Managing herbicide resistant annual ryegrass (*Lolium rigidum* Gaud.) in no-till systems in Western Australia using occasional inversion ploughing

Alexandra Douglas¹ and Sally C. Peltzer²

¹ Department of Agriculture Western Australia, 10 Dore Street, Katanning, Western Australia 6317, Australia
² Department of Agriculture Western Australia, 444 Albany Highway, Albany, Western Australia 6330, Australia

**Summary** Sites at Katanning and Beverley, Western Australia, were selected in 2002 to investigate the efficacy of mouldboard ploughing for the control of herbicide resistant annual ryegrass populations. The mouldboard plough was compared with disk ploughing, full cut and no-till tillage regimes. Cereal crops were planted and assessed in 2002 and 2003. Mouldboard ploughing reduced the number of annual ryegrass seedlings by over 95% at both sites in 2002, compared with the other tillage treatments. The differences in annual ryegrass density were maintained into the 2003 crops. Cereal yields were significantly higher on mouldboard ploughed plots at Katanning in 2002 and 2003 and at Beverley in 2002. Mouldboard ploughing shows great promise as a one-off treatment to ‘reset’ the resistance clock. It is estimated that an inversion treatment may only be required once every 8–10 years.

**Keywords** Soil inversion, mouldboard plough, herbicide resistance, annual ryegrass.

**INTRODUCTION**

Herbicide resistant annual ryegrass (*Lolium rigidum* Gaud.) is a major cost to the Western Australian grains industry. Recent surveys indicate that 50% of the annual ryegrass populations across Western Australia are resistant to one or more herbicide groups. As annual ryegrass can produce large numbers of seed after one herbicide failure, a successful cropping program the following season may not be an option without drastic control measures. Further, many farmers in Western Australia have tight rotations without pastures that limit the number of techniques available to them for annual ryegrass management.

Seed burial, by use of a specialist mouldboard plough with skimmers, could place the annual ryegrass seeds at depth where they would fail to establish and eventually die. Inversion ploughing could be practised every 8–10 years with conservation tillage in the intervening years.

This paper reports the effects of a one-off mouldboard ploughing on annual ryegrass control at two locations in Western Australia. The results were compared with continuous no-tillage and scarification. Disk-ploughing was used as a comparison whereby the soil was deeply tilled but was not fully inverted.

**MATERIALS AND METHODS**

The effect of a one-off soil inversion following long-term conservation tillage on annual ryegrass control was measured in two field trials in the south-west land division of Western Australia. Sites at Katanning (33.7°S, 117.5°E, sand over clay) and Beverley (32.1°S, 116.9°E, red-brown loam) were selected with background populations of annual ryegrass in early 2002. Both sites had five tillage treatments: mouldboard plough (with skimmers – AB 85 Kverneland) 15–20 cm deep every year; mouldboard plough (with skimmers) 15–20 cm deep in year 1 only; disk plough to 15 cm deep; full-cut (complete soil disturbance with scarification); and no-till (with knife-points). There were four replicates in a randomised block design. The tillage treatments (mouldboard plough, disk plough and full-cut) were implemented prior to seeding, and all plots were sown with knifepoints. The tillage treatments (except for the mouldboard plough in year 1 only) were repeated in 2003. Measurements taken throughout both seasons included crop and annual ryegrass density, dry weights at anthesis, grain yield and grain protein.

At Katanning in 2002, the site was pre-treated with a single knockdown of paraquat/diquat then sown to barley (cv. Stirling at 125 kg ha⁻¹) with 100 kg ha⁻¹ of basal fertiliser (14.1 kg N ha⁻¹). In 2003, the entire site was burnt in autumn and then pre-treated with a double knockdown (glyphosate followed five to seven days later by a mixture of paraquat/diquat). Trifluralin was applied at 768 g a.i. ha⁻¹ immediately prior to planting barley (cv. Gairdner) at 125 kg ha⁻¹ plus 100 kg ha⁻¹ of basal fertiliser (14.1 kg N ha⁻¹). MCPA, diflufenican and metsulfuron – methyl were applied post-emergence for broad-leaf weed control. Nitrogen was topdressed at 55 kg ha⁻¹.

