Weed seed persistence with changing farming practices in southern Queensland

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Summary  Persistence of common winter and summer weeds was reviewed from seven experiments in the northern grain region to assist with development of weed management strategies. Seed of barnyard grass, bladder ketmia, climbing buckwheat, common sowthistle, liverseed grass, paradoxa grass, turnip weed, wild oat, and wireweed were sown, either in large in-ground pots or weed-free field plots, or sampled from naturally infested paddocks. In many cases, seeds were buried at different depths, and one experiment compared undisturbed and tilled soil environments.

In general, ≤4% of seed remained in the top 2 cm of soil after two years of burial, and ≤1% remained after four years without new seed input, apart from bladder ketmia, climbing buckwheat, turnip weed, and wireweed. For the majority of weeds, persistence increased substantially with burial at 10 cm depth. Cultivation tended to slightly decrease persistence or had minimal impact.

The data indicate the importance of keeping weed seeds near the soil surface, and that effective management of emergence from surface layers will result in major depletion of the seed-bank of annual grasses and some broadleaf weeds, such as common sowthistle, within a short period. However, it is particularly important to prevent seed production on all survivors of weeds with a hard seed coat, such as turnip weed, bladder ketmia and climbing buckwheat, as 5 to 37% of seed persisted for four years in the seed-bank.

Keywords  Seed persistence, barnyard grass, bladder ketmia, climbing buckwheat, common sowthistle, liverseed grass, paradoxa grass, turnip weed, wild oat, wireweed.

INTRODUCTION Effective management of annual weeds requires an understanding of the seed-bank dynamics, particularly persistence (Cousens and Mortimer 1995). This is especially important when managing weed populations that have developed herbicide resistance, as this will determine the time that alternative management strategies need to be implemented to reduce the resistant seed-bank to very low levels (Matthews 1994). This paper reports on seed persistence of barnyard grass (Echinchloa colona (L.) Link), bladder ketmia (Hibiscus trionum L.), climbing buckwheat (Fallopia convolvulus (L.) A.Love), common sowthistle (Sonchus oleraceus L.), liverseed grass (Urochloa panicoides P.Beauv.), paradoxa grass (Phalaris paradoxa L.), turnip weed (Rapistrum rugosum (L.) All.), wild oat (Avena spp.), and wireweed (Polygonum aviculare L.) in the sub-tropical environment of the northern grain region. It also compares the impact of cultivation and burial depth on persistence.

MATERIALS AND METHODS
Four pot and three field experiments examined the persistence of seed of nine weeds. In the pot experiments, seed were sown in 25 cm diameter black plastic pots, which were sunk into the ground with the rims protruding approximately 5 cm above ground level. All pots and field plots were managed to prevent any new weed seed replenishment after commencement of the experiments. The experiments were located within 20 km of Toowoomba in southern Queensland, apart from Experiment G, which was approximately 200 km south-west of Toowoomba. Soil was a vertosol in all experiments.

Experiment A  Seed of climbing buckwheat, liverseed grass, paradoxa grass, turnip weed, wild oat, and wireweed were sown in pots at 0–8 cm depth, and soil was mixed manually four times per year. Pots were exhumed after four years. This experiment was duplicated with second series sown a year later.

Experiment B  Seed of barnyard grass (540), bladder ketmia (350), and liverseed grass (350) were sown in pots at three depths (0–2, 5 and 10 cm) in soil that was left undisturbed. Pots were exhumed after four years. Pots were exhumed at six intervals over two years.

Experiment C  Seed of common sowthistle (500) were sown in pots at 0, 2 and 10 cm depths in soil that was left undisturbed (Widderick et al. 2004). Pots were exhumed at twelve intervals over 2.5 years.
**Experiment D** Seed of paradoxa grass (500) were sown in pots at 0, 2 and 10 cm depths in soil that was left undisturbed (Taylor et al. 2005). Seed were also mixed in the top 10 cm, and this soil was manually mixed annually. Pots were exhumed at seven intervals over three years.

**Experiment E** Soil cores (30; 0–10 cm) were collected at 18 intervals over three years within a defined zero-tilled field plot artificially infested with paradoxa grass. This experiment was duplicated a year later, with half of the area undisturbed and other half cultivated annually. Cores were collected at 12 intervals over two years (Taylor et al. 2005).

**Experiment F** Soil cores (84; 0–10 cm) were collected at nine intervals over 4.5 years from a defined zero-tilled field plot artificially infested with turnip weed.

**Experiment G** Soil cores (240; 0–10 cm) were collected at five intervals over two years from eight defined areas within a zero-tilled paddock naturally infested with wild oat.

**Measurements** The contents of each pot or cores were tipped out and washed through a series of wire sieves of suitable size to capture the weed seeds. Viable seed, defined as firm seed with no evidence of decay, were counted. Seed viability was also confirmed with germination tests under optimal conditions (Experiments B, C), treating non-germinating seed with tetrazolium (Experiment B) or squeezing with tweezers (Experiment C).

**Analyses** Exponential curves were fitted to the seed data (Experiments B–G) to estimate the percentage remaining after three and four years of burial.

**RESULTS**

**Experiment A** No liverseed grass or paradoxa grass seed were detected after four years of burial (Table 1). As well, no wild oat seed or very few seed were detected. However, 2–11% of seed of climbing buckwheat, turnip weed and wireweed persisted for four years.

<table>
<thead>
<tr>
<th>Weed</th>
<th>Persistence (% of seed sown)</th>
<th>Exper. A.1</th>
<th>Exper. A.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liverseed grass</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Paradoxa grass</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wild oat</td>
<td>0</td>
<td>&lt;0.1</td>
<td></td>
</tr>
<tr>
<td>Wireweed</td>
<td>2</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Turnip weed</td>
<td>5</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Climbing buckwheat</td>
<td>6</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1.** Persistence of six weed species remaining after four years of burial in a disturbed soil at 0–8 cm depth in duplicated Experiment A.

