Chemical fallow systems for wheat production in the Victorian Wimmera

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Summary

Several combinations of herbicides were evaluated for use in chemical fallow systems in the Victorian Wimmera. It was shown that herbicides could be substituted for tillage on fallows without reducing the yield of the following wheat crops.

Amitrole-T, glyphosate and paraquat/diquat were effective as initial knockdown herbicides, while atrazine at 0.6 kg ha^{-1} applied in spring provided useful long-term control but required supplementary weed control by means of other herbicides. Atrazine at 0.8 kg ha^{-1} was effective when applied without a 'knockdown' herbicide 1 year before the crop was sown. Chlorsulfuron provided long-term control when applied alone or with atrazine. Cyanazine and diuron have potential as pre-sowing herbicides towards the end of chemical fallows, but use of oxyfluorfen resulted in crop damage. The main weeds causing problems on fallows were *Picris echioides*, *Lactuca serriola*, *Cirsium vulgare* and *Sonchus oleraceus*.

Introduction

In North America, chemical fallowing prior to planting dryland crops is widespread (Smika and Wicks 1968; Fenster and Wicks 1982) and has been shown to be more effective than cultivation. For example, over a 10-year period in the Central Great Plains of U.S.A., 38 mm more moisture was stored in the soil in chemically treated than in cultivated fallows and wheat yields 0.49 t ha^{-1} higher were obtained (Greb and Zimdahl 1980). In Australia, concern about the increasing cost of cultivation and its effects on soil structure have led to an evaluation of herbicides in reduced tillage systems in northern New South Wales and Queensand (summer dominant rainfall), South Australia and the Victorian Wimmera (winter dominant rainfall) (Holland and Doyle 1981; Freebairn and Ward 1981; Herrman and Fawcett 1985; Amor *et al.* 1986).

Chemical fallow systems based solely on the use of herbicides have three requirements. Firstly, the site has to be cleared with 'knockdown' herbicides such as amitrole-T, (3-amino-1, 2, 4-triazole, plus ammonium thiocyanate), paraquat/diquat and glyphosate. Thereafter the land should be maintained weed free over the summer. This is best achieved with a residual herbicide because repeated applications of knockdown herbicides are generally too expensive. Thirdly, weed control in autumn both prior to and after sowing the crop is required. As there is the possibility that the available residual herbicides may damage the crop, there is a need for chemicals which will control weeds at the end of the fallow and also provide selective control in the crop. The objectives of the investigations reported here were to determine the most appropriate herbicides currently available for chemical fallowing on clay soils in the Wimmera and to identify which weed species present the main problems.

Methods

Five trials were conducted between 1980 and 1982 at the Cereal Experimental Centre, Dooen, Vic., and the sixth trial, in 1982–83, was on an adjacent farm. The soils were alkaline (pH 8.3–8.6) grey self mulching clays (Ug 5.2; Northcote 1979). Those at the Cereal Experimental Centre were of high fertility (0.11–0.12% totals oil nitrogen in the surface 0–15 cm) while that on the farm site was of lower fertility (0.09% T.S.N.).

Rainfall and air temperatures at Dooen between 1980 and 1983 were given by Amor *et al.* (1986). The drought in 1982 had a severe effect on crop yield, the level of weed control achieved on fallows and the amount of moisture retained in the fallows prepared in that year.

The trials compared the effectiveness of herbicides applied either in spring or autumn of the year preceding a wheat crop with crops grown on conventionally cultivated fallows. The two objectives were to evaluate:

1. Chemical fallows commenced in spring at the normal time of fallowing (July–August);
   - *(a) Trial 1.* Evaluation of herbicides, in particular the use of an initial amitrole-T/atrazine application (1979/80).
   - *(b) Trial 2.* Evaluation of the use of chlorsulfuron or cyanazine to maintain an amitrole-T/atrazine fallow (1980/81).
   - *(c) Trials 3 and 4.* Revised treatments, to evaluate the use of an initial chlorsulfuron application with amitrole-T on wheat stubble (Trial 3) and pasture (Trial 4) 1980/81.
   - *(d) Trial 5.* Revised treatments, to enable further evaluation of chlorsulfuron and cyanazine (1981/82).
2. Chemical fallows commenced in autumn or spring;
   - *(a) Trial 6.* Evaluation of herbicides first applied in autumn or spring (1982/83).