In 2002 at Beverley, the site was sown to wheat (cv. Brookton at 120 kg ha⁻¹) with basal fertiliser at 100 kg ha⁻¹ (14.1 kg N ha⁻¹) after a knockdown of paraquat/D
diquat. Post-seeding treatments included a mixture of MCPA/bromoxynil/dicamba for broadleaf control as well as 34.5 kg ha$^{-1}$ of nitrogen (top-dressed). A low rate of diclofop-methyl (187.5 g a.i. ha$^{-1}$) was applied post-emergence but had no apparent effect.

In 2003 the site was burnt in autumn and then treated with a double knockdown. The trial was seeded with barley (cv. Gairdner at 125 kg ha$^{-1}$) plus 768 g a.i. ha$^{-1}$ trifluralin plus 100 kg ha$^{-1}$ (14.1 kg N ha$^{-1}$) basal fertiliser. A mixture of MCPA/bromoxynil/dicamba was again applied for broadleaf control as well as 32 kg ha$^{-1}$ of nitrogen (top-dressed).

**RESULTS**

Inverting the soil by use of a mouldboard plough reduced the number of annual ryegrass seedlings by over 95% both at Katanning and Beverley in 2002 (Figure 1, P <0.05) compared with deep ploughing with a disk plough, and full or no-till. At Katanning, there continued to be low numbers of annual ryegrass in the mouldboard treatments in 2003 (Figure 2, P <0.05). There was also a reduction in seedling numbers with disk ploughing in the second year. At Beverley in 2003, the trifluralin maintained low numbers of annual ryegrass in all five treatments (Figure 2, P <0.05).

Higher yields and higher protein levels were associated with mouldboard ploughing compared with full-cut and no-till. At Katanning, in both 2002 (despite a poor season) and in 2003, barley yielded over 50% more in the mouldboard treatments (Figure 3). Similarly at Beverley in 2002, there was a 0.5 t ha$^{-1}$ increase in wheat yield, however there was no difference between the treatments in 2003, all plots yielding over 4 t ha$^{-1}$ of barley. The one-off mouldboard operation (mouldboard in 2002 only treatment) produced similar yields and grain protein to the annual disk plough and mouldboard treatments, both of which had two years of soil disturbance.

As the amount of annual ryegrass differed between the treatments, it was difficult to assess whether the increased yields associated with mouldboard ploughing were entirely due to reduced weed competition. This effect of weed competition was statistically removed from all treatments (by using annual ryegrass seedling numbers as a covariate in the analysis) and the yields adjusted accordingly. At Katanning, the increased yields in the mouldboard plough treatment for both 2002 and 2003 were partially due to the reduced numbers of weeds and partially due to other factors (P <0.05). This phenomenon also occurred in the disk plough treatments where the soil was disturbed to 15 cm but did not fully bury the annual ryegrass seed. Using the same analysis at Beverley, for the 2002 results, revealed that the increased yields due to mouldboard ploughing were almost entirely due to the reduced presence of annual ryegrass rather than other factors.

![Figure 1](image1.png)  **Figure 1.** The effect of tillage treatments on seedling emergence of annual ryegrass at Katanning and Beverley in 2002.

![Figure 2](image2.png)  **Figure 2.** The effect of tillage treatments on seedling emergence of annual ryegrass at Katanning and Beverley in 2003.

![Figure 3](image3.png)  **Figure 3.** The effect of tillage treatments on the yield and grain protein of barley over two years at Katanning (LSD (P = 0.05), protein per cent (2002) = 0.66, protein per cent (2003) = 1.1).
The incidence of take-all (*Gaeumannomyces graminis* var. *tritici*) was assessed at the Katanning site in 2003. There was take-all present on all plots although the incidence was light (1–25% of roots affected). There was no significant difference in incidence between treatments, however the mouldboard in year one only had a slightly higher incidence of the disease than the other treatments.

