evidence to indicate the earliest stage at which linuron can be applied to onions. Because the spectrum of weed control of linuron was already known, the trial was conducted more as a study of crop tolerance than as an exercise in perfect weed control. With the object of maintaining weed control of the variously treated plots at a commercially acceptable standard, follow-up treatments were made as and when considered necessary.

Pukekohe Longkeeper seed was sown on July 4, 1965, at 5 lb per acre, soil type basaltic red brown loam. Plot sizes were 40 ft × 5 ft and were replicated five times. Applications were made by a modified Oxford Precision Sprayer fitted with FS 4.5 nozzles to deliver 50 gal per acre at 30 lb/sq. in.

The major weeds present in this trial were fathen (*Chenopodium album*), redroot (*Amaranthus hybridus*), twin cress (*Coronopus didymus*), barnyard grass (*Echinochloa crus-galli*), nightshade (*Solanum nigrum*), fumitory (*Fumaria* spp.), wireweed (*Polygonum aviculare*), groundsel (*Senecio vulgaris*). It was necessary to supplement spraying by one additional hand-weeding on September 16 to remove all resistant weeds. These were mainly fumitory, twin cress and wireweed. Nutritional deficiencies caused by the heavy sowing rate became obvious and onions not thinned by weedkiller or by other causes were small, particularly the sulphuric acid treated plots. On the other hand, the chlorpropham/linuron treatment produced many big onions. It is possible that hand-weeded control yield suffered by careless weeding and nutrition problems. Onions were counted on September 10 after all plots had had one treatment and the final count on January 26 was made just before harvesting. The counts indicate that chlorpropham cannot be recommended for pre-emergence control in Pukekohe. This is confirmed by many field applications where widespread damage has occurred. Yield results indicate that it is safe to use linuron at 0.5 lb once the onions have grown to 2 in. or have formed two true leaves but the earlier application is damaging. Crop damage caused by linuron spraying took seven to ten days to appear. The characteristic "drooping" of onion plants caused by post-emergence linuron sprays, which was noted, disappeared after fourteen days and caused no permanent damage.

WHEAT

There has been considerable interest in Australia in recent years in the use of linuron at 3 to 6 oz for the control of *Amsinskia* spp. Following up this information, local observational trials were planned. Because it was realized that linuron alone would not control thistles and fumitory, mixtures of linuron with mecoprop or 2,3,6-TBA were applied in Trial 2. It was appreciated that linuron at rates as low as 3 to 6 oz will give good weed control; however, it must be applied at a much earlier stage of weed development than that at which it is safe to use hormone preparations — usually the tillering stage of the crop. This condition was met in Trial 1, but in Trial 2 weeds had grown past the stage at which low rates of linuron would perform satisfactorily. All plots were sprayed by means of a modified Oxford Precision Sprayer, fitted with FS 4.5 nozzles and delivering 35 gal of water per acre at 30 lb/sq. in. Plot sizes were 10 ft × 10 ft.

TABLE 1: ASSESSMENT OF YIELD AND ONION COUNTS
Treatments (lb)

<i>Initial</i>	<i>Follow-up</i>	<i>Yield</i> (tons/acre)	<i>Onion Counts</i> (Mean Numbers) Sep. 10 Jan. 26
Linuron 0.5 (2 in. stage)		16.07 aA	713 abAB 652 aA
Hand-weed control		16.05 aA	700 abAB 601 aAB
Chlorpropham 2/Diquat 0.5 (pre-em.)		14.22 abAB	430 cC 312 cD
Linuron 0.5 (pre-em.)		13.74 abAB	590 abcABC 479 bBC
Linuron 0.5 ("hook stage")		12.66 abcAB	543 bcABC 477 bBC
Chlorpropham 2/CDA 3 (pre-em.)		11.20 bcAB	469 cBC 320 cD
Chlorpropham 2/Diquat 0.5 (pre-em.)		10.94 bcAB	465 cBC 383 cCD
Chlorpropham 2/CDA 3 (pre-em.)		9.45 cB	430 cC 312 cD
H ₂ SO ₄ 70%		9.38 cB	771 aA 601 aAB
CV		22.9%	3.6% 2.6%

H₂SO₄ — rates varied from 50 to 75 gal of 1/10 to 1/17 dilutions depending on weed size and type.

