Competitiveness and persistence of wild radish (*Raphanus raphanistrum* L.) in a wheat-lupin rotation

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Summary A field study was conducted from 1997 to 2001 to study the competitiveness and persistence of wild radish in wheat-lupin rotation on a sandy loam duplex soil at the Merredin Research Station, Western Australia. During the wheat phase in 1997, autumn tickling, wheat seeding rates, wheat seeding time and one or more herbicides from different modes of action were combined to achieve eight treatments including an untreated control and a treatment to completely prevent seed production of radish.

Regression equations predicted that presence of 10–75 plants m^{-2} of radish at the reproductive stages of crops could reduce wheat yield by 7–56%, lupin yield by 28–92% and increased wheat screenings up to 9.5%. Competition from radish reduced lupin seed size and protein percentage of lupin seed. Lupin seed protein percentage decreased with the decreases in seed size due to competition. In the absence of fresh seed production, at least 9% seeds of the original seed bank of radish persisted in viable conditions for up to five years while 3% seeds of the original seedbank were unaccounted for up to the end of 2001 cropping season.

Keywords Wild radish, competition, yield reduction, wheat screenings, lupin seed size, lupin protein percentage, persistence of wild radish.

INTRODUCTION

Wild radish (*Raphanus raphanistrum* L.) is a very competitive weed to cereals and other winter crops (Cheam and Code 1995). This weed is hard to control in dicot crops such as canola (*Brassica napus* L.), lupins (*Lupinus* spp.), and other pulses in the Western Australia (WA) wheatbelt. In the WA wheatbelt, this weed has evolved widespread resistance to acetolactate synthase-inhibiting herbicides (Hashem *et al*. 2001, Walsh *et al.* 2001). Wild radish has also evolved resistance to photosystem II-inhibitors such as simazine and atrazine (Hashem *et al.* 2001) and carotenoid synthesis inhibitors such as diflufenican (Cheam *et al.* 2000) within the WA wheatbelt. Wheat yield was reduced by about 50% due to competition from 200 plants m^{-2} of radish in Victoria (Code *et al*. 1978).

Although crop yield losses occur due to competition from wild radish in WA, documented information on such yield losses is scarce in WA situations. Competition from radish not only reduces crop yield, but may also affect seed quality such as seed size and protein percentage. Once radish seeds go into soil seedbank, these may stay there in viable conditions for several years (Peltzer and Matson 2002). However, in the absence of fresh seed production of wild radish in the second and third crop of wheat, radish seedbank declined substantially and 0.7 to 1.7 seedlings m^{-2} had emerged in the subsequent wheat crop (Code and Donaldson 1996).

However, information on the persistence of wild radish seeds in a known wild radish seedbank under continuous cropping systems such as a wheat-lupin rotation in the WA wheatbelt is scarce in literature. A long-term study on a wheat-lupin rotation was conducted at the Merredin Research Station from 1997 to 2001 to examine the effect of long-term competition from wild radish on the yield and quality of wheat and lupins in the WA wheatbelt.

MATERIALS AND METHODS

The study was conducted on a sandy loam duplex soil with wheat (cv. Amery) in 1997, lupins (cv. Kalya) in 1998, wheat (cv. Westonia) in 1999, lupins (cv. Mayallie) in 2000 and wheat (Westonia) in 2001. Since the radish seedbank was historically very low in this paddock, about 350 pod fragments m^{-2} (equivalent to 350 seeds m^{-2}) were introduced uniformly over all plots (5.4 m × 20 m with 1.8 m buffer between plots) prior to season break in 1997. Cheam and Code (1995) indicated that each pod fragment of radish contains one seed. During wheat phases, chemical (herbicides from different modes of action) and non-chemical (autumn tickle, wheat seeding rate, and seeding time) weed control options were combined to achieve eight treatments including an untreated control and a treatment for total prevention of radish seed production. In addition to chemical and non-chemical treatments, total prevention of radish seed production was ensured by hand pulling of the surviving radish plants at the flowering stage. The herbicides were either rotated or repeated in the subsequent wheat crops. In 1998 and 2000 lupin crops, simazine 1 kg a.i. ha^{-1} was sprayed uniformly in all treatments before seeding and a mixture of metribuzin + diflufenican was sprayed in selected treatments at post-emergence. The plots of the treatment where radish seed production was totally prevented both in wheat and lupins were tickled in autumn in 1997–2000 to stimulate pre-seeding emergence of radish.

These combinations of treatments provided a range of radish control levels varying from very high radish burden to absolutely no radish plants at flowering stage of crop in this rotation. The treatment where radish seed production was totally prevented provided the information on the persistence of radish seedbank. Emergence of wild radish before and after crop seeding was recorded from fixed quadrats from April to September each year. Wheat yield, lupin yield and wheat screenings were recorded at harvest in each year. In 2000, after four years of competition, seed samples of lupin were collected and, seed size (g 1000^{-1} seeds) and seed protein percentage were determined. All data except radish seedling emergence and persistence of radish seed were subjected to regression analysis using GENSTAT. All parameters were significant ($P<0.05$).

