Germination of wild radish (*Raphanus raphanistrum* L.)

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SUMMARY

Wild radish (*Raphanus raphanistrum* L.) is a widespread and troublesome weed in cereal crops in southern Australia. This paper describes experiments investigating the germination behaviour of wild radish.

Results suggested that wild radish is an abundant and persistent weed in crops because it produces large quantities of seed, the seed germinates sporadically over several years, and the seed germinates best in cultivated situations. It is likely that fallowing before sowing will reduce the abundance of wild radish in crops.

INTRODUCTION

Wild radish (*Raphanus raphanistrum* L.) is a widespread species throughout the world, and it has been reported as a troublesome weed in cropping land in the British Isles (Blackman and Templeman, 1938; Clapham, Tutin and Warburg, 1952; Butcher, 1961), throughout Europe (Chater, 1964), in the north-east, central and pacific north-west United States and Canada (Mekenian and Willemsen, 1975), in Chile (De Vallejo, n.d.) and in all Australian states.

The plant was probably introduced accidentally into Australia, and spread, as a contaminant in agricultural produce. It does not seem to have been intentionally introduced and grown as a garden species by the early settlers. It was reported to be naturalized in Victoria around Melbourne by 1860, soon after settlement (Hooker, 1860), in New South Wales around Sydney by 1867 (Woolls, 1867; Moore, 1884), in South Australia around Adelaide by 1875 (Schomburgk, 1875), and in Queensland by 1913 (Bailey, 1913). Wild radish is now well-established in Western Australia (Gardner, 1930; Meadly and Pearce, 1954; Meadly, 1965), South Australia (Black, 1909, 1948), Queensland (Everist, 1974), New South Wales (Burbidge and Gray, 1970; Beadle, Evans and Carolin, 1962; Leigh and Mulham, 1977), Victoria (Ewart and Tovey, 1909; Adcock, 1914; Willis, 1972; Goodman, 1973), and Tasmania (Curtis, 1956; Hyde-Wyatt and Morris, 1975).

Wild radish is considered to be a serious weed in crops because it:

(i) reduces grain yield

(ii) contaminates the harvested grain with its seed

(iii) makes harvesting difficult, and

(iv) may increase the moisture content of harvested grain above acceptable limits.

Opinions differ on the weediness of wild radish in pastures. Meadly (1965) conceded that it has some forage value, but Ewart and Tovey (1909) considered that its fodder value was nil. Orchard (1946) reported that it may taint milk, butter and cereal grain products, and Everist (1974) has cited cases from Australia and overseas where poisoning of livestock has been ascribed to consumption of wild radish.

In recent years, the plant seems to have been increasing as a problem in cereal crops in Victoria. For example, of the 48 telephone enquiries about weeds to the Rutherglen Research Station from farmers in 1975, only 7 (14%) concerned wild radish. In 1977, 58 of the 304 weed enquiries (19%) concerned wild radish. Whilst some of this increase may be due to greater farmer awareness of the problem, it probably also reflects an increase in the distribution and abundance of the plant.

A research program on wild radish was commenced at Rutherglen in 1976. This aimed to investigate reasons for the success of the plant in cereal crops, the nature of competition between wild radish and wheat, and the control of the plant in crops. Because wild radish is an annual species, the phases of seed germination and seedling establishment are most important in determining the success of the plant. Results from seed germination experiments are discussed in this paper.

EXPERIMENTAL FINDINGS AND DISCUSSION

Germination studies have highlighted several characteristics which accentuate the significance of wild radish as a weed and increase the difficulties of control. They also indicate "weaknesses" that may be exploited to assist control by cultural means.

(a) Seed production

Wild radish is a prolific seeder. Germinations of about 1000 seeds/m^2 have been recorded in natural populations at Corowa, N.S.W., during 1977 (Table 1), and laboratory tests suggest that this would not be more than 40 to 50% of the seed in the soil (Tables 2 and 3). Thus, seed burdens of over 2000 seeds/m^2 in the soil may not be uncommon.

(b) Seed survival

Between about 20 to 40% of the seed produced in any year remains viable in the soil after 12 months, the actual survival varying with time and depth (Table 4). This means that the plant can be successful in any year despite failure to produce seed in the previous year.