TABLE 2: WHEAT, TRIAL 1

Wheat variety: Gamenya Sown: Nov. 10, 1965
 Treated: Nov. 24, 1965 (2- or 4-leaf) and Nov. 30, 1965 (tilling),
 growers' practice
 Weeds: Fathen (2- or 4-leaf), nightshade (2-leaf), redroot (2- to 4-leaf),
 barnyard grass (4-leaf)
 Soil: River silt

Treatment (2 replications) (oz)	% Weed Control Dec. 14, 1965	Crop Damage* Dec. 14, 1965
Linuron 4	95	5.0
Linuron 8	97	5.0
Linuron 16	98	3.5
Control	0	4.0
MCPA 16	70	4.5

* 0, Eliminated. 5, Normal.

TABLE 3: WHEAT, TRIAL 2

Wheat variety: Cappel Sown: Oct. 29, 1965
 Treated: Nov. 27, 1965
 Weeds: 1. Fathen (6-8 leaf). 2. Fumitory (3-4 in.). 3. Chickweed
 (*Stellaria media*) (4-6 leaf). 4. Californian thistle (*Cirsium
 arvense*) regrowth. 5. Spurrey (*Spergula arvensis*) (4 leaf). 6.
 Deadnettle (*Lamium purpureum*) (seedling). 7. Yarrow (*Achillea
 millefolium*) (seedling)
 Soil type: Clay loam

Treatment (3 replications) (oz)	% Weed Control Dec. 17, 1965							Crop Damage* Dec. 17, 1965
	1	2	3	4	5	6	7	
Linuron 3	10	24	12	0	20	13	0	5
Linuron 6	25	40	70	0	50	35	0	5
Linuron 8	80	50	95	0	90	75	0	5
Linuron 12	98	60	100	0	100	100	0	5
Linuron 16	100	60	100	0	100	100	0	5
Linuron 24	100	65	100	0	100	100	0	4.5
Linuron 3/Mecoprop 12	100	100	100	100	100	100	90	5
Linuron 6/Mecoprop 12	100	100	100	95	100	100	95	5
Linuron 8/Mecoprop 12	100	100	100	95	100	100	95	5
Linuron 3/2,3,6-TBA 4	100	100	100	95	100	100	90	5
Linuron 6/2,3,6-TBA 4	100	100	100	95	100	100	90	5
Linuron 8/2,3,6-TBA 4	100	100	100	95	100	100	95	5
Control	0	0	0	0	0	0	0	2.5

* 0, Eliminated. 5, Normal.

TRIAL 1

Linuron suppressed barnyard grass at all rates. By comparison, mecoprop-treated areas were soon overrun by the grass and the yield was obviously reduced. The observable damage caused by linuron at 16 oz rate consisted of leaf burn which appeared 10

days after spraying but which had completely grown out four weeks later. It was noted on linuron-treated plots that, while there was a delay in formation of the ears, the plant on the other hand appeared stronger, and a broader leaf width was noticeable.

TRIAL 2

Linuron gave disappointing weed control below 8 oz. However, at the time of application, weeds had grown past the stage when rates of 3 to 6 oz would perform satisfactorily. Crop scorch which was observed on one replication at the 24 oz rate was very mild and soon grew out. There was very little difference between mecoprop- or 2,3,6-TBA-linuron mixtures and both of these additives gave satisfactory weed control. Comparison of the results of these two trials indicate that it is essential that linuron be applied as early as possible at the 2- to 4-leaf stage in order to obtain an effective control of weed. Since mecoprop is tolerated by wheat at the 2- to 4-leaf stage, this material is a candidate for use as an additive to linuron. Additional observational trials were conducted on Aotea, Arawa and Hilgendorf varieties of wheat in Canterbury. No crop damage was observed at rates ranging from 3 to 6 oz.

MAIZE

In an earlier paper (Sumich, 1963) describing trials carried out in Gisborne, it was found that rates of 3 to 4 lb of linuron were needed for complete control of barnyard grass. It was suggested that the addition of a surfactant to linuron might produce greater foliar activity than linuron alone. A trial was therefore designed to compare various rates of linuron with and without the addition of surfactant at various concentrations. A one-acre block was divided into plots, each of 4 rows, and an application was made by means of a tractor-mounted boom using two sets of dropper arms to allow for directed spraying. The surfactant used was Du Pont Surfactant WK 99% active. The area was sown on October 25 and was sprayed on December 15 at the rate of 40 gal per acre. Two cultivations had been made to the maize previously in order to obtain a differential in height between the weeds and maize, and at the time of treatment the maize was 16 to 24 in. high and the weeds 2 to 10 in.