RESULTS

Wheat yield reduction Competition from radish greatly reduced yield of wheat in Merredin. Linear regression on the effect of radish density on the yield of wheat in 1997 and 1999 predicted that if 10, 25, 50 and 75 radish plants m^{-2} were present at the anthesis stage of wheat, its yield was reduced by 7, 20, 37 and 56% respectively. These yield losses occurred when compared to an expected maximum yield of 3010 kg ha^{-1} in a wheat crop where radish was effectively controlled at the early stages of wheat (Figure 1A).

Wheat screenings Competition from radish not only reduced wheat yield but also increased wheat screenings. When 5, 10, 25, 50, or 75 radish plants m^{-2} were present at the anthesis stage, wheat screenings were increased to 3.7, 4.1, 5.3, 7.4, and 9.5% respectively compared to the screenings of 3.3% of the treatment where radish was effectively controlled at the early stages of wheat (Figure 1B).

Lupin yield reduction When 10, 25, 50 and 75 radish plants m^{-2} were present at flowering stage of lupins, its yield was reduced by 28, 56, 81, and 92% respectively, compared to the yield of 541 kg ha^{-1} obtained in the treatment where radish plants were completely controlled (Figure 2).

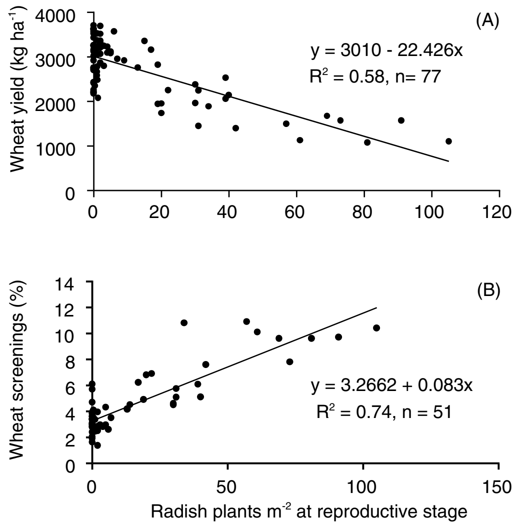

Figure 1. Regression equations predicting the effect of radish density on (A) wheat yield and (B) wheat screenings in 1997 and 1999 in a wheat-lupin rotation in Merredin.

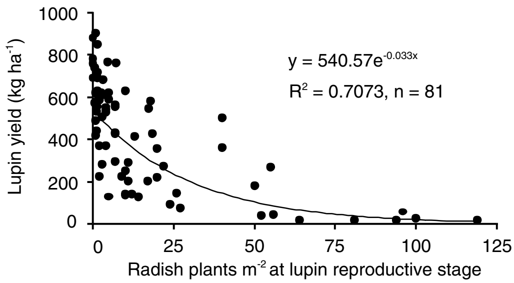

Figure 2. Regression equation predicting the effect of radish density on the yield of lupin in 1998 and 2000 in a wheat-lupin rotation in Merredin.

Lupin seed size and seed protein percentage Regression analyses indicate that seed size of lupin was reduced as the radish density increased in lupin at three weeks after emergence of lupin (Figure 3). In contrast, lupin seed protein percentage increased linearly as seed size of lupin increased. In other words, as the seed size of lupin was reduced by the competition from wild radish, protein percentage in lupin seed was also reduced.

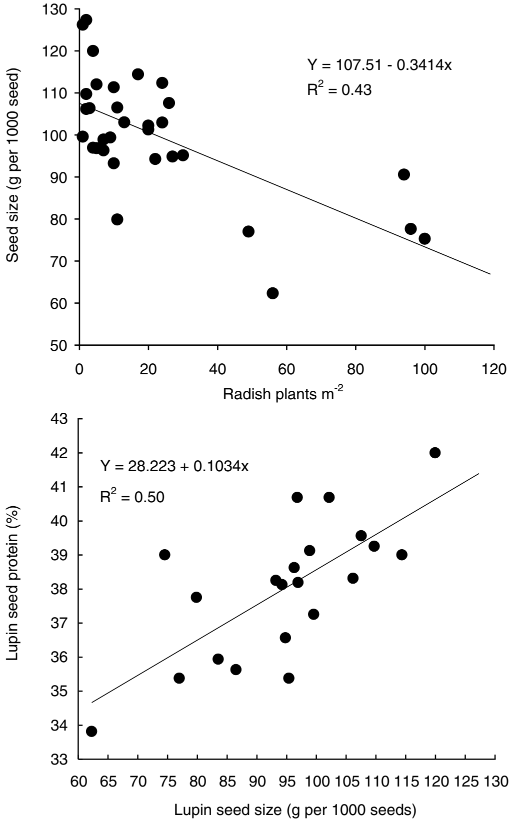

Figure 3. Competition from radish reduced the seed size of lupin and lupin protein percentage decreased with decreases in lupin seed size in 2000.

