Wild radish (*Raphanus raphanistrum* L.): a review of research on its biology and control in Victoria, 1976–1982

T. W. Donaldson[A]
Keith Turnbull Research Institute, Department of Conservation, Forests and Lands, Frankston, Victoria 3199

Summary

Wild radish is an increasing problem in the cropping areas in Victoria and the results of research into why this plant is a successful weed in crops, and effective methods for its control, are reviewed.

Wild radish competes strongly with wheat during the early growth of the crop and densities as low as seven plants m^{-2} reduced yields by 10%. It can be controlled effectively in cereal crops, but to obtain long-lasting suppression, seed production must be prevented and the existing seed load in the soil destroyed. Experiments based on different cultural techniques designed to achieve this are discussed.

Introduction

Wild radish (*Raphanus raphanistrum* L.), a member of the family Cruciferae, is an annual plant which is widespread throughout the world. It has been reported as a troublesome weed in cropping land in the British Isles, Europe, U.S.A., Canada, Chile and all Australian States (Piggin *et al.* 1978). It reduces grain yield, contaminates harvested grain which is discounted at the silo, makes harvesting difficult and may increase the moisture content of harvested grain above acceptable limits (Piggin *et al.* 1978).

Opinions differ concerning its 'weediness' in pastures. It has been held to have some fodder value (Meadly 1965), while Orchard (1946) claims that it may taint milk, butter and cereal grain products. Also, instances of poisoning of livestock have been mentioned (Everist 1981).

Wild radish was probably introduced accidentally into Australia and spread as a contaminant in agricultural produce. It was reported to be naturalized in Victoria, in the area around Melbourne by 1860 (Piggin *et al.* 1978), and since then it has become well established both in this State and in all the others.

[A] Dr T. W. Donaldson died on 2 October 1983. This paper was completed by his colleagues at the Keith Turnbull Research Institute.

This paper reviews the findings of a research program into the biology and control of wild radish undertaken by the Department of Agriculture and the Department of Crown Lands and Survey (now part of the Department of Conservation, Forests and Lands), with financial support from the wheat industry.

Distribution in Victoria

A survey of weeds of cereal crops in June 1977 showed that wild radish was present in less than 3% of Victorian crops (Wells and Lyons 1979). However, it did occur in all cropping regions included in the survey. In the newer cropping area of south-west Victoria, wild radish was not found in any of the crops inspected during a survey carried out in 1981, although small areas of the weed were known to be present in the region (Velthuis and Amor 1982).

Wild radish is present in almost all parts of Victoria and is regarded as a significant weed of crops in the North East, parts of the Western District and in the cropping areas of east Gippsland.

Possibility of spread to uninfested areas

An understanding of the phenological development of an annual plant is necessary in order to assess the likelihood of its spread to uninfested areas. This was investigated in a trial at Rutherglen by Reeves *et al.* (1981) who made sequential sowings of wild radish seed at approximately monthly intervals between December 1977 and February 1979. A range of environmental conditions was thus experienced during plant growth. The time of sowing had a marked effect on development. The life span of plants varied from 317 days (sown December) to 134 days (sown September), the duration of flowering being the phase most affected. Plants germinating in summer flowered throughout autumn, winter and spring and died during the following summer (provided moisture was adequate), while plants germinating in the spring flowered for a short period and died during summer.

An analysis of the relative importance of temperature and day length on the development of each phase indicated that temperature was the major factor controlling development up to flowering, while day length, as well as temperature, influenced the duration of flowering (Reeves *et al.* 1981). This experiment showed that wild radish has a thermal requirement (number of days × average daily mean temperature less 4.5°C per day) of just under 600°C-days for the period emergence to flowering – conditions which are likely to be met in most parts of Victoria. Thus wild radish has the capacity to grow and flower in virtually all areas of the State.

Success of wild radish as a weed

Being an annual plant the growth phases of seed production, seed germination and seedling establishment are most important in determining the success of wild radish as a weed.

Seed production

Wild radish is a very prolific seed producer. Reeves *et al.* (1981) measured the number of seeds produced over 3 years when wild radish was sown at various densities in a wheat crop. They showed that seed production ranged from 292 seeds m^{-2} from one plant m^{-2} to 17 275 seeds m^{-2} from 51.7 plants m^{-2}. As the density of wild radish increased, seed production per plant decreased, while the number of seeds per m^2 increased.

Seed survival

Reeves *et al.* (1981) investigated the longevity of wild radish seeds buried at various depths to 10 cm in soil. The number of viable seeds declined with time, the greatest decline being for seed on the soil surface, where only 5% were viable after 2 years. Part of this loss was due to seed germination before recovery. For seed buried at 5 and 10 cm the decline in the number of viable seed was slower, with 43% remaining viable 4 years after burial at 10 cm.

Seedling emergence

Emergence of seedlings from seed at various depths in the soil was also investigated by Reeves *et al.* (1981). Seedlings that emerged from buried samples of 1000 seeds at various depths to 10 cm were counted periodically and removed over a 4-year period.