Dates of spraying and sowing are given in Table 1 and herbicide rates in subsequent tables. Some treatments involved two herbicide applications on the same day, but no tank mixes were used. Follow-up herbicides were applied when necessary to control weeds.

All trials had randomized block designs with three or four replicates In trials 1–5, the plots were 2×15 m in area and sprayed with a pressurized knapsack sprayer at 125 l ha^{-1} and 200 kPa via a 2-m boom fitted with Spraying Systems 8001 nozzles. In trial 6 the plots were 6×60 m in area and sprayed at 140 l ha^{-1} and 200 kPa with a 6-m, tractor-mounted boom fitted with Spraying Systems 8002 nozzles.

The wheat (cv. Olympic) was sown with a modified drill, fitted with narrow tynes and off-set press wheels which sows 7 rows at 25-cm row spacing and is designed to enable direct drilling into heavy stubble residues. Crops were sown at a rate of 90 kg ha^{-1} with 10 kg phosphorus ha^{-1} applied as superphosphate.

Results

Weeds present

The main weeds occurring on the fallows were deadnettle (*Lamium amplexicaule*), fumitory (*Fumaria* spp.), Indian hedge mustard (*Sisymbrium orientale*), ox-tongue (*Picris echioides*), prickly lettuce (*Lactuca serriola*), sow thistles (*Sonchus* spp.), spear thistle (*Cirsium vulgare*), hogweed (*Polygonum aviculare*), prickly paddy melon (*Cucumis myriocarpus*), Dyer's litmus (*Chrozophora tinctoria*), red root amaranth (*Amaranthus retroflexus*), annual ryegrass (*Lolium rigidum*),

Table 1 Spraying and sowing dates

Trial description	Apr.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.Mar.Apr.	May	Wheat Jun.
							Chemical fallow in spring					
1. 1979/80	Pasture	Pasture	Pasture	Pasture	17[A] spray		29 2,4-D				14 pre-sow herbicides	23 sown
2. 1980/81	Pasture	Pasture	Pasture	18 Atrazine/ amitrole-T		19 Glyphosate			9 Chlorsulfuron or cyanazine		5 & 26 Chlorsulfuron	18 sown
3. 1980/81 stubble (Table 4)	Stubble	Stubble	Stubble	5 spray		14 Glyphosate		2 Glyphosate	22 Glyphosate		6 pre-sow herbicides	18 sown
4. 1980/81 pasture (Table 4)	Pasture	Pasture	Pasture	Pasture	23 spray		17 Glyphosate		22 Glyphosate		26 pre-sow	19 sown
5. 1981/82	Pasture	Pasture	Pasture	'Knockdown'[B] 24 residuals			25 Glyphosate 26 Residuals					3 sown
							Chemical fallow in autumn					
6. 1982/83	Pasture 29 residuals					8 residuals					7 Cyanazine 13 Glyphosate	16 sown

[A]Such values give the date in the month.
[B]Knockdown = paraquat/diquat plus 2,4-D ester.

Table 2 Trial 1: evaluation of herbicides, particularly the use of an initial amitrole-T/atrazine application 1979/80

Fallow treatment: Start of fallow (17.ix.79)	Pre-sowing (14.v.80)	Weed control in crop*[A] 17.ix.80: Broad-leaf	Annual ryegrass	Grain yield (t ha^{-1})
Cultivated fallow	Trifluralin 0.4 kg	1.7	1.1	3.44
Paraquat 0.38 kg, diquat 0.22 kg, cyanazine 2.5 kg	Cyanazine 2.5 kg	1.5	1.7	3.50
Amitrole-T 0.60 kg + atrazine 0.60 kg	Cyanazine 2.5 kg	1.5	1.2	3.10
Amitrole-T 0.60 kg + atrazine 0.60 kg	Trifluralin 0.4 kg	2.6	3.5	3.18
Amitrole-T 0.60 kg + atrazine 0.60 kg	Chlorsulfuron 25 g	1.0	1.0	3.13
Amitrole-T 0.60 kg + atrazine 0.60 kg	Oxyfluorfen 0.48 kg	2.2	3.1	3.11
LSD(P = 0.05)		1.2	0.9	0.28

[A]Weed control rating: 1 = 100%, 5 = no control.

barley grass (*Hordeum leporinum*) and brome grass (*Bromus diandrus*). In the subsequent wheat crops the main weeds were deadnettle, hogweed, fumitory and Indian hedge mustard.