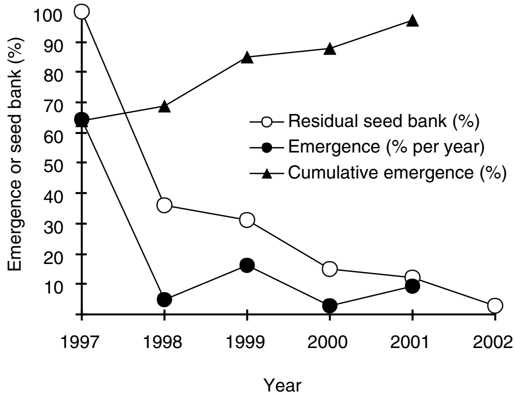

Figure 4. Annual emergence, cumulative emergence and persistence of residual seedbank of wild radish as percentage of 350 pod fragments introduced in 1997 in a wheat-lupin-wheat-lupin-wheat rotation.

Persistence of radish in seedbank In the absence of any seed production of radish, 64% of the 350 seeds introduced in 1997 before seeding wheat crop emerged in 1997, 5% in 1998, 16% in 1999, 3% in 2000 and 9% in 2001 (Figure 4). The trend in the cumulative emergence of radish from 1997 to 2001 indicates that 97% of the wild radish seeds in the seedbank had emerged by 2001 and 3% was still unaccounted for.

DISCUSSION

Wheat yield was reduced by up to 56% and lupin yield by up to 92% due to competition from 75 m^{-2} wild radish plants most of which had emerged at early crop stages. The yield loss data of wheat and lupin clearly established that radish is highly competitive to both crops and it was more competitive to lupin than wheat. Code *et al.* (1978) found 50% reduction in wheat yield due to competition from 200 radish. Since the intensity of competition between species depends on the site quality and size of radish plants, scope of prediction of the competition in this study is limited to the data set of this study. The relationship between wheat yield and radish density in 1997 and 1999 was linear. Donald and Khan (1992) also found a linear relationship between the relative yield of wheat and Canadian thistle shoot density in North Dakota, USA. The maximum possible yield (541 kg ha^{-1}) of lupin in absence of competition was low mainly due to overall low yield of lupin in 2000 season (Figure 2) when the site received only 121 mm rain after cop seeding.

Wheat initially overtops wild radish canopy through leaf expansion and subsequently through stem elongation during early reproductive stages (double ridge to booting). This enables wheat canopy to dominate over radish canopy during vegetative and early reproductive stages (Cousens *et al.* 2001), probably minimising the intensity of competition of radish with wheat compared to lupins. This probably triggers wild radish plants to expand leaf area through the process of shade avoidance response to maximise capture of light (Ballare *et al*. 1991), usually the photosynthetically active radiation (PAR). However, radish subsequently overtops wheat reducing PAR intercepting on wheat canopy by about 15% at wheat anthesis when competition for water also may become intensive. The extent of yield loss in lupin due to the competition from radish was greater than wheat. An exponential relationship between lupin yield and radish density indicates that competition of radish with lupin was more intensive even at lower density of radish compared to wheat. Since both lupin and radish are dicot plants, they probably exert similar demand on the resources simultaneously resulting in more intensive competition.

Wheat screenings increased with the increases in radish density and lupin seed size decreased with increases in radish density. A small seed of lupin had lower protein percent than a large seed, clearly indicating that protein percent of lupin seed decreased with a decrease in lupin seed size as result of competition from radish. The R^2 (coefficient of determination) values for the regression equation between wheat or lupin yield and radish density were reasonably high suggesting that radish density was an important factor that influenced the majority of the variation in yield of wheat and lupin.

About 64% of the original radish seedbank had emerged in 1997, 5% in 1998, 16% in 1999, 3% in 2000 and 9% in 2001. These results indicate that 97% of the total seeds emerged over a five-year period under minimum or no tillage continuous cropping systems with autumn tickle (2–3 cm deep) carried out to stimulate pre-seeding emergence of radish in four out of five years in the rotation. The depth of seed burial (Piggin and Reeves 1978, Code and Donaldson 1996) and coat-imposed dormancy (Cheam 1984) regulate the emergence pattern of radish seeds. About 9% of the viable seeds in the original seedbank can persist in the soil under continuous cropping systems for up to five years. The remaining 3% seeds that are unaccounted for at the end of five years, may still be in the soil in viable conditions, may have partly decayed or been predated.

The results of this study clearly suggest that radish is highly competitive to crops and its seedbank life is at least five years long in continuous cropping systems. Appropriate integrated management options must be developed and adopted to control this weed and prevent enrichment of seedbank.

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