FIELD SCREENING TECHNIQUES TO ASSESS NEW CROP WEEDS

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Abstract Early action to contain the spread of serious new weeds will minimise the long-term costs of impact and control. Identifying such weeds is difficult, and comparative field screening was done to determine if serious crop weeds could be distinguished from minor crop weeds and non-weeds. Thirty-nine crucifer species (Brassicaceae) were tested. Measurements of germination, seedling survival and seed production were used to develop a simple measure of the finite rate of increase, \( R \), within a winter wheat crop. Most crop weeds had positive rates of increase \( (R > 1) \) and most garden plants and non-crop weeds were unlikely to persist \( (R < 1) \). Strong performing species included Sisymbrium orientale L., Raphanus raphanistrum L. and the new weed Chorispora tenella (Pall.) DC. Crop species had low or negative rates of increase, provided that germination in the first month was ignored. The field screening approach shows promise for assessing recently naturalised species as potential crop weeds. However, refinements need to address persistence of perennial species, soil type preferences and selection of germination periods.

INTRODUCTION

An average of 12 new plant species are found naturalised in Australia each year (Groves and Hosking 1998) but only between 5% and 20% have the potential to become weeds of significant economic and/or ecological impact (Williamson and Fitter 1996). Early containment of serious new weeds is cost-effective, avoiding the much greater, long-term impact and control costs if such weeds were to become widespread. There is a need for relatively simple yet accurate techniques to identify and prioritise the serious weeds amongst the recent naturalisations.

Rigorous assessments of invasiveness have been achieved by comparing groups of related species in a specific ecosystem (Mack 1996). This paper reports on a field comparison of crucifers (Brassicaceae), which aimed to rank species according to their risk as crop weeds. The focus on crucifers was initially detailed in Virtue (1996). Parker and Kareiva (1996) recommended the finite rate of increase \( (\lambda) \) as the most appropriate measure of risk of invasiveness of plant species. It compounds plant performance throughout the life cycle and is biologically meaningful.

Germination, seedling survival and seed production in a wheat field were measured for a selection of known crop weeds, non-crop weeds, crop plants, garden plants and new species. Data presented is preliminary, covering one time of sowing, excluding seed dormancy and dispersal measurements, and averaging multiple seed lots for some species.

MATERIALS AND METHODS

Seed of 39 crucifer species (Table 1) were obtained in summer 1996-97, from naturalised populations in South Australia (SA), interstate seed collections and commercial seed suppliers.

Seed viability Seeds were germinated in petri dishes on moist filter paper. There were fifty seeds per dish, with two dishes per seed lot. Seeds were incubated at 25°C/15°C (12h/12h) for three weeks. Seeds were in darkness for the first week, and had light at 25°C for the latter two weeks. Ungerminated seeds were then incubated at 15°C in darkness for a further week. The different light and temperature regimes provided a range of conditions to promote germination. Seeds that rotted during the germination test were considered non-viable. Viability of ungerminated seed was tested using tetrazolium stain. For some species with poor germination, tests were redone after removing indehiscent pods surrounding seeds or after a period of chilling.

Field germination The number and timing of germinations were examined at Roseworthy, SA. The soil was an alkaline sandy loam. Seeds were sown in lots of 100, with two to six replicates (replicates were completely randomised and rain prevented the sowing of all replicates for some species). Seeds were sown in the week of 12th May 1997. The first autumn rains occurred on 17th May. A hoe was used to make six furrows (depth 2 cm, width 15 cm, length 3 m), 0.5 m apart. The furrows were filled with topsoil that had been steamed to kill existing weed propagules, and weedmat was placed between them. The topsoil was smoothed, and 100 cell, square grids were placed along the rows. The grids were clear plastic frames of 1 cm
squares, 0.5 cm deep. One seed was placed in each cell and then covered with washed sand. The rows of cells were covered with wire gauze for protection from birds. The dates of germination (seedling emergence) were recorded weekly in the first three months, then fortnightly or monthly depending on rainfall frequency. Seedlings were discarded.