1. Chemical fallows commenced in spring
   (a) Trial 1. Evaluation of herbicides, particularly the use of an initial amitrole-T/atrazine application 1979/80 (Table 2)

The initial kill of spear thistle in all herbicide treatments was poor and they were re-sprayed with 2,4-D. The degree of weed control achieved with the pre-sowing application of chlorsulfuron (25 g)* was outstanding and cyanazine (2.5 kg) and oxyfluorfen (0.48 kg) provided adequate residual control in the crop. However, all three herbicides caused some crop damage.

Two treatments – paraquat (0.38 kg)/diquat (0.22 kg) plus cyanazine (2.5 kg) followed by cyanazine (2.5 kg), and amitrole-T (0.6 kg) plus atrazine (0.6 kg) followed by trifluralin (0.4 kg) – resulted in similar grain yields to the cultivated fallow plus trifluralin (0.4 kg) control.

(b) Trial 2. Maintenance of an amitrole-T/atrazine fallow with chlorsulfuron or cyanazine 1980/81

A chemical fallow was commenced by spraying with amitrole-T (1.1 kg) plus atrazine (0.6 kg) on 18.viii.80. A few large ryegrass plants had to be resprayed with glyphosate (0.45 kg) on 19.xi.80 and the fallow was maintained by spraying on either 9.i.81, 5.v.81 or 26.v.81 with one of the following: chlorsulfuron (10 g), chlorsulfuron (20 g), cyanazine (1.25 kg) or cyanazine (2.5 kg) (Table 1).

There were no observable differences between treatments in the weed control achieved on the fallows. The average weed densities (plants m^{-2}) in the crop on 27.viii.81 were deadnettle 4.4, hogweed 5.5 and fumitory 5.0. The only significant differences (P = 0.05) were that there were fewer deadnettle plants after the latest application of either chlorsulfuron or cyanazine. The average grain yield was 5.5 t ha^{-1} and there were no significant differences between treatments. The main finding in the trial was that wheat has a high toler-

*Herbicide rates are expressed as kg ha^{-1} or g ha^{-1} of active ingredient.

Table 3 Trials 3 and 4: revised treatments including the use of an initial chlorsulfuron application 1980/81

Fallow treatment		Stubble site				Pasture site		
		Weed density m^{-2} in crop (26.viii.81)			Grain yield ($t\ ha^{-1}$)	Weed density m^{-2} in crop (24.viii.81)		Grain yield ($t\ ha^{-1}$)
Start of fallow	Pre-sowing	Deadnettle	Hogweed	Fumitory		Deadnettle	Hogweed	
Cultivated fallow	Cultivation	5.8	11.8	18.0	5.00	7.3	24.5	5.33
Cultivated fallow	Cyanazine 1.25 kg	5.3	10.3	7.3	4.93	14.8	18.8	5.29
Glyphosate 0.36 kg, as required	Cyanazine 1.25 kg	3.8	5.3	3.0	5.23	12.3	14.0	5.17
Amitrole-T 0.6 kg, atrazine 0.6 kg	Cyanazine 1.25 kg	4.8	13.0	3.3	5.00	19.8	9.8	4.67
Amitrole-T 0.6 kg, atrazine 0.6 kg	Oxyfluorfen 0.48 kg	0	1.0	2.5	4.88	0	0	4.72
Amitrole-T 0.6 kg, atrazine 0.6 kg	Diuron 0.8 kg	8.0	7.5	6.8	5.13	27.8	6.3	5.00
Amitrole-T 0.6 kg, diuron 2.0 kg	Diuron 0.8 kg	4.8	6.0	4.8	5.05	22.3	9.8	4.69
Amitrole-T 0.6 kg, chlorsulfuron 40 g	Nil	3.5	4.0	1.8	5.00	35.0	9.3	4.87
Amitrole-T 0.6 kg, chlorsulfuron 80 g	Nil	1.3	4.8	1.5	4.75	33.0	7.8	5.08
LSD(P = 0.05)		5.4	6.5	6.9	N.S.	N.S.	11.6	0.34

ance to these rates of chlorsulfuron and cyanazine.

