REVIEWS

Weed control in rapeseed crops in Australia

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Summary

Rapeseed is intolerant of weed competition in the first weeks after emergence but is a good competitor once established. Grasses are the most serious weeds but broad-leafs may also cause significant yield reductions in particular situations. Current weed control practices include cultivation and the use of a small range of pre-emergence herbicides which are mainly suitable for grass control. Newly-developed herbicides facilitate the post-emergence control of grasses but the control of broad-leafs still remains a problem.

Introduction

The production of rapeseed (*Brassica napus* var. *oleifera* subvar. *annua*) and other oilseed crops increased dramatically in Australia in the late 1960s and early 1970s as a result of the imposition of wheat quotas, a fall in prices for wool and meat and a buoyant world market for oilseeds. Rapeseed production rose from virtually nil in 1967–68 to a peak of 25 000 t in 1971–72, but then declined rapidly, due partly to blackleg disease in Western Australia and partly to the lifting of wheat quotas and the improvement in wool prices. Varieties resistant to blackleg have recently been released and production has gradually risen again to near the peak levels of 1971–72.

Few attempts have been made to assess losses caused by weeds in rapeseed or other field crops, and this is an important deficiency in weed research. However, such losses are thought to be substantial (Vere, 1979). An index of competition between rapeseed and wild oats has been developed in Canada by Dew and Keys (1976). In an Indian study with the closely related mustard (*Brassica juncea*), although weeds accounted for only about 20% of the total biomass production in the crop ecosystem, manual weeding increased seed production by more than 100% (Ambasht and Chakhaiyar, 1979).

Weed control in rapeseed in Australia is achieved largely by cultivation and the use of a few pre-emergence herbicides which are mainly suitable for grass control, and this imposes significant restraints on production. This review surveys the problems caused by weeds in rapeseed and the other herbicides which may be used for their control.

Weeds of rapeseed and their effects on the crop

Rapeseed has a small seed and seedling and will not tolerate weed competition in the first weeks after emergence, but after establishment in weed-free conditions it produces rosettes of leaves and competes well with seedling weeds (Pearce, 1971). Rapeseed seedlings do not compete well with established weeds or those that are shifted but not killed during cultivation.

Grass weeds

Wild oats (*Avena* spp.) occur in almost all winter-cropping areas in Australia (Wilson, 1979) and as with other weeds, reduce crop yields by competing for light, water and nutrients. Since the competitive effect begins at a very early stage and yield losses increase with increasing duration of competition, the earlier the competition is removed the smaller will be the resultant yield loss. Sharma (1979) tabled the effect of different wild oat densities on yield of rapeseed when the wild oat emerged at the same time as the crop and showed that yield reduction is proportional to weed density (Table 1).

Chow and Dorrell (1979) found that the yields from plots infested with wild oats were 25 to 66% lower than from those in which wild oats were controlled. The removal of wild oat competition also increased the oil content of the rapeseed from 35 to 37% without affecting residual protein content of the meal.

Annual ryegrass (*Lolium* spp.) are commonly important weeds in field crops in southern Australia (Pearce, 1971; Reeves, 1976), and rapeseed is markedly affected by ryegrass competition. T. G. Reeves and H. D. Brooke (pers. comm.) found for ryegrass that 500 plants m^{-2} reduced rapeseed yield by 45%, whilst twice this density reduced yield by 65%. The major effect of ryegrass competition is a reduction in plant size, with fewer and smaller inflorescences and pods containing less seed. Critical competition of annual ryegrass in rapeseed begins about eight weeks after crop emergence, and yield losses increase with duration of competition beyond this time.

Canary grasses (*Phalaris* spp.) are also commonly seen as weeds of rapeseed in southern Australia, but no information has been found on their competitive effects in rapeseed or any other crops.

Broad-leaf weeds

Capeweed (*Arctotheca calendula*) is widespread and common in the higher rainfall areas of southern Australia, occurring in both crops and pastures and

Table 1 Effect of varying wild oat densities on yield of rapeseed

Wild oat plants (m^{-2})	Reduction in rapeseed yield (%)
0	0
10	9
30	16
50	21
100	32
150	37
220	48

often indicating high fertility. Its vigorous rosettes compete strongly with crop seedlings and only a few plants per square metre can cause substantial yield losses. In trials in New South Wales on capeweed 17 plants m^{-2} reduced rapeseed yields by 0.5 t ha^{-1} (A. R. Leys and B. D. Hill, pers. comm.).

