Defining the distribution of branched broomrape (*Orobanche ramosa* L.) by tracing the movement of potential vectors for the spread of seed

Nick Secomb
Department of Water, Land and Biodiversity Conservation, GPO Box 2834, Adelaide, South Australia 5001, Australia

Summary Branched broomrape, *Orobanche ramosa* L., is a parasitic weed that is subject to a nationally funded eradication program in the Murray Mallee region of South Australia. In early 2000, a study was initiated into the possible movement of branched broomrape seed from properties found to be infested in 1998 and 1999. The results from this study formed the basis for field surveys in the spring of 2000.

Keywords Branched broomrape, vectors, *Orobanche ramosa*, weed spread.

INTRODUCTION

Orobanche ramosa L. is a parasitic weed of a wide range of broadleaf crops in the Mediterranean, Europe, central Asia, the Middle East, South Africa and North and South America. Broomrapes are root parasites that are totally dependant on the host for all organic carbon (Parker and Riches 1993). *O. ramosa* spends most of its growing period below the ground. It is capable of setting seed within 14 days of emergence of its flowering stem.

The only known population of *O. ramosa* in Australia was discovered in 1992 in the Bowhill area (see Figure 1). The detected plants were eradicated by fumigation with methyl bromide gas. Between 1993 and 1997, plants were found at six more sites on the original property and an adjoining property. In late 1998 *O. ramosa* was detected at a further 16 sites within 15 km of the original infestation. Large-scale surveys followed these discoveries, resulting in the identification of 137 infestations covering 1244 ha of land.

In 2000 a containment program was introduced to prevent the spread of *O. ramosa* and better define its actual distribution. The Branched Broomrape Quarantine Area (Figure 1) was established and protocols restricting the movement of soil, livestock, machinery, conserved fodder, grain and horticultural produce were introduced to prevent the movement of *O. ramosa* seed.

As part of the containment strategy it was necessary to more accurately define the actual distribution of *O. ramosa*. Under the protocols established by Primary Industries and Resources South Australia (PIRSA) in late 1999, all fields within the Quarantine Area were surveyed to determine if livestock, produce and machinery could be moved without the threat of further spread. In itself this procedure proved to be a useful tool for identifying the local distribution of *O. ramosa.* Another method was required to determine if *O. ramosa* had spread outside of the quarantined area.

The seeds of *O. ramosa* are dust sized (approx. 0.2 mm in length) and a single capsule can contain 600–800 seeds (Parker and Riches 1993). The small size of the seeds means that they are virtually impossible to physically remove from soil or produce. Wind dispersal is also possible with seeds shown to travel at least 8 m in a confined wind tunnel (E. Crossfield unpublished data), but wind is not thought to be a major vector (Cooke and Jupp 2000).

It is thought that contaminated soil and vectors carrying soil, such as machinery, pose the greatest risk to long distance seed dispersal. The 1999 survey results support this theory with information on the movement of share-farmers and contaminated machinery leading survey crews to 137 infestations found in late 1999. Table 1 shows a list of vectors isolated for attention in this study. It is not an exhaustive list of vectors for the spread of *O. ramosa* seed, but seems a logical means of identifying areas at risk.

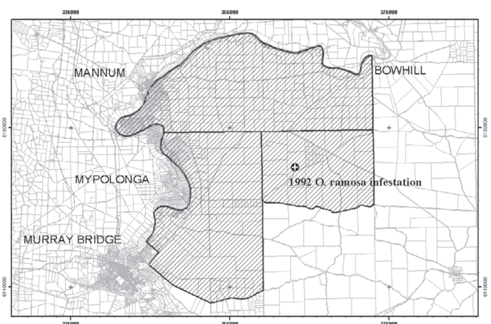

Figure 1. *O. ramosa* Quarantine Area – 1999 with original infestation.

MATERIALS AND METHODS

Links to properties infested with *O. ramosa* were identified in a number of ways:

- All landholders within the Quarantine Area were surveyed and asked to provide information on the movement of vectors from their properties. The potential vectors identified in Table 1 were used as a guide;
- Machinery dealers were interviewed and their records on the movement of machinery from infested properties were collected, and;
- Livestock agents were visited and saleyard records were collected which showed where livestock had moved after leaving the Quarantine Area. Public livestock sales are held fortnightly in both Murray Bridge and Strathalbyn. Some livestock were also sent to the weekly Gepps Cross sale in Adelaide.