Emergence was greatest from the 1-cm depth where 72% emerged in the first year, while only 0.5% emerged from 10 cm. Most seedlings emerged shortly after the autumn break in each year, but emergence continued at a lower level throughout the winter and early spring. This staggered germination ensures that some seedlings will survive even if many are killed by adverse conditions, such as moisture stress, during establishment. It also makes the timing of control measures difficult.

The effect of soil-surface treatment on the emergence of wild radish was another factor investigated by Reeves *et al.* (1981) who found that emergence of seedlings was greater on the cultivated plots than on the mown plots. In each year a flush of germination occurred after the autumn break, particularly on the cultivated plots, and, as above, sporadic germination continued throughout the growing season.

Seed germination

Tests in the laboratory by Piggin *et al.* (1978) showed that wild radish seed germinated over a wide range of alternating and constant temperatures, and that maximum germination occurred with widely fluctuating temperatures (e.g. where day and night temperatures differed by 10 to 20°C). This could partly explain why wild radish germinates well in the field after autumn rains when temperatures fluctuate widely.

Removal of the seed pod greatly increased germination (Piggin *et al.* 1978). When the seed pod was removed from seed that had not germinated after 3 weeks at 25/5°C, 64% germination occurred during the next 20 days, while no further seeds germinated when the pod was left intact. Perhaps the sporadic germination of seed in the field throughout the year is due to slow and varying rates of breakdown of seed pods on or below the soil surface.

Competition with wheat

Studies in England have shown that wild radish competes strongly with cereal crops and that grain yields can be increased by up to 160% by removing the weed from the crop (Blackman and Templeman 1938). Competition appears to be mainly for nitrogen, but also partly for light and moisture.

In trials at Rutherglen (Reeves and Code, unpublished data) wild radish densities as low as seven plants m^{-2} have reduced wheat yields by 10%, ten plants m^{-2} by 20%, while 200 plants m^{-2} have reduced yields by as much as 50%.

Competition from wild radish with wheat occurs during the early growth stages of the crop, as significant yield increases have resulted when wild radish was controlled by herbicide application during the two- to five-leaf stage of the crop. When control is delayed until the post-tillering crop stage, yield increases have rarely been obtained (Code *et al.* 1978; Code and Reeves 1981*a*).

Contamination of harvested grain

Segments of wild radish seed pods may contaminate the cereal grain during the harvesting of weed-infested crops. These are difficult to separate from the grain because the two are of similar size and weight. Although contaminated grain may be docked at the silo, information obtained from the Grain Elevators Board of Victoria indicates that the incidence of such dockage is extremely low. For example, in a survey of samples representing all wheat received at each silo in Victoria during the 1979/80 harvest, wild radish was found in samples from only six out of a total of 229 silos (Donaldson, unpublished data). The low level of contamination of harvested grain reflects the success of farmers in controlling wild radish in their crops.

Control of wild radish

To achieve long-lasting control of wild radish, seed production must be prevented and the existing seed bank in the soil destroyed. Strategies for its control include cultural and chemical techniques.

Cultural control

The biology of wild radish suggests that cultural practices could be used to reduce the problem of residual seed loads in the soil. Shallow burial of the seed to depths from 0 to 1 cm should result in a rapid loss of viable seed, and seed production by plants which emerge could be prevented by the use of herbicides. Also, deep burial of the seed should reduce the density of wild radish as very few plants emerge from seed buried at 10 cm in the soil. However, since a high percentage of the seed remains viable after deep burial, subsequent cultivation would need to be shallow to avoid bringing seed back to the surface (e.g. direct drilling).

The effect of these strategies, i.e. (i) deep burial followed by direct drilling or scarifying in subsequent years, (ii) scarifying and (iii) direct drilling, on the wild radish population in subsequent crops were investigated by Donaldson and Code (1981). The results (Table 1) show that burial of the seed by mouldboard ploughing significantly reduced the density of wild radish in the crop. Further information is required on the effect on seed banks in subsequent years.

Table 1 Effect of cultural treatments in autumn on the density of wild radish in the following wheat crop (After Donaldson and Code (1981)).

Treatment	Wild radish seedlings, July 1979 (no. m^{-2})	
	Site 1	Site 2
Scarified to 7 cm	119b	39b
Mouldboard ploughed to 15 cm	41a	14a
Direct drilled	202c	106b

Within columns, values followed by the same letter are not significantly different (P = 0.05) as determined by Duncan's multiple range test on ln x or ln $(x + 1)$ transformed data.

Chemical control: wheat

As cultural techniques will not eliminate wild radish completely, and even low densities of wild radish can cause marked reductions in the yield of wheat, it is essential that wild radish be controlled by chemicals in crops. Numerous experiments during the course of this research program, using many different herbicides, have shown that wild radish can be effectively controlled in cereal crops (Code *et al.* 1978; Code and Reeves 1981*a*).

Control of wild radish by early post-emergence application of herbicide generally resulted in significant increases in grain yield. Results from experiments over the 3-year period 1978 to 1980 are shown in Table 2.

