# IMPROVING THE ASSESSMENT OF NEW WEED THREATS: DEVELOPING TECHNIQUES WITH CRUCIFEROUS WEEDS OF CROPPING

J.G. Virtue
SA Animal and Plant Control Commission, GPO Box 1671, Adelaide, South Australia 5001, Australia

**Summary** Techniques to predict the invasiveness, impact and distribution of recently naturalized plants in South Australia (SA) are being developed. Data for cruciferous weeds of grain crops are being used. Some crucifers have become major crop weeds in SA and there are new crucifers of unknown potential. Ecological and biological attributes which relate to invasiveness of crucifers in grain crops are being determined. Other principles of invasiveness being evaluated are history as a weed, current distribution, time since naturalization, size of native range and absence of natural enemies. A subsequent model which ranks the invasiveness of established crucifers as grain crop weeds will be used to assess recently naturalized crucifers. The impact of those identified as highly invasive will then need to be quantified in crop yield loss experiments. Methods to predict potential distribution of new weeds based on climatic, soil and landuse preferences are being developed with the crucifers. Successful predictive techniques developed with the crucifers will be expanded to other weeds and ecosystems.

## INTRODUCTION

Plants have naturalized in South Australia (SA) at an average rate of six species per year since 1802 (Kloot 1991). Some have become major weeds whereas others have remained insignificant. The Animal and Plant Control Commission (APCC) co-ordinates the control of proclaimed plants in SA. Early confirmation and subsequent containment of major new weed threats are required to substantially reduce their long-term costs of impact and control. The APCC is developing techniques to predict the relative weed threats of recently naturalized species. Species will be assessed for invasiveness, impact and potential distribution.

Successful approaches to predictions of weediness have focused on a group of related species in a specific ecosystem (e.g. Richardson *et al.* 1990). This approach has been adopted to examine naturalized crucifers (Brassicaceae) as weeds of SA dryland grain cropping. There are approximately 40 crucifer species naturalized in grain regions of SA (Kloot 1986a). Many of these are listed in Table 1, including eleven crop weeds which have specific herbicide recommendations. Crucifers are likely to be of increasing importance as weeds in SA. Resistance to Group B herbicides (i.e. ALS inhibitors) occurs in *Sisymbrium orientale* L. and *Brassica tournefortii* Gouan (Boutsalis 1996). Increased planting of dicot crops (e.g. canola, pulses, coriander) have limited in-crop herbicide choices against crucifer weeds. New crop weeds include *Matthiola longipetala* (Vent.) DC., *Myagrum perfoliatum* L. and *Neslia paniculata* (L.) Desv.

This paper describes the research approach being taken by the APCC to develop weed assessment techniques, using crucifer weeds in grain crops as a working example.

## INVASIVENESS

Invasiveness relates to the rate of spread of a naturalized plant population. It is difficult and long-term to directly measure this rate, but some general principles have been established which reflect the likely invasiveness of a plant species.

**Ecological and biological attributes** There have been failures and successes in using biological and ecological attributes to predict invasiveness. Baker's (1965) list of weediness attributes provided a basis for predicting invasiveness. However Perrins *et al.* (1992) were unsuccessful in identifying weeds from non-weeds for 49 British annual species, based on Baker's (1965) list. They concluded that the attributes were too general, and that one must use attributes which are specific to successful invasion in the ecosystem of interest. Missing data were also a weakness of their study. Richardson *et al.* (1990) were successful in predicting which species of *Pinus* were most likely to be invasive in the disturbance regime of the South African mountain fynbos ecosystem. They used specific attributes (without missing data) to predict that *Pinus* species with a short juvenile period, poor fire tolerance, strong serotiny and small seeds were the most invasive. Given the successful approach of the *Pinus* example, what are the key attributes that enable certain crucifers to be highly invasive in SA grain crops? The APCC is collecting data for the following attributes:

- Time to 50% germination at diurnal 7/15°C (i.e. average crop planting temperature regime in SA). Crucifers which establish with the crop will interfere most. However rapid germination may make a crucifer more susceptible to pre-planting cultivations and herbicides.