**DISCUSSION**

The mouldboard plough was successful in burying the majority of the weed seed thereby preventing the emergence of large numbers of seedlings in the absence of post-emergent selective herbicide use. At Katanning, the effect of burial persisted for two years. High numbers of annual ryegrass in the full-cut and no-till treatments continued in 2003 despite the site being burnt in autumn, having two pre-seeding knockdowns and an application of trifluralin at sowing.

After long-term reduced tillage, most weed seed is located in the top 1 cm of soil (Yennish *et al.* 1992). A single mouldboard operation inverts the soil and buries the seed at depths greater than 15 cm from where they cannot emerge. A small proportion of annual ryegrass seeds was able to begin germination at these depths in Western Australia (Gramshaw and Stern 1977) but they were unable to survive. Wild radish seedlings rarely emerged from depths greater than 5 cm (Young and Cousins 1999). Disk ploughing also buries a proportion of the weed seed but tends to favour a more even distribution throughout the soil (Mohle 1993). This accounted for the reduction in seedling numbers in the second year where some of the annual ryegrass seeds were buried to depths below those favourable for emergence. Re-inverting the soil in year 2 did not increase annual ryegrass numbers. This was not expected as the emergence of several other species was encouraged with further tillage practices (Yennish *et al.* 1992) due to the re-inversion of the soil bringing the seeds back to the surface. The dormancy of most seeds increases with soil depth (Mohler 1993) and the cases where persistence decreases with depth involve annual grasses with large short-lived seeds. Annual ryegrass is relatively small and possesses dormancy. Over 20% of seed were dormant in a Western Australian study and persisted for several years (Peltzer and Matson 2002). The burial of annual ryegrass seeds at greater than 8 cm enforced dormancy (Gramshaw and Stern 1977).

Higher yields and grain protein levels were associated with the mouldboard treatment compared with full-cut and no-till predominantly due to the reduction in annual ryegrass numbers in crop. Similarly, downy brome populations were reduced by 97% following mouldboard tillage in the US, resulting in a 30% increase in wheat yields (Kettler *et al.* 2000). Competition with annual ryegrass can cause large losses in grain crops (Gill 1996) and can also cause reductions in grain protein (Peltzer 1997).

At Katanning in 2002 and 2003, some of the yield and grain protein increase could also be associated with increased soil nitrogen mineralisation due to soil disturbance. Mineralisation of nitrogen has been doubled in the surface 5 cm after mouldboard ploughing (Pierce 1994). The site was not top-dressed with nitrogen and soil tests in 2002 indicated below optimal total soil nitrogen (<35 mg kg$^{-1}$ total nitrogen). The no-till and full-cut treatments appeared nitrogen deficient at anthesis. At Beverley, the increased yields and grain protein were mainly due to reduced annual ryegrass and the total soil nitrogen was optimal (45 mg kg$^{-1}$ total nitrogen). The extra yield could also be associated with nutrient redistribution. Soil tests in 2002 revealed higher levels of phosphorus, potassium and organic carbon at depth after mouldboarding compared with the other treatments. The reverse was true for the top 10 cm of soil. In Michigan, soil surface nutrients were also redistributed by ploughing after long-term no-tillage (Pierce 1994).

The use of a single mouldboard plough for the control of herbicide resistant weeds has great potential. It is estimated that the tillage treatment would only need be used approximately every 10 years with conservation tillage practices in between. Previous work in the US has reported that after 4–5 years, most soil properties return to levels of no-tillage (Kettler *et al.* 2000 and Pierce 1994). The soils used in this prior work have however been much heavier than here in Western Australia. Further investigation in Western Australia would need to be done before recommending this practice. Future work also includes the use of the mouldboard plough to control other pests and to ameliorate sub-surface acidity.

**ACKNOWLEDGMENTS**

We are grateful to the Grains Research and Development Corporation for providing the funding for this study. We would also like to thank Paul Matson for his technical help and staff from the Department of Agriculture Research Stations for their assistance in the maintenance of some of these trials.

**REFERENCES**