Vector movement It was not always clear whether a vector had come into contact with *O. ramosa* seed. For example, some machinery may not have been used in infested fields. At the same time, there was a risk that although *O. ramosa* had only been detected on part of an infested property, undetected seed may have been spread across other fields. This risk was compounded by the fact that the presence of *O. ramosa* can be masked by land use. For example, cereal cropping removes most of the available hosts for *O. ramosa* thus preventing emergence. To address this issue, vectors were not assessed according to where they had been used on a farm. All vectors leaving an infested property were included in the links program.

Risk assessment It was thought that some links would be more significant than others. For example, the movement of livestock included the movement of broadacre, intensive and domestic animals. Each has a different chance of coming into contact with and moving *O. ramosa* seed. A risk assessment was applied to all links to isolate those most likely to have spread seed.

Land tenure The risk assessment process provided an account of the properties at risk of having contact with *O. ramosa* seed. Information on the property owned by those in the quarantine zone was required in a format that could easily be used by field staff. Property Assist (a publicly accessible government managed land information database) was used to find all sections of land owned by a landholder. Survey targets were printed using a GIS (Arcview 3.2).

Survey technique *O. ramosa* relies on finding a suitable host plant root for germination. While some landholders grow pulse crops and many encourage medics in the pasture rotation, the highest densities of broad-leafed plants are found at the perimeter of fields (conventional weed control doesn't target these areas). Therefore, teams of two people trained in weed identification undertook a visual inspection of field perimeters on foot, or where possible, on a 4WD motorbike to identify and record the location of *O. ramosa* plants (step 1, Figure 2).

Orobanche ramosa has also been observed growing in sandy soil types and in areas where high densities of host plants are growing. After completing a perimeter search, teams undertook three transects across each field. Targeting obvious sandy areas or areas where host plants appeared to be growing in high densities was seen as a priority (step 2, Figure 2).

RESULTS

In total, 244 properties were surveyed as part of the links program. This represented surveys across 192,304 ha in South Australia (Figure 3) and approximately 20,000 ha in Victoria. Of these properties, 40 (16.4%) were infested with *O. ramosa*, of which 25 positive links were found outside of the quarantine area (Figure 4). All of the links were found within 70 km of the original quarantine area (Figure 4).

Table 1. Potential vectors for the spread of *O. ramosa* seed.

Potential vector	Description
Farm machinery	Ground penetrating machinery, such as tillage equipment, is seen as the highest risk for spread.
Livestock	Livestock are capable of transporting seed both within the gut and through seed adhering to wool, hides and hooves.
Soil / gravel	*O. ramosa* seed cannot be easily removed from soil and can be physically moved between sites as a contaminant of soil.
Contaminated fodder and seed	Hay and cereal grains are harvested when *O. ramosa* plants are actively growing above ground. There is potential for harvesters to cut broomrape plants and for seed to contaminate fodder and/or grain.

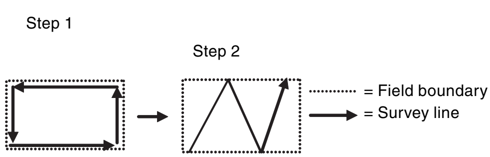

Figure 2. Survey paths for detecting *O. ramosa*.

The results of the link program suggest that machinery is the most important vector for the spread of *O. ramosa* seed (Figure 5). The next most significant vector is livestock, followed by cereal seed and then hay. Tracing the movement of bulk soil/gravel did not result in the discovery of any new infestations.

DISCUSSION

Movement of vectors within the existing quarantine area has been frequent and the links identified are only a small sample of the movements that take place. The further a link is from quarantine, the more confident we can be that these are isolated events. While each positive link is important in establishing patterns of movement, the following analysis concentrates on the 25 positive links found outside of quarantine on the assumption that we can be more confident that the identified vector was responsible for the movement of broomrape seed.

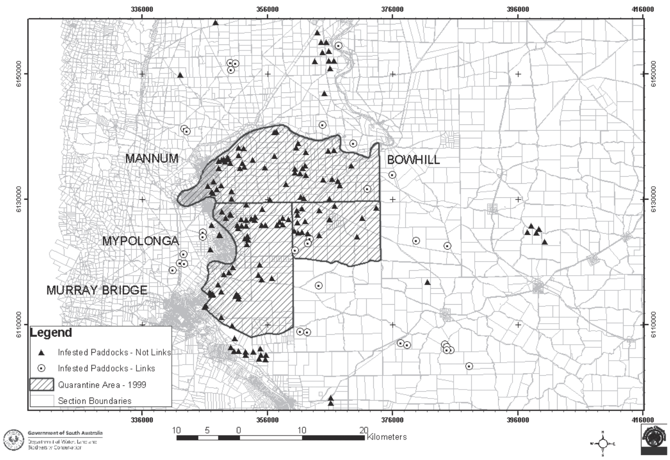

Figure 4. *O. ramosa* links survey results in and around the quarantine zone.