(c) Revised treatments, including the use of an initial chlorsulfuron application with amitrole-T on fallows commenced in wheat stubble (Trial 3) or pasture (Trial 4) 1980/81 (Table 3)

Chemical fallows based on atrazine (0.6 kg) remained weed free until late November when thistles became a problem and about half the plots had to be re-sprayed. Compared with other plots sprayed with amitrole-T the initial knockdown on chlorsulfuron (40 g and 80 g) plots was poor, probably due to antagonism between this herbicide and amitrole-T. However, these treatments provided excellent residual control of summer weeds and significantly reduced weed populations in the following crop.

The most effective pre-sowing treatment for in-crop weed control was oxyfluorfen at 0.48 kg but this caused severe crop damage on the pasture site. Only poor weed control was achieved with pre-sowing cyanazine (1.25 kg) and diuron (0.8 kg).

(d) Trial 5. Revised treatments, including further evaluation of chlorsulfuron and cyanazine 1981/82

In the first few months after spraying, control of annual ryegrass and barley grass by cyanazine (2.5 kg), and chlorsulfuron (20 g) plus cyanazine (1.25 kg) was better than by the other treatments. Chlorsulfuron was the outstanding herbicide for summer-weed control, although it was not effective when applied under dry conditions in November.

There were no weeds in the crop during the 1982 drought and, although emergence was slow, there were no visible effects of the herbicides on crop establishment. The highest yields occurred after chemical fallows based on chlorsulfuron or cyanazine and the lowest after fallows based on atrazine or diuron (Table 4).

2. Chemical fallows commenced in autumn or spring 1982/83

(a) Trial 6 (Table 5)

The first herbicide application (29.iv.82) coincided with the opening rains of the season but the second application (8.x.82) was delayed past the normal time at which fallows are initially cultivated, because of the very dry conditions.

Cyanazine (2.5 kg) and wetter was applied on 7.v.83 to evaluate its knockdown and residual effect prior to sowing on 18.v.83. All other plots were sprayed with glyphosate (0.65 kg) on 13.v.83. After the weeds in the crop were counted, all plots were sprayed with bromoxynil (0.28 kg) plus MCPA (0.28 kg) and diclofopmethyl (0.56 kg).

The 1982/83 fallow was so dry that it was not possible to assess the performance of the residual herbicides until after the opening rains in 1983. Chlorsulfuron (30 g) at either application date was the most effective herbicide for controlling the broadleaf weeds on the fallow but a rate of 15 g applied on 8.x.82 was not as effective, particularly on Indian hedge mustard. Atrazine (0.8 kg), diuron (2 kg), cyanazine (2.5 kg), and mixtures of atrazine with either diuron or cyanazine controlled Indian hedge mustard but not deadnettle or fumitory. There was no significant residual effect of the herbicides on the weed densities within the crop.

The grain yields on six treatments were significantly less than those after conventional fallow. These were cyanazine (2.5 kg) in October and May, atrazine (0.6 kg) in October and chlorsulfuron (15 g) in October.

Table 4 Trial 5: revised treatments, including further evaluation of chlorsulfuron and cyanazine 1981/82

Fallow treatment Start of fallow (24.viii.81)	26.xi.81	Grain yield ($t.\ ha^{-1}$)
Cultivated fallow	Nil	0.61
Atrazine 0.6 kg	Nil	0.44
Atrazine 0.6 kg + cyanazine 1.25 kg	Nil	0.56
Cyanazine 2.5 kg	Nil	0.76
Diuron 1.6 kg	Nil	0.36
Chlorsulfuron 20 g	Nil	0.72
Chlorsulfuron 40 g	Nil	0.72
Atrazine 0.6 kg	Cyanazine 1.25 kg	0.61
Atrazine 0.6 kg	Chlorsulfuron 20 g	0.47
Atrazine 0.6 kg	Diuron 2 kg	0.54
Atrazine 0.6 kg	Oxyfluorfen 0.48 kg	0.34
LSD(P = 0.05)		0.23