**Seed production** Seedling survival and seed production were examined in a wheat crop, adjacent to the germination study. Wheat (*Triticum aestivum* ‘Frame’) was sown on 28th May in a 10 × 10 m plot (33 plants m⁻², 15 cm rows), and the crucifers were planted in the following week. The plot was divided into a 0.25 m square grid. Each square within the grid was randomly allocated to a crucifer seedlot. At each square corner, several seeds were placed on the soil (inside 2 cm lengths of 2 cm diameter polythene pipe), and covered with sand. There were five replicate squares per seedlot, giving a potential of 20 plants per seedlot. Seedlings were thinned to one per square corner. Germination date, seedling survival and first flowering date were recorded. Plants were harvested in the week of 22nd December 1997, after wheat maturity. Seeds remaining were counted and seeds dropped were estimated. The site was burnt after harvest and sprayed twice with glyphosate in 1998 and 1999. Monitoring is continuing to avoid any escapes from the experiments.

**Data analysis** A simplified measure (*R*) of the finite rate of increase (λ) was calculated as:

\[
R = \frac{g}{v} \cdot d \cdot F
\]

(Equation 1)

Where: 
- *g* = proportion of seed germinating
- *v* = proportion of viable seeds at start
- *d* = proportion of plants setting seed in crop
- *F* = average seed production per plant

Dividing *g* by *v* corrected for seed quality between seedlots. *d* takes account of plants which died before seeding or which failed to seed prior to harvest. Two values of *R* were calculated, using *g* for seed germination in the first 3 months after sowing, and *g* for the 2nd-3rd months only. Plants growing from germinations after the 3rd month were assumed to not set seed within the crop.

**RESULTS**

Data for the 39 species are given in Table 1. The species are ordered according to the finite rate of increase for germination in the first 3 months. Species with values of *R* < 1 are predicted to increase in population size, whereas those with *R* > 1 will not persist.

For the crop weeds, 10 out of 17 species were predicted to increase if germination in the first three months was used to calculate *R*. *Sisymbrium orientale*, *Matthiola longipetala* and *Lepidium africanum* had very high rates of increase, mainly due to high seed production. High rates of increase were observed for *Rapistrum rugosum*, *Brassica tournefortii*, *Capsella bursa-pastoris* and *Raphanus raphanistrum*. *Neslia paniculata*, *Sisymbrium thellungi* and *Myagrum perfoliatum* had insufficient seed production to persist. *M. perfoliatum* also had very low seed germination. *Diplotaxis muralis* had just commenced seed production and *Hirschfeldia incana* had just started to flower when the crucifers were harvested. The perennials *Diplotaxis tenuifolia* and *Cardaria draba* were yet to flower. When *R* was calculated using germinations in the 2nd and 3rd months only, the top species were *S. orientale*, *R. raphanistrum*, *L. africanum*, *B. tournefortii* and *C. bursa-pastoris*.

For the crops, *Brassica nigra*, *Sinapis alba* and *Brassica juncea* had very high rates of increase using germination in the first 3 months. *Brassica napus* had a substantially lower rate of increase, and had been damaged by red-legged earth mites (RLEM), *Halotydeus destructor* (Tucker). The crop species had minimal seed dormancy, so that there was negligible germination in the 2nd and 3rd months after sowing, and thus *R* values close to or less than one.

Amongst the ten garden species, only *Malcolmia maritima* had seed production, giving *R* > 1 for both germination periods. *Lobularia maritima* died after flowering, setting no seed. *Iberis umbellata* flowered too late to set seed before the December harvest. The remaining species were still vegetative at harvest.

*Sisymbrium erssimoides* was the only non-crop weed to have seed production, and had *R* > 1 for both germination periods. *Cakile maritima* flowered but failed to seed before dying. *Lepidium latifolium* and *Rorippa nasturtium-aquaticum* prefer wet soils, and died before seeding.

Of the recently naturalised crucifers, *Chorispora tenella* had a very high *R*. Seed production was high, and there was substantial germination in the second and third months after sowing. *Malcolmia africana* had moderate rates of increase for both germination periods. *Euclidium syriacum* and *Calepina irregularis* appeared to be unlikely to persist due to poor germination. *C. irregularis* was also heavily attacked by RLEM, and did not set seed.
Table 1. Life cycle data for the crucifers tested as weeds of winter wheat. Species are grouped by their current status in Australia into crop weeds (registered for herbicidal control in winter wheat, PIRSA 1999), crop plants, garden plants, non-crop weeds and recently naturalised. Proportional data for seed viability ($v$), germination ($g$) and plants seeding in crop ($d$). Mean seed per plant ($F$) is based on seeding plants only. Finite rate of increase ($R$) is calculated for two germination periods; germination within the first 3 months after sowing, and in the 2nd and 3rd months after sowing only. Species are ordered based on the first calculation of $R$ within their groups. Life cycles are annual (A), biennial (B) and perennial (P).