TABLE 4: ADDITION OF SURFACTANT TO LINURON IN MAIZE
Sowing date: October 25, 1965

<i>Treatment (lb)</i>	<i>Weed Control* Jan. 18, 1965</i>
Linuron 2/0.125% WK	5.0
Linuron 2/0.25% WK	5.0
Linuron 2/0.5% WK	9.5
Linuron 2/1.0% WK	10.0
Linuron 2	3.0
Linuron 4	9.5

* 0, No control. 10, Complete control.

There was no reduction in crop vigour on visual inspection—some plants showed signs of burning of leaves which had been unintentionally sprayed. Barnyard grass control was excellent at the linuron 4 lb rate alone, and the linuron 2 lb rate with 0.5 to

TABLE 5: RECOVERY OF LINURON

No.		Linuron Added (ppm)	Linuron Found (ppm)	Recovery (%)
1		1.00	0.90	90
2		2.00	2.01	101
3		2.99	3.01	101
4		4.99	4.62	93
5		1.00	1.00	100

TABLE 6: LINURON RESIDUES IN ASPARAGUS
Sampling times and results obtained

Sample Time	Control	0.5 lb	Linuron (ppm)		1.5 lb	2.0 lb
			1.0 lb			
Day of applica- tion	0.24	1.5	2.2		2.4	4.7
1 day after	0.17	0.12	2.3		2.3	2.2
2 days after	0.48	0.70	1.3		1.7	1.8
3 days after	0.34	0.50	0.59		0.53	1.1
4 days after	0.15	—	0.24		0.21	0.30
5 days after	0.13	0.15	0.16		0.17	0.22
6 days after	0.02	0.11	0.11		0.13	—

1% WK concentration. Where surfactant was used, the effect was noticeable after 10 days. When linuron was used alone, the results were slower to appear and 20 to 24 days elapsed before complete collapse of weeds. It is clear that the addition of surfactant reduces the rate of linuron necessary to control barnyard grass adequately. It is still necessary, however, to treat barnyard grass at the earliest possible stage so that the maize may have free access to available nutrients and moisture.

ASPARAGUS

Webster (1962) pointed out that crust formation on silty soil followed by heavy rains is a problem associated with the replacement by chemicals of traditional cultivation methods of annual weed control. In Hawke's Bay, however, rainfall generally declines by the beginning of October and crust formation becomes a decreasing hazard. There is here a place for a herbicide which can be applied between cuts, and which will not only give control of existing annuals, but also residual control until the end of harvest. Linuron gives excellent control of redroot, fathen and nightshade, the three main annual weeds in the Hawke's Bay area, and therefore fulfils these requirements. However, application of herbicides to asparagus during the cutting season must result in a residue problem. It is not known whether residue figures for linuron in asparagus have yet been published.

In order to investigate this matter, a trial was laid down on November 11, 1964, plot size 50 ft × 2½ ft, replicated three times. Application was made before a normal day's cutting and before the

first sample was taken. Linuron was applied at 0.5, 1.0, 1.5 and 2 lb per acre by means of a modified Oxford Precision Sprayer fitted with FS 4.5 nozzles which delivered 50 gal per acre at 30 lb/sq. in. Samples were cut immediately after spraying and thereafter each day for the following 6 days.

METHOD OF ANALYSIS

The method followed was described for diuron in the *Journal of the A.O.A.C.*, 45 (2): 377-81 (1962). This method calls for a chromatographic column 24 in. in length. In this work linuron was the only substituted urea present and therefore the shorter column as described in the *Journal of Agriculture and Food Chemistry*, p. 652 (1954) was used. The method of analysis was of sufficient accuracy for residue testing as can be seen from Tables 5 and 6.

Table 6 indicates that the results on the control varied to a great extent. The reason for this is not certain, but it appears that there could be some contamination of weed control plots. Since no approval has been granted by the Health Department and no official tolerance has yet been set in New Zealand, applications should not be made during the cutting season. Most weeds were only in the cotyledon stage and hence all rates, including the ½ lb, gave satisfactory weed control.

CONCLUSION

There is no doubt that a herbicide with the range of weed control shown by linuron, together with the crop tolerance it exhibits, will find an increasing place in New Zealand agriculture.

From the work discussed above, further trials are obviously needed in onions to establish tolerances on various soil types and under various rainfall conditions. In wheat, yield trials are obviously necessary to determine the effects of early application on the crop, and of course this can also be extended to oats and barley. It is hoped that reasonable tolerances can be set for the use of linuron during the cutting season in asparagus.

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