The higher yield with metribuzin/methabenzthiazuron was probably due to the presence of other weeds in the plots, as well as wild radish, which were controlled by this mixture but not by the other herbicides (Code and Reeves 1981*a*). With the dicamba/MCPA mixture, a number of plants survived and seed production was not greatly reduced. When spraying of wild radish was delayed until the post-tillering stage of the crop, 2,4-D amine or MCPA gave good control with little

Table 2 Control of wild radish and average yield increases after spraying 6 weeks postemergence (Code and Reeves 1981*a*)

Herbicide	Control (%)	Yield (t ha^{-1})
Bromoxynil + MCPA ester	95	0.8
Metribuzin + Methabenzthiazuron (Sencor T)	88	1.69
Dicamba + MCPA amine	70	0.67

seed production but no significant increase in grain yields.

To minimize loss of yield, spraying within 5–7 weeks of sowing is suggested if wild radish is present in a wheat crop at a density of 10 or more plants m^{-2}. Where light infestations are present, and overall yield losses are likely to be negligible, or some plants have survived or germinated after early post-emergence treatments, spraying at the post-tillering stage of the crop with either 2,4-D amine or MCPA is recommended to prevent seed production and contamination of the harvested grain (Reeves and Code 1980).

Chemical control: lupins

Production of grain lupins has increased dramatically in Victoria in recent years owing to greater demand for high protein grain. Moreover, lupins boost the yields of subsequent cereal crops (Boundy 1980). Code and Reeves (1981*b*) have tested a number of chemicals (atrazine, propazine, metribuzin, oxyfluorfen, linuron and monolinuron) which gave good control of wild radish.

Conclusions

The studies on seed production, seed germination and seedling establishment have shown that wild radish is a successful weed in cereals because: (i) it produces large quantities of seed; (ii) a flush of germination occurs shortly after the autumn break when crops are normally sown; (iii) germination continues over an extended period which makes the timing of control measures difficult; (iv) germination is greatly increased by cultivation; and (v) seed can remain viable for several years.

In addition, wild radish grows and flowers in virtually all areas of Victoria and is already present over much of the State. The ability of the seed to retain viability and germinate over a period of several years means that it is highly unlikely that it will be eradicated from areas where it is already present.

Noxious weed legislation should aim at eradication of proclaimed species or prevention of their spread to uninfested areas. Under such legislation landholders have a legal obligation to control a proclaimed weed wherever it occurs on their property. Because of its widespread distribution and the difficulty of achieving eradication, the proclamation of wild radish as a noxious weed would serve little purpose and place an undue burden on landholders. Landholders will control it where it affects their livelihood such as in cereal crops. Following consideration of the results of their research program, a decision has been made not to proclaim wild radish a noxious weed in Victoria (Vermin and Noxious Weeds Destruction Board, personal communication).

References

Blackman, G. E., and Templeman, W. G. (1938). The nature of competition between cereal crops and annual weeds. *Journal of Agricultural Science* **28**, 247–71.

Boundy, K. A. (1980). Growing lupins. Department of Agriculture, Victoria, Agnote (Order no. 1154/80. Agdex 142/20).

Code, G. R., Reeves, T. G., Brooks, H. D., and Piggin, C. M. (1978). The herbicidal control of wild radish (*Raphanus raphanistrum* L.). Proceedings First Conference Council of Australian Weed Science Societies, pp.241–8.

Code, G. R., and Reeves, T. G. (1981*a*). Chemical control of wild radish in wheat. Proceedings Sixth Australian Weeds Conference Volume 1, pp.59–63.

Code, G. R., and Reeves, T. G. (1981*b*). Control of wild radish with herbicides in lupins. Proceedings Sixth Australian Weeds Conference, Volume 1, pp.227–8.

Donaldson, T. W., and Code, G. R. (1981). Effect of cultural treatments on wild radish density in wheat. Proceedings Sixth Australian Weeds Conference, Volume 1, pp.79–80.

Everist, S. L. (1981). 'Poisonous Plants of Australia.' 2nd edition, p.213. (Angus and Roberston: Sydney.)

Meadly, G. R. W. (1965). 'Weeds of Western Australia', p.77. (Department of Agriculture: Western Australia.)

Orchard, H. E. (1946). Weeds which taint food. *Journal of the Department of Agriculture, South Australia* **50**, 173–80.

Piggin, C. M., Reeves, T. G., Brooke, H. D., and Code, G. R. (1978). Germination of wild radish (*Raphanus raphanistrum* L.). Proceedings First Conference Council of Australian Weed Science Societies, pp.233–40.

Reeves, T. G., and Code, G. R. (1980). Biology and control of wild radish. Department of Agriculture, Victoria. Agnote (Order no. 1090/80. Agdex 100/642).

Reeves, T. G., Code, G. R., and Piggin, C. M. (1981). Seed production and longevity, seasonal emergence and phenology of wild radish (*Raphanus raphanistrum* L.). *Australian Journal of Experimental Agriculture and Animal Husbandry* **21**, 524–30.

Velthuis, R. G., and Amor, R. L. (1982). Weed survey of cereal crops in south-west Victoria. *Australian Weeds* **2**, 50–2.

Wells, G. J., and Lyons, F. J. (1979). Weed Survey of Victorian Cereal Crops, 1977. Research Project Series No. 66, Victorian Department of Agriculture, Melbourne.