<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>$v$ 3 mths</th>
<th>$g$ 2nd-3rd mths</th>
<th>$d$ 3 mths</th>
<th>$F$ 3 mths</th>
<th>$R$ 3 mths</th>
<th>$R_2$ 2nd-3rd mths</th>
<th>Life cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crop weeds:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sisymbrium orientale L.</td>
<td>Indian hedge mustard</td>
<td>0.96</td>
<td>0.44</td>
<td>0.19</td>
<td>0.56</td>
<td>1643</td>
<td>419.47</td>
<td>178.12</td>
</tr>
<tr>
<td>Matthiola longipelata (Vent.) DC.</td>
<td>scented nightstock</td>
<td>0.84</td>
<td>0.73</td>
<td>0.02</td>
<td>0.54</td>
<td>544</td>
<td>253.65</td>
<td>6.22</td>
</tr>
<tr>
<td>Lepidium africanum (Burm. f.) DC.</td>
<td>common peppercress</td>
<td>0.35</td>
<td>0.32</td>
<td>0.03</td>
<td>0.23</td>
<td>624</td>
<td>133.30</td>
<td>13.17</td>
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<tr>
<td>Rapistrum rugosum (L.) All.</td>
<td>short-fruited turnip</td>
<td>0.94</td>
<td>0.40</td>
<td>0.03</td>
<td>0.61</td>
<td>190</td>
<td>49.20</td>
<td>3.10</td>
</tr>
<tr>
<td>Brassica tournefortii Gouan</td>
<td>long-fruited turnip</td>
<td>0.99</td>
<td>0.62</td>
<td>0.17</td>
<td>0.36</td>
<td>172</td>
<td>38.41</td>
<td>10.31</td>
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<tr>
<td>Capsella bursa-pastoris (L.) Medikus</td>
<td>shepherd’s purse</td>
<td>0.58</td>
<td>0.41</td>
<td>0.12</td>
<td>0.25</td>
<td>183</td>
<td>32.17</td>
<td>9.06</td>
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<tr>
<td>Raphanus raphanistrum L.</td>
<td>wild radish</td>
<td>1.00</td>
<td>0.24</td>
<td>0.13</td>
<td>0.53</td>
<td>235</td>
<td>29.67</td>
<td>16.48</td>
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<tr>
<td>Sinapis arvensis L.</td>
<td>charlock</td>
<td>1.00</td>
<td>0.30</td>
<td>0.06</td>
<td>0.60</td>
<td>70</td>
<td>12.65</td>
<td>2.62</td>
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<tr>
<td>Carrichtera annua (L.) DC.</td>
<td>Ward’s weed</td>
<td>0.88</td>
<td>0.08</td>
<td>0.01</td>
<td>0.32</td>
<td>190</td>
<td>5.53</td>
<td>0.89</td>
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<tr>
<td>Sisymbrium irio L.</td>
<td>London rocket</td>
<td>0.87</td>
<td>0.15</td>
<td>0.02</td>
<td>0.15</td>
<td>98</td>
<td>2.52</td>
<td>0.26</td>
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<tr>
<td>Neslia paniculata (L.) Desv.</td>
<td>ball mustard</td>
<td>0.80</td>
<td>0.85</td>
<td>0.79</td>
<td>0.13</td>
<td>6</td>
<td>0.77</td>
<td>0.72</td>
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<tr>
<td>Sisymbrium thellungii O.Schulz</td>
<td>African turnip weed</td>
<td>0.96</td>
<td>0.95</td>
<td>0.23</td>
<td>0.10</td>
<td>5</td>
<td>0.49</td>
<td>0.12</td>
</tr>
<tr>
<td>Myagrum perfoliatum L.</td>
<td>muskweed</td>
<td>0.96</td>
<td>0.03</td>
<td>0.02</td>
<td>0.32</td>
<td>23</td>
<td>0.23</td>
<td>0.17</td>
</tr>
<tr>
<td>Diplotaxis muralis (L.) DC.</td>
<td>dog weed</td>
<td>0.94</td>
<td>0.53</td>
<td>0.52</td>
<td>0.04</td>
<td>8</td>
<td>0.18</td>
<td>0.18</td>
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<tr>
<td>Cardaria draba (L.) Desv.</td>
<td>hoary cress</td>
<td>0.71</td>
<td>0.39</td>
<td>0.15</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Diplotaxis tenuifolia (L.) DC.</td>
<td>sand rocket</td>
<td>0.99</td>
<td>0.57</td>
<td>0.46</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Hirschfeldia incana (L.) Lagr.-Foss.</td>
<td>Buchan weed</td>
<td>0.79</td>
<td>0.47</td>
<td>0.27</td>
<td>0.00</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Crops:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brassica nigra (L.) S.Kohl ex Koch</td>
<td>black mustard</td>
<td>1.00</td>
<td>0.98</td>
<td>0.02</td>
<td>0.74</td>
<td>221</td>
<td>161.56</td>
<td>2.81</td>
</tr>
<tr>
<td>Sinapis alba L.</td>
<td>white mustard</td>
<td>0.97</td>
<td>0.93</td>
<td>0.01</td>
<td>0.86</td>
<td>174</td>
<td>142.59</td>
<td>1.68</td>
</tr>
<tr>
<td>Brassica juncea (L.) Czernj.</td>
<td>Indian mustard</td>
<td>0.96</td>
<td>0.95</td>
<td>0.01</td>
<td>0.55</td>
<td>240</td>
<td>129.94</td>
<td>0.69</td>
</tr>
<tr>
<td>Brassica napus L.</td>
<td>canola</td>
<td>1.00</td>
<td>0.95</td>
<td>0.01</td>
<td>0.43</td>
<td>45</td>
<td>18.37</td>
<td>0.13</td>
</tr>
</tbody>
</table>
Field measurement of the finite rate of increase is a promising means of identifying serious crop weeds amongst recently naturalised species. Most known crop weeds had an increasing population growth rate, and most common garden plants and non-crop weeds were predicted not to persist. Without an independent ranking of the test species it is difficult to confirm that major and minor crop weeds were distinguished. However, high \( R \) species *S. orientale*, *R. raphanistrum*, *R. rugosum* and *B. Tournefortii* have previously been ranked in the top 15 of broadacre weeds in SA (Mayfield and Edwards 1992). Anomalies in the results indicate that the field screening techniques need further improvement.