Discussion

The results presented indicate that it is possible to replace cultivated fallows by chemical fallows without reducing the yield of wheat in the Wimmera. The main weeds causing problems on the experimental fallows were annual thistles (*P. echioides, L. serriola, C. vulgare* and *S. oleraceus*) but perennial weeds such as skeleton weed (*Chondrilla juncea* L.), soursob (*Oxalis pes-caprae* L.) and hoary cress (*Cardaria draba* (L.) Desv.) could also require specific attention on some fallows. Atrazine suppresses skeleton weed (Wells 1971) and glyphosate effectively controls soursob and hoary cress (Mahoney 1982; Waterhouse and Mahoney 1983).

As mentioned in the introduction, either those herbicides which kill existing vegetation or those which provide various levels of long-term control can be used on chemical fallows. Amitrole-T, glyphosate and paraquat/diquat are widely used to kill existing vegetation and were effective in the investigations reported here, except that spear thistle had to be re-sprayed with 2,4-D in 1979.

Amor *et al.* (1986) suggested the use of a low rate of atrazine (0.6 kg) as a base herbicide for chemical fallows in the Wimmera and Mallee, although it is known that higher rates may result in crop damage, particularly in very dry years. The results presented here support these conclusions in that even in 1982/83, when the rainfall on the fallow between August and May was only 228 mm, atrazine (0.6 kg) with either diuron (2 kg) or cyanazine (1.5 kg) did not cause any visible crop damage or a significant reduction ($P < 0.05$) in yield. The reduction in yield when atrazine (0.6 kg) alone was used is attributed to the inadequate level of weed control achieved on the fallow.

Chlorsulfuron (30 g) provided long-term weed control on fallows when applied in the preceding autumn or spring and a mixture of atrazine (0.8 kg) plus chlorsulfuron (20 g or 30 g) was also effective. Rates of 10 or 20 g of chlorsulfuron provided satisfactory supplementary weed control on fallows in January or May but its usefulness is limited on alkaline soils because of its residual effect on medic pastures and crops other than wheat and triticale. Recently, Swinnerton and Davis (1984) reported good weed control with a rate of 22.5 g on fallows and in the subsequent wheat crops in alkaline Wimmera soils; Pollock and Davis (1984) provided similar information on the effectiveness of 15–22.5 g chlorsulfuron on alkaline soils in New South Wales.

Cyanazine at rates from 1.25 kg to 2.5 kg was found to be an effective and safe pre-sowing herbicide to supplement the long-term control achieved with atrazine and it was effective on fallows when applied in January. However, when applied alone at a rate of 2.5 kg in October, its residual life was insufficient to provide the necessary long-term control.

Diuron (2 kg) gave long-term control when used to commence chemical fallows in autumn or spring but a rate of 1.6 kg was insufficient in 1981/82. Based on the results reported here, and those of earlier Victorian work summarized by Ridge (1983), it is concluded that diuron has potential for chemical fallowing, particularly as a pre-sowing supplement to an atrazine fallow.

Although providing a high level of weed control, oxyfluorfen applied 1–4 weeks pre-sowing at 0.48 kg reduced wheat yields on three out of four sites. This is consistent with other results with this herbicide on Wimmera grey clays (Amor, unpublished data).

The rate of adoption of chemical fallowing will depend largely on its effectiveness and cost relative to conventional fallows. Prices of herbicides vary considerably according to the size of the market, the keenness of commercial competition and the age of the product. Of the herbicides investigated, the relatively old atrazine and diuron are economical and have considerable potential for use in chemical fallow systems.

Caution is necessary when herbicide mixtures are being considered in a chemical fallowing program. For example, during the investigations reported here it was found that chlorsulfuron and amitrole are antagonistic and should not be applied on the same day. Likewise, atrazine, cyanazine and diuron may reduce glyphosate activity if mixture ratios are unfavourable (Wallens, personal communication).