**Table 1.** Naturalised crucifer species in SA grain regions (Kloot 1986a).

| Species | Common Name | First recorded[A] | Major weeds[B] | Life cycle[C] | Crop weed overseas[D] | Breeding system[E] |
|---|---|---|---|---|---|---|
| *Alyssum linifolium* | flaxleaf alyssum | 1848 | | A | | |
| *Brassica elongata* | | 1949 | | B, P | | I |
| *B. juncea* | Indian mustard | 1910 | | A | Y | C |
| *B. napus* | canola | 1908 | | A, B | | C |
| *B. tournefortii* | long-fruited turnip | 1936 | Y | A | Y | C |
| *Cakile maritima* | sea rocket | 1918 | | A | | I |
| *Calepina irregularis* | white ball mustard | 1986 | | A | Y | C |
| *Capsella bursa-pastoris* | shepherd's purse | 1848 | Y | A | Y | C |
| *Cardaria draba* | hoary cress | 1904 | Y | P | Y | I |
| *Carrichtera annua* | Ward's weed | 1915 | Y | A | | C |
| *Coronopus didymus* | lesser swinecress | 1848 | | A, P | Y | |
| *C. squamatus* | creeping wartcress | 1908 | | A, B | | C |
| *Diplotaxis muralis* | dog weed | 1880 | | A | Y | C |
| *D. tenuifolia* | Lincoln weed | 1907 | Y | P | | I |
| *Eruca sativa* | rocket salad | 1911 | | A | Y | I |
| *Euclidium syriacum* | | 1963 | | A | | |
| *Hirschfeldia incana* | Buchan weed | 1880 | | A, B | | I |
| *Hymenolobus procumbens* | | 1848 | | A | | |
| *Iberis crenata* | | 1957 | | A | | |
| *Lepidium africanum* | common peppercress | 1894 | | A, B, P | Y | C |
| *L. bonariense* | | 1977 | | A, B | Y | |
| *L. latifolium* | perennial peppercress | 1949 | | P | Y | |
| *Malcolmia africana* | Turkish mustard | 1988 | | A | Y | |
| *Matthiola longipetala* | nightstock | 1905 | | A, B | | I |
| *Myagrum perfoliatum* | muskweed | 1925 | Y | A | Y | C |
| *Neslia paniculata* | ball mustard | 1932 | Y | A | Y | C |
| *Raphanus raphanistrum* | wild radish | 1879 | Y | A | Y | I |
| *Rapistrum rugosum* | short-fruited turnip | 1903 | Y | A, B | Y | I |
| *Sinapis arvensis* | charlock | 1923 | Y | A | Y | I |
| *Sisymbrium erysimoides* | smooth mustard | 1916 | | A | | C |
| *S. irio* | London rocket | 1931 | | A, B | Y | C |
| *S. officinale* | hedge mustard | 1847 | | A, B | Y | C |
| *S. orientale* | Indian hedge mustard | 1879 | Y | A, B | Y | C |

[A] Herbarium collections (Kloot 1986b).
[B] Listed in the 1995 Primary Industries SA cereal and pulse weed spraying guides.
[C] Annual (A), biennial (B) and perennial (P).
[D] Recurrently occur as weeds of annual crops outside Australia.
[E] Self-incompatible (I) or self-compatible (C) (from Kunin (in press), Salisbury 1991).

- Seedling root and shoot relative growth rates at 7/15°C. Faster growing crucifer seedlings may be more competitive with crops.
- Tolerance to herbicides. Many of the major crucifer crop weeds (Table 1) have a degree of tolerance to phenoxy herbicides.
- Time to flowering. Crucifer seed must be mature at crop maturity for dispersal by the combine harvester.
- Seed production per unit shoot dry matter. Greater fecundity may enable greater local and distant dispersal.
- Breeding system. Seed production in obligate out-breeders is dependent on pollinator and plant density (Kunin 1993). However this may not be a major disadvantage in SA crops, with Table 1 listing some major crop weeds that are self-incompatible (e.g. *Raphanus raphanistrum* L.).

- Number of long-distance seed dispersal mechanisms. These include grain contamination, attachment to machinery and animals, excretion by animals and wind dispersal.