Machinery Of the 25 properties outside of the quarantine area found infested during the links program, 52% were linked through the movement of machinery. Of these, over half (61.5%) were linked by machinery used to till the soil (Figure 6). Other properties were linked by machinery used to make hay and machinery used to harvest cereal seed. These results suggest that *O. ramosa* is capable of travelling on machinery. Moving tillage equipment seems to either increase the chances of successful seed attachment and/or increase the chances of successful establishment once the machinery is moved to another field. Both hay-making machinery and machinery used to harvest cereal seed

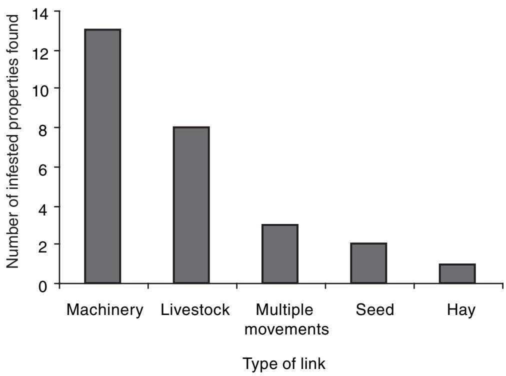

Figure 5. Links surveys results.

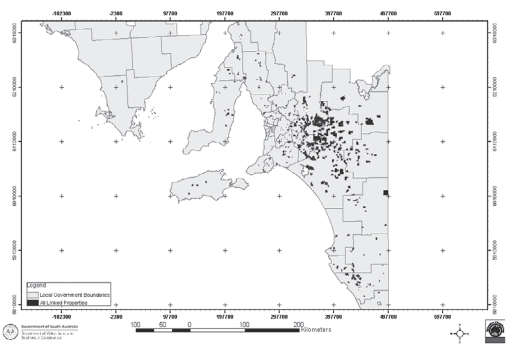

Figure 3. *O. ramosa* links survey targets in South Australia.

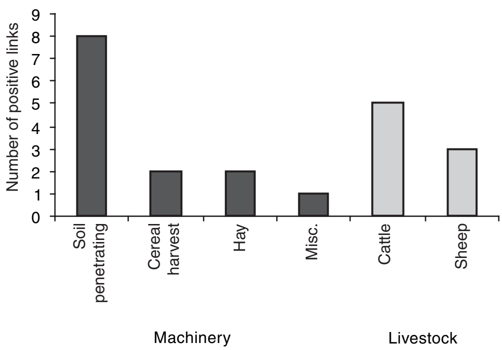

Figure 6. Link summary: machinery and livestock links.

are used in field at the time that *O. ramosa* is growing above the ground. The presence of seed above ground level when these types of machinery are used may have contributed to movement.

Livestock Of the 25 positive links outside of the quarantine area, eight (~30%) were linked to movement of livestock. Of these eight properties, five were linked through the movement of cattle and three were linked through the movement of sheep (Figure 6). Viable seeds of *Orobanche* spp. have been found to pass through the digestive system of sheep (Jacobsohn *et al.* 1986). Crossfield (unpublished data) has shown that most viable *O. ramosa* seed moves out of the digestive tract of sheep after two days. All of the infested properties received their livestock during the growing season for *O. ramosa*. This would be expected if the seed is moving through the gut and if the seed has a relatively short life within the digestive tract. Crossfield (unpublished data) also showed that seed could remain in the wool of sheep for long periods of time. This has the potential to transport viable seed that has been picked up as a contaminant from infested soil, outside of the growing season for *O. ramosa*.

Cereal seed Two of the positive links outside of the quarantine area were linked to *O. ramosa* through the movement of cereal seed. It seems possible that *O. ramosa* could contaminate cereal seed, but analysis of samples delivered to Ausbulk in 1999 did not reveal any contamination. This may be due to the fact that *O. ramosa* plants are generally low-growing (less than 150 mm), which places them below the cutting height for most cereal harvesters.

Hay One infested property outside of the quarantine area was linked to *O. ramosa* through the movement of hay. It seems likely that hay could transport *O. ramosa* seed (D. Joel pers comm.). Cereal hay is cut at the time that *O. ramosa* is actively growing and the relatively low cutting height and raking and baling mean that *O. ramosa* plants could easily be included in a hay sample. Most of the hay that is cut in the quarantine area is traditionally sold to dairy farmers who own land on the river flats adjacent to the river Murray. *O. ramosa* has not yet been found growing on river flats. It's not clear whether this is related to the soil type being unfavourable, to the fact that many of these flats are waterlogged for long