The two most important cruciferous weeds are wild turnip (*Brassica tournefortii*) and charlock (*Sinapis arvensis*) (Buzza, 1979). Wild radish (*Raphanus raphanistrum*) has caused problems in Tasmania (Russell, 1980). Wild turnip is a serious weed of the dry, sandy regions of southern Australia, particularly in the 400 to 600 mm rainfall area of south-western Western Australia and the Mallee region in Victoria (Buzza, 1979), and contamination of rapeseed by the seed of wild turnip reduces the oil content of the harvested crop. Since the two seeds cannot be separated, it is important that wild turnip is prevented from contaminating rapeseed crops (Crosbie, 1971).

Chemical weed control

Chemical weed control is as important in rapeseed as in other crops, especially where wet weather prevents adequate seedbed preparation and in reduced tillage systems of production. Herbicides currently registered for use in rapeseed are restricted to a small range of pre-emergence products, although some others are being recommended by agricultural advisers for post-emergence control of grasses. No herbicide is currently recommended for control of broad-leaf weeds in rapeseed because all are likely to damage severely or even destroy the crop (Marrett and Cocks, 1981).

Herbicides registered for weed control in rapeseed

Paraquat and paraquat plus diquat are registered as Gramoxone and Spray-Seed in all States for weed control prior to planting. They are used either to kill pasture and weed growth before ploughing as well as weeds that have survived cultivation or partially to replace cultivation (Pearce, 1971; Wightman, 1973), and are an integral management tool in the developing practice of reduced tillage.

The herbicide most widely used for the control of grass weeds in rapeseed is trifluralin, which is applied before sowing and incorporated by shallow cultivation. Trifluralin kills weed seeds as they germinate and is effective against wild oats, annual ryegrass, canary grass and some broad-leaf weeds including wireweed (*Polygonum aviculare*) and fumitory (*Fumaria* spp.) (Pearce, 1971; Wightman, 1973).

Di-allate (as Avadex) was previously registered for use in rapeseed (Pearce, 1971; Wightman, 1973) but is no longer being manufactured, and its place has been taken by tri-allate (as Avadex BW). Tri-allate is applied before sowing and incorporated by cultivation to kill seeds of wild oats and annual ryegrass as they germinate (Kloot, 1980).

Alachlor is registered as Lasso for use in rapeseed for ryegrass control only. It is applied as a pre-emergence spray within two days after sowing and needs to be washed into the soil by 7 to 12 mm of rainfall (Wightman, 1973). Alachlor is a useful alternative where wet or cloddy soils prevent effective incorporation of trifluralin or tri-allate.

EPTC (as Eptam) has recently been registered for use in rapeseed in New South Wales. It is applied before sowing and needs to be thoroughly incorporated into the soil to control wild oats, annual ryegrass and some broad-leaf weeds including mustards (*Sisymbrium* spp.) and shepherd's purse (*Capsella bursa-pastoris*). The effectiveness of EPTC is reduced if rain does not fall within a few days of spraying (Gammie and Scarsbrick, 1981).

Nitrofen was registered as Tok E25 for use in rapeseed but is no longer available commercially in Australia. It is applied when the weeds are at the 2- to 4-leaf stage and controls ryegrass and many broad-leaf weeds including fumitory, wireweed and capeweed (Swarbrick, 1979). Nitrofen is recommended for weed control in British and European rapeseed crops (Fryer and Makepeace, 1978; Gummeson, 1979).

The herbicides that are or have been registered in Australia for weed control in rapeseed are listed in Table 2.

Herbicides recommended but not registered for weed control in rapeseed

Trial work in Australia has indicated that penoxalin (as Stomp 330E) is suitable for use in rapeseed when applied before sowing and incorporated by cultivation. The herbicide may be applied up to 24 hours before sowing into a well prepared seedbed and incorporated by the sowing process. Penoxalin is effective against annual ryegrass and wireweed, suppresses fumitory and wild oats (Kloot, 1980), and could be useful as an alternative to trifluralin.

Napropamide (as Devrinol) has given good control of grasses in rapeseed trials in New South Wales and controls a wider range of broad-leaf weeds than trifluralin (A. R. Leys and B. D. Hill, pers. comm.; Anon., 1974–75). It should be applied before sowing and incorporated into the soil by cultivation to control annual ryegrass, wild oats and wireweed. A proprietary mixture of napropamide plus trifluralin (as Devrinol T) is available for use in rapeseed crops in Britain (Anon., 1980).