(c) Seasonal emergence

Seedlings continue to emerge after rainfalls throughout most of the year, especially if seed is buried (Tables 1 and 5).

Table 1. Emergence (seedlings/m^2* for 6 replicates) of wild radish at Corowa, N.S.W. under various soil surface treatments

	Soil surface treatment (12 April 1977)		
	Bared	Cultivated (disc)	Undisturbed
5 May	0.3 b**	58.2 a	0.1 b
26 May	144.9 b	701.3 a	65.3 b
26 June	58.7 a	147.9 a	51.6 a
14 August	12.0 a	15.9 a	7.0 a
31 December	0	0	0
Total	225.1 b	962.9 a	139.6 b

* seedlings removed at each count

** values followed by different letters are significantly different ($P<0.05$) as determined by Duncan's Multiple Range Test on log ($\times + 1$) transformed data (comparisons within rows only).

Table 2. Germination (% after 28 days for 3 replicates of 50 seeds) of wild radish under constant and alternating temperatures (values are means of 1975 and 1976 seed, and light/dark ($^{12}/_{12}$ H) and dark germination treatments)

Night temperature	Day temperature °C (6 h)			
°C (18 h)	35	25	15	5
35	0.3 d*			
25	6.2 b	4.5 b		
15	13.7 a	7.4 b	2.3 c	
5	13.9 a	17.8 a	5.2 b	1.0 cd

* values followed by different letters are significantly different ($P<0.05$) as determined by Duncan's Multiple Range Test on log ($\times + 1$) transformed data.

Table 3. Germination (% after 29 days for 3 replicates of 50 seeds) of wild radish at $^{25}/5^{0}$C (^{6}/18 h) in the light/dark (^{12}/12 h) or dark after vernalization at 5^{0}C in the light/dark or dark for 0, 1, 2, or 4 weeks

Time of storage (weeks)	Storage conditions		Germination conditions	
	light/dark	dark	light/dark	dark
0	27 (0.55)*	20 (0.46)	29 (0.57)	18 (0.44)
1	32 (0.60)	19 (0.46)	21 (0.48)	30 (0.58)
2	26 (0.54)	11 (0.34)	12 (0.35)	25 (0.52)
4	41 (0.69)	13 (0.37)	23 (0.50)	29 (0.57)
L.S.D. (P = 0.05)	(0.09)		(0.09)	

* figures in parentheses are angular transformations (radians).

Table 4. Viability (% of 50 seeds for 2 replicates) of seed of wild radish buried in May 1976 at 4 depths and recovered 3, 6, 9, or 12 months

Recovery date	Depth (cm)			
	0	1	5	10
2 Sept. 1976	71 a*	34 a	49 ab	54 ab
7 Dec. 1976	48 a	19 b	17 b	46 a
1 Mar. 1977	52 a	23 b	14 c	40 ab
25 May 1977	18 b	14 b	34 a	37 a

* values followed by different letters are significantly different ($P<0.05$) as determined by Duncan's Multiple Range Test (comparisons within rows only).

Table 5. Seasonal emergence (seedlings/1000 seeds for 4 replicates) of seed of wild radish collected in March 1976 and sown at 4 depths on 25 May 1977

	Depth (cm)			
	0	1	5	10
21 June	61.7 b*	289.0 a	47.5 b	1.3 c
30 June	99.4 a	87.4 a	29.7 b	0.4 c
15 July	26.8 b	105.8 a	11.3 b	0.9 c
11 Aug.	111.1 b	196.1 a	39.0 c	0.4 d
6 Sept.	12.0 b	29.8 a	14.3 b	1.3 c
28 Nov.	2.3 b	10.9 a	8.9 a	0.4 b
31 Dec.	0	0	0	0
Total	319.3 b	724.7 a	154.7 c	5.6 d

* values followed by different letters are significantly different ($P<0.05$) as determined by Duncan's Multiple Range Test on log ($x+1$) transformed data (comparisons within rows only).