Substitution of herbicides for tillage may have both economic and environmental advantages and the choice of systems will depend on an individual consideration of these advantages. There need not necessarily be total reliance on herbicides as in these investigations. For example, herbicides may be used to enhance the grazing value of fallows. To achieve this goal, the herbicides are applied to the pastures in winter–spring and the dry herbage reserved for grazing in summer–autumn before crops are sown. Other forms of reduced tillage fallows include the following schemes.

1. Commencement of fallows with herbicides followed by tillage when the level of chemical weed control declines in summer. (The 'ecofallow' concept of Greb and Zimdahl (1980) uses subsurface tillage only, to maintain the fallow on erodible soils in the Great Plains region of the U.S.A.)

Table 5 Trial 6: chemical fallows commenced in autumn or spring 1982/83

Fallow treatment	Date applied	Weed density 5m^{-2} on fallow 27/4/83				Yield (t ha^{-1})
		Deadnettle	Fumitory	Indian hedge mustard	Annual ryegrass	
Cultivated fallow		–	–	–	–	2.41
Atrazine	29/4/82	61 (1.79)[A]	10 (1.04)[A]	28 (1.46)[A]	23 (1.38)[A]	2.29
Chlorsulfuron 30 g	29/4/82	8 (0.93)	4 (0.73)	3 (0.58)	16 (1.24)	2.55
Atrazine 0.8 kg, diuron 2 kg	29/4/82	50 (1.71)	18 (1.27)	6 (0.86)	10 (1.04)	2.47
Diuron 2 kg	29/4/82	101 (2.01)	27 (1.44)	31 (1.51)	20 (1.32)	2.32
Atrazine 0.8 kg, cyanazine 1.5 kg	29/4/82	80 (1.91)	9 (1.00)	68 (1.84)	35 (1.55)	2.37
Cyanazine 2.5 kg + wetter	7/5/82	79 (1.90)	15 (1.20)	144 (2.16)	27 (1.44)	2.12
Atrazine 0.6 kg	8/10/82	57 (1.76)	6 (0.83)	27 (1.44)	19 (1.29)	2.20
Atrazine 0.6 kg, diuron 2 kg	8/10/82	53 (1.73)	16 (1.23)	18 (1.28)	13 (1.14)	2.31
Diuron 2 kg	8/10/82	97 (1.99)	11 (1.07)	24 (1.40)	12 (1.11)	2.34
Atrazine 0.6 kg, cyanazine 1.5 kg	8/10/82	125 (2.10)	15 (1.20)	39 (1.60)	8 (0.97)	2.30
Cyanazine 2.5 kg + wetter	8/10/82	77 (1.89)	16 (1.24)	18 (1.27)	7 (0.91)	2.22
Chlorsulfuron 15 g	8/10/82	19 (1.30)	7 (0.89)	25 (1.42)	31 (1.50)	2.08
Chlorsulfuron 30 g	8/10/82	9 (1.101)	3 (0.57)	1 (0.30)	20 (1.32)	2.49Z
LSD ($P = 0.05$)	(0.50)	(0.48)	(0.67)	N.S.	0.18	

[A]Log (X + 1) transformation

2. A cultivation at the end of a chemical fallow to reduce possible crop damage caused by *Rhizoctonia* spp.
3. Fallows can be commenced at the normal time in spring or, as investigated in Trial 6, in the preceding autumn if winter grazing for animals is not required. One advantage of commencing chemical fallows in autumn is that there is no need for relatively expensive knockdown herbicides.
4. Grazing of weeds on fallows by sheep in addition to chemical control at the commencement or during a fallow. This is an effective means of controlling low densities of weeds which invariably occur on fallows prepared with herbicides.

Regardless of the type of chemical fallow system adopted, there is a need for investigation of the most effective herbicide rates for controlling weeds which develop on chemical fallows, as field experience suggests that when some weeds mature they are difficult to kill. This applies particularly to summer weeds such as melons and heliotrope. The economics of spraying low densities of weeds on fallows is unknown and also warrants investigation.

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