The present calculation of \( R \) is not suitable for ranking invasiveness of perennial crop weeds. *C. draba* and *D. tenuifolia* are serious crop weeds, but had a \( R \) of zero as they did not seed. For perennials, the field study would need to continue for another crop cycle to compare species’ survival (during summer and after cultivations) and reproduction.

Several crop weeds with \( R < 1 \) performed more poorly than expected, which may have been due to soil type.
or season. In SA *M. perfoliatum* is mainly found in clay textured soils. Certainly replication of the field screening (ie. different sites and years) would increase confidence in the species rankings.

Selection of the germination period to calculate \( R \) had a major influence on species rankings. Species with minimal seed dormancy had a much lower ranking when germination in the first month was ignored, especially for the crop plants. It is preferable to calculate \( R \) this way, as early germinating species would normally be controlled by pre-sowing crop preparation, and thus be less important crop weeds. Some species with indehiscent pods did not have considerable germination until 1998 (e.g. *C. irregularis*). It may be better to use germination data recorded over two years.

The inclusion of herbicide-induced mortality would have significantly reduced \( R \) values. However, the ease of controlling species is a secondary issue. It is better to avoid having new crop weeds to control.

The study has highlighted *C. tenella* and *M. africana* as two new crop weeds of concern. *C. tenella* in particular had a high \( R \), and is a serious weed of winter wheat and alfalfa in the USA (Wicks *et al.* 1985). It is presently restricted to northern Victoria, and its containment to this area is recommended. There are few mentions of *M. africana* in the crop weed literature, despite its presence in Europe and North America. Further study of its impact on crop yields is needed before suggesting containment.

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REFERENCES