Two herbicides are recommended but not registered for post-emergence grass control in rapeseed. Barban (as Neoban) controls wild oats which are in the 1- to 2½-leaf stage, and correct timing of application is very important (Kloot, 1980). Barban is recommended for use in British rapeseed crops (Fryer and Makepeace, 1978). Diclofop-methyl (as Hoegrass) controls annual ryegrass and wild oats from the 2- to 4-leaf stage through to tillering, although early removal gives maximum yield response (Kloot, 1980). In Canadian trials, diclofop-methyl controlled 65 to 87% of the wild oats in rapeseed without injuring

Table 2 Herbicides registered in Australia for weed control in rapeseed

Common name	Application rate and timing (kg ha^{-1})	Susceptible weeds
paraquat	0.28–0.5 post-emergence	emerged grasses and broad-leafs
trifluralin	0.5–1.5 preplanting incorporated	grasses and broad-leafs from seed
di-allate[1]	0.6–2.0 preplanting incorporated	grasses from seed
tri-allate[2]	0.6–2.0 preplanting incorporated	grasses from seed
EPTC	1.8–4.5 preplanting incorporated	grasses and broad-leafs from seed
alachlor	1.1 pre-emergence	grasses from seed
nitrofen[1]	1.5–3.0 post-emergence	emerged broad-leafs and grasses

[1]No longer commercially available in Australia.
[2]Not registered for weed control in rapeseed, but substituted for di-allate. Registered for use in wheat and barley.

Table 3 Herbicides recommended but not registered for weed control in rapeseed in Australia

Common name	Application rate and timing (kg ha^{-1})	Susceptible weeds
penoxalin	1.0–2.0 preplanting incorporated	grasses and broad-leaf weeds from seed
napropamide	1.5–2.5 preplanting incorporated	grasses and some broad-leaf weeds from seed
barban	0.25 post-emergence	emerged wild oats
diclofop-methyl	0.5–1.0 post-emergence	emerged annual grasses

the crop and yield was significantly increased (Chow and Dorrell, 1979), whilst in pot experiments in England the crop was tolerant to diclofop-methyl at 3 kg ha^{-1} which is well above the level needed for effective weed control (Richardson and Parker, 1976).

The herbicides that are recommended but not registered for weed control in rapeseed in Australia are listed in Table 3.

Registered herbicides suggested for trial work in rapeseed

Herbicides that are registered in Australia for weed control in crops other than rapeseed but which may be suitable for trial work in this crop include chlorthal, metolachlor, aziprotryne, carbetamide, 2,2-DPA and propyzamide.

Chlorthal is registered as Dacthal for use in various horticultural crops including brassicaceous vegetables. Even though its costs may be too high for a broadacre crop such as rapeseed, chlorthal may be useful in certain situations for its control of a wide range of weeds including ryegrass, canary grass, capeweed, wireweed and fumitory. Its requirements for soil preparation and moisture levels at application are, however, fairly critical (Swarbrick, 1979).

Metolachlor is related and similar to alachlor and is registered as Dual in Australia for weed control in maize, sweetcorn and sorghum. It is a pre-emergence herbicide which is applied immediately after planting for the control of many annual grasses including wild oats, ryegrass and canary grass (Richardson and Parker, 1979a). It requires 7 to 12 mm of rainfall within two weeks of application to move the chemical into the soil.

Aziprotryne is registered as Brasoran for post-emergence weed control in some brassicaceous vegetable crops. It is effective on broad-leaf weeds (particularly capeweed) but in trials in New South Wales has caused slight damage to the crop (A. R. Leys and B. D. Hill, pers. comm.; Anon., 1974–75).

Carbetamide is registered as Carbetamex for control of many annual grass weeds in lucerne, clover and medics and is recommended for weed control in rapeseed in Britain and Europe, where it is also sold in a proprietary mixture with the broad-leaf herbicide dimefuron for control of a wide range of weeds (Fryer and Makepeace, 1978; Richardson and Parker, 1979b). In trials conducted in Victoria, carbetamide reduced ryegrass density and increased the yield of rapeseed at one site. At other sites carbetamide did not reduce the ryegrass density but did restrict growth of the weed, apparently by reducing root development (Reeves and Lumb, 1974).

2,2-DPA is recommended in Britain for the control of wild oats and other annual grasses in rapeseed but may give a slight temporary check to the crop (Fryer and Makepeace, 1978). It has been tested in rapeseed trials in New South Wales and has increased yields in some cases (Anon., 1974–75).

Propyzamide (as Kerb) is recommended in British and European rapeseed crops to control wild oats, other annual grasses and some annual broad-leaf weeds. It can be applied as soon as the crop has three full leaves (Fryer and Makepeace, 1978) and is commonly tank mixed with the broad-leaf herbicide Benazalox discussed below. Its cost may be too high for economical use in rapeseed.

Alloxydim-sodium gives post-emergence grass control in many broad-leaf crops including rapeseed, and has recently been registered in Australia as Fervin for weed control in onions. Its cost may make it uneconomical in rapeseed. Alloxydim-sodium controls many annual grasses including wild oats, ryegrass and canary grass and some perennial grasses at higher rates (Richardson and Parker, 1978; 1979a). Selectivity is excellent since the chemical does not damage rapeseed at 4.5 kg ha^{-1} which is several times the rate needed for effective weed control (Ingram *et al.*, 1978).