This staggered germination ensures that some seedlings will survive, even if many are killed by adverse conditions (e.g. moisture stress) during establishment. It also makes it difficult to decide on the timing of cultural and chemical control in crops to obtain maximum yield responses and minimum contamination of the harvested grain. Early spraying (4 to 6 weeks after emergence) gives the best yield responses, but some contamination due to late-emerging wild radish plants, whilst late spraying (post-tillering) gives lower yield responses but usually no contamination. Depending on the importance placed on contamination, control may be best obtained by two sprayings, one early and one late.

(d) Seed germination

Tests in the laboratory showed that wild radish germinates well over a wide range of alternating and constant temperatures, in the light or dark, and germinates best with widely-fluctuating temperatures (Table 2). This explains why wild radish germinates well in the field after rainfalls in autumn, when temperatures fluctuate widely, and continues to germinate throughout the year when moisture is available (Table 5).

Germination at 25/5°C was also generally enhanced if the seed was vernalized at 5°C in the light and germinated in the dark. This light/dark effect helps explain why disc cultivation greatly increases seedling emergence in wild radish-infested situations (Table 1); seed exposed to light on the soil surface is buried by cultivation and thus germinates readily.

The seed pod plays an important part in determining germination behaviour of wild radish. In a laboratory experiment, seed that would not germinate after 3 weeks at 25/5°C (6/18 h) was used to

test the effect on germination of removal of the seed pod. Four replicates of 10 seeds were used for each treatment, and germination after a further 20 days was 64% and 0% respectively for seed with pods removed or not removed. This effect was similar in the light/dark (12/12 h) or dark. Perhaps the sporadic germination of seed during the year in the field is due to slow and varying rates of breakdown of seed pods on or below the soil surface.

(e) Effect of cultivation

As mentioned earlier, emergence in the field is greatly increased by disc cultivation (Table 1) because seed is buried, and seed germination is stimulated by darkness and higher moisture levels below the soil surface. Such increases help explain why wild radish is often abundant in cultivated situations. They also suggest that disc fallowing and working of the seed bed before sowing may stimulate germination, kill the resultant seedlings, and reduce wild radish infestations in the subsequent crops. Control of wild radish by pre-sowing cultivation is being investigated near Rutherglen in 1978.

The method of cultivation before and during crop establishment is important in determining the density of wild radish in the subsequent crop (Table 6). Radish density was high when the ground was scarified once before sowing, probably because seed was buried just below the soil surface and its germination was stimulated. Establishment of the crop by direct drilling gave a somewhat reduced density of radish because limited disturbance of the soil left much seed on the surface where its germination and establishment were poor. Mouldboard ploughing to 10 cm greatly reduced the density of radish because most seed was buried deeply and was unable to germinate and/or emerge. Direct drilling and mouldboard ploughing may be useful in the future in some situations to reduce densities of weeds such as wild radish.

Table 6. Density of wild radish (seedlings/m for 3 replicates) in wheat crops established on 23 May 1977 with direct-drilling, scarifying to 5 or 10 cm, and mouldboard ploughing to 10 cm

	Radish density (1 Aug. 1977)
Direct-drilling	207 bc*
Mouldboard ploughing 10 cm	90 c
Scarifying 5 cm	323 b
10 cm	490 a

* values followed by different letters are significantly different ($P<0.05$) as determined by Duncan's Multiple Range Test.

It is emphasized that depth of burial of seed has a big effect on its survival, as well as on seedling emergence (Tables 4 and 5). Seed left on the soil surface, by direct drilling for example, has a relatively low seedling emergence and loses viability quite rapidly; seed sown just below the soil surface by disc ploughing or scarifying has a high emergence and loses viability quite rapidly; seed sown deeply by mouldboard ploughing has a low emergence but loses viability slowly. Thus, care should be taken not to plough

deeply where mouldboard ploughing has been used to bury weed seeds in recent years, or viable seed may be raised near the surface where it will germinate and establish readily.

CONCLUSIONS

These studies show that the "weediness" of wild radish in crops is enhanced by the ability of the species to:

(i) produce large quantities of seed

(ii) germinate sporadically over several years, and

(iii) germinate best in cultivated situations.

The high germination of the plant after cultivation suggests that its incidence in crops may be reduced by fallowing and cultivating after rainfalls through summer and autumn before the crop is sown.

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