**Previous history as a weed elsewhere** This has been a good indicator for predicting invasiveness in several studies (e.g. Reichard in press, Scott and Panetta 1993). Of the eleven crucifers listed in the SA crop spraying guides, only *Carrichtera annua* (L.) DC. and *Diplotaxis tenuifolia* (L.) DC. are not known as weeds of crops overseas.

**Current distribution** More foci and/or wider spacing between foci will give faster spread rates. Simulations by Auld and Coote (1980) showed that a scattered initial population had a greater rate of spread than a central population.

**Time since naturalization** Scott and Panetta (1993) and M. Mulvaney (personal communication 1995) found that increased time since naturalization increased the likelihood that a plant had became an invasive weed. Historical reviews of weed invasions suggest that there is an initial lag phase of minimal spread, afterwhich a rapid, exponential expansion in range occurs (Groves 1992). Thus the longer a plant has been naturalized in Australia, the more likely that it is in a phase of rapid range expansion. The major crop weeds in Table 1 have been present in SA for over 50 years.

**Size of native range** Several studies have shown that within a genus the more invasive weeds have a larger native distribution (e.g. Forcella and Wood 1984).

**Absence of natural enemies** This may allow dominance in a community rather than abiotic or management influences (Cousens and Mortimer 1995).

Data on the above principles will be compared for the established naturalized crucifers in SA, with the aim of developing a model which ranks their invasiveness as grain crop weeds. New crucifers will then be assessed for invasiveness. A successful modelling approach will form the basis for assessing invasiveness of other naturalized dicots as weeds in grain crops, with later extension to other weeds and ecosystems. The approach is more detailed and quantitative than the Weed Risk Assessment System for plant imports into Australia (Pheloung 1996). Greater confidence is needed in assessing naturalized species, as any subsequent co-ordinated control program involves substantial costs to land owners affected.

## IMPACT

The local impact of naturalized plant species which have been identified as highly invasive weeds will need to be quantified in comparative field experiments. For crop weeds economic impact can be estimated by weed density-yield loss response curves. New crucifer threats would be formally compared with major crop weeds such as *B. tournefortii*, *R. raphanistrum* and *S. orientale*. The data would be used by grain growers to budget for control costs of the new weed, and by the APCC to determine the benefit/cost ratio of a proposed co-ordinated control program. Species of high impact are also priorities for integrated weed management research.

## POTENTIAL DISTRIBUTION

Knowledge of the potential distribution of a major new weed enables landholders to be alerted of the risk of invasion, and justifies enforcement of measures to prevent the introduction of weed disseminules into such areas. Software based on climate to predict distribution are well developed; CLIMEX (CRC for Tropical Pest Management), BIOCLIM (Centre for Resource and Environmental Studies) and Climate (Agriculture WA). Studies using BIOCLIM (Panetta and Mitchell 1991, Panetta and Dodd 1987) indicated that factors such as the local disturbance regime and soil type limited distribution where climate was optimal. Geographic predictions based on climate need to be overlaid with the distribution of the ecosystem of interest (e.g. annual cropping systems). Soil mapping by Primary Industries SA provides the opportunity to also overlay a weed's soil tolerances (e.g. pH, drainage, water holding capacity and chemical fertility). Thus a system of predicting weed distribution based on climate and soil tolerances and ecosystem locations is envisaged.

The APCC is mapping the current distributions of established crucifer weeds of grain crops in SA. Such data can then be compared with climate-based predictions to confirm their validity. It should also indicate which (if any) soil attributes are useful in predicting weed distribution in SA. Predictions of potential distribution will then be made for the major new crucifer weeds.

## CONCLUSION

The APCC is taking a comprehensive approach in developing techniques to assess the invasiveness, impact and potential distribution of recently naturalized plants. The APCC and local animal and plant control boards spent approximately $A4 million co-ordinating the control of proclaimed plants in 1995–96. Control costs for landholders are considerably greater. These costs are particularly inflated by enforced control of weeds which are already widespread (e.g. horehound, *Marrubium vulgare* L.). It is imperative that major new weed threats be confidently identified and contained early to reduce their long term costs.

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