The herbicides which are currently available in Australia and that may be suitable for trial work in rapeseed are listed in Table 4.

Unregistered herbicides suggested for trial work in rapeseed

Several herbicides appear to be suitable for further testing in rapeseed, and some of the products mentioned will soon be or have recently become registered in Australia for weed control in other crops.

Dimethachlor (as Teridox) is a pre-emergence herbicide that is recommended for use on European rapeseed crops for the control of annual grasses and broad-leaf weeds including wild oats, ryegrass, canary grass and wireweed (Richardson and Parker, 1979a). Dimethachlor has markedly increased yields in rapeseed trials in Sweden (Gummeson, 1979). A product with the code number BAS 479 00H is being tested in Canadian rapeseed trials. It can be applied either before emergence or before planting with shallow incorporation in drier areas and controls a wide range of grass and broad-leaf weeds (Saidak, 1979).

Two further post-emergence herbicides for grass control are nearing commercial release in Australia. NP55 (proposed common name 'cietoxidim') controls most annual and perennial grass weeds with the exception of winter grass (*Poa annua*) and is related to alloxydim-sodium but has greater activity on grasses. PP009 (proposed common name 'fluazifop-butyl') is almost identical (Richardson, West and Parker, 1980).

Benazolin is recommended for post-emergent broad-leaf weed control in European rapeseed crops and has been tested in Canada. It is claimed to control charlock without damaging the rapeseed crop, and has been developed primarily for use in mixtures. Benazalox is a combination of benazolin and 3,6-dichloropicolinic acid and has been used on European rapeseed crops since 1976 (Olsson, 1979). 3,6-dichloropicolinic acid also possesses excellent post-emergence activity against many weeds from the Asteraceae, Polygonaceae, Apiaceae and legume families (Rea, Palmer and de St Blanquat, 1976), and has been tested as Lontrel in Australia and shown to give good control of capeweed in rapeseed. As benazolin, 3,6-dichloropi-

Table 4 Herbicides registered in Australia and suggested for trial work in rapeseed

Common name	Application rate and timing (kg ha^{-1})	Susceptible weeds
chlorthal	6.0–12.0 pre-emergence	grasses and broad-leaf weeds from seed
metolachlor	1.0–2.0 pre-emergence	grasses from seed
aziprotryne	1.5 post-emergence	emerged annual broad-leaf and grass weeds
carbetamide	1.0-2.0 post-emergence	emerged annual grass and broad-leaf weeds
2,2-DPA	0.8-2.8 post-emergence	emerged annual and perennial grasses
propyzamide	0.5–0.7 post-emergence	emerged annual grasses and some broad-leaf weeds
alloxydim-sodium	0.75–1.5 post-emergence	emerged annual gasses

Table 5 Unregistered herbicides suggested for trial work in rapeseed in Australia

Common name	Application rate and timing (kg ha^{-1})	Susceptible weeds
dimethachlor	1.5–2.0 pre-emergence	annual grasses and some broad-leaf weeds from seed
BAS 479 OOH	1.0–1.5 pre-emergence	annual grasses and broad-leaf weeds from seed
NP55 (cietoxidim)	0.2–0.5 post-emergence	emerged annual and perennial grasses
PP009 (fluazifopbutyl)	0.2–0.5 post-emergence	emerged annual and perennial grasses
benaxolin[1]	0.5–0.9 post-emergence	emerged broad-leaf weeds
3,6-dichloropicolinic acid[1]	0.05–0.1 post-emergence	emerged broad-leaf weeds

[1]Benazolin plus 3,6-dichloropicolinic acid is available in Europe as Benazalox.

colinic acid and Benazalox have no activity against grass weeds, mixtures are necessary if control of grasses is desired. Benazalox plus propyzamide is a recommended tank mixture for European rapeseed crops (Rea, Palmer and de St Blanquat, 1976; Olsson, 1979).

The herbicides which are not yet registered in Australia but which may be suitable for trial work in rapeseed are listed in Table 5.

Cropping rotations

Considerable advantages in weed control can be gained from careful planning of cropping rotations which include cereals, rapeseed and legumes, since the herbicides used on one crop in the rotation are often complementary to those used in the next. For example, grasses can be controlled very effectively in the rapeseed phase with many of the herbicides mentioned above and broad-leaf weeds with other herbicides in the cereal phase, so that the amount of weed seed carried over into the subsequent crop is progressively reduced (Pearce, 1971; Marrett and Cocks, 1981). The possibility of residues of residual herbicides applied to one crop in the rotation remaining in the soil to affect a subsequent susceptible crop should not be overlooked. For example, methabenzthiazuron applied to a cereal crop is degraded more slowly under dry conditions and can damage a following rapeseed crop (Schmidt, 1977).

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