**Experiment B** After two years of burial, only 1–4% of barnyard grass and liverseed grass seed remained after four years of burial (Table 1). As well, no wild oat seed or very few seed were detected. However, 2–11% of seed of climbing buckwheat, turnip weed and wireweed persisted for four years.

<table>
<thead>
<tr>
<th>Weed</th>
<th>Depth (cm)</th>
<th>1 y</th>
<th>2 y</th>
<th>3 y</th>
<th>4 y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnyard grass</td>
<td>0–2</td>
<td>13</td>
<td>2</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>40</td>
<td>19</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Liverseed grass</td>
<td>0–2</td>
<td>24</td>
<td>1</td>
<td>&lt;1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>67</td>
<td>21</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Bladder ketmia</td>
<td>0–2</td>
<td>71</td>
<td>38</td>
<td>27</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>72</td>
<td>64</td>
<td>47</td>
<td>37</td>
</tr>
</tbody>
</table>

**Table 2.** Persistence of three weed species remaining after one and two years of burial in a non-disturbed soil at different burial depths (Experiment B), with estimated persistence after three and four years in italics.

were <0.1% in the surface soil for the grasses and 17% for bladder ketmia.

**Experiment C** Less than 1% of common sowthistle seed remained on the soil surface after two years, whereas 2% and 10% remained at 2 and 10 cm depths respectively (Table 3). No seeds were estimated to remain on the soil surface after four years, in contrast to 2% at 10 cm (R² = 0.61–76).

**Experiment D** After two years of burial, only 1–4% of paradoxa grass seed remained irrespective of depth or soil disturbance (Table 3). The estimated portions (R²=90–96%) after four years of burial were <1% on soil surface and <0.1% for other depths and for tilled soil. After the first year, there was a trend of seed persisting longer on soil surface than when buried.

**Experiment E** In the first experiment (E.1), paradoxa grass seed-bank declined from 6990 to 0 seed m⁻² in three years. In the second experiment (E.2), the seed-bank declined from 61,600 to 153 seed m⁻² in non-disturbed plot and to 4 seed m⁻² in the disturbed plot in two years, although the parameters for the non-linear regression were not significantly different.
Persistence of weed seed differed substantially between species in the sub-tropical environment of the northern grain region. The annual grasses, irrespective whether they were summer or winter growing species, had only a short persistence in the surface soil. Less than 5% remained after two years and between 0 and 1% remained, or was predicted to remain, after four years. Common sowthistle also had a similar short persistence.

However, seed persistence of barnyard grass, liverseed grass, wild oat and common sowthistle increased markedly when seed were buried at lower depths. For example, 10–21% of the seed remained after two years compared with 1–2% in the top 2 cm. In contrast, burial depth did not influence persistence of paradoxa grass seed.

Seed persistence of bladder ketmia, climbing buckwheat, turnip weed and wireweed, weeds with a hard seed coat, was much longer than for the annual grasses. For example, 36–64% of bladder ketmia and turnip weed remained after two years, whilst 5–11% remained after four years for climbing buckwheat, turnip weed and wireweed in the top 8–10 cm of soil. Burial depth also influenced persistence of bladder ketmia, with 38% remaining in the top 2 cm after two years compared with 64% at 10 cm. The impact of burial depth was not measured for the other three weeds with hard seed coats.

Soil disturbance appeared to have only minimal impact on weed seed persistence. For paradoxa grass, the only weed with experimental comparisons between disturbed and non-disturbed soil, the rate of seed loss tended to be slightly greater in cultivated pots or plots compared with zero-tilled treatments. This was due to cultivation stimulating significantly greater emergence of paradoxa grass seedlings (Taylor et al. 2005). The measured persistence of liverseed grass, turnip weed, and wild oat seed after four years of tilled soil in Experiment A was very similar to that measured and/or predicted in zero-tilled soil in Experiments B, F and G respectively. However, a tillage operation that inverts soil and buries weed seed is likely to have a much greater impact on seed persistence in contrast to tillage operations that regularly mix the weed seed throughout the top 8–10 cm.

The differences among weed species in seed persistence and the impact of seed burial have implications with regard to management strategies of these weeds. For all weeds, it is critical to leave weed seed on or near the soil surface, as this will lead to more rapid decline in the seed-bank.

For annual grasses and common sowthistle, management strategies without weed seed burial or seed rain will lead to ≥99% reduction in the seed-bank in the surface soil within 2–3 years. This indicates that paddocks heavily infested with these weeds could be managed to substantially minimise the impact of weeds within a relatively short period. As well, most of these weeds have developed resistance to Group A, B and/or C herbicides in the northern grain region (Adkins et al. 1997, Storrie and Walker 1999). For paddocks
with resistant annual grasses and common sowthistle, management strategies that prevent weed seed burial and seed rain, and do not rely heavily on herbicides to which resistance has developed, will lead to a rapid decline in herbicide resistant populations.

Whilst the same approach could be applied to weeds, such as bladder ketmia, climbing buckwheat, turnip weed and wireweed, the management strategy will need to be in place for at least 4–5 years to reduce the seed-bank by ≥95%. For these weeds, it is much more critical to prevent any seed rain, given that their seeds are much more persistent, and therefore more costly to manage than annual grasses and common sowthistle. It is also important to implement preventive strategies for herbicide resistance prior to these weeds developing resistance, due to the long persistence of these weed seeds in the soil seed-bank.

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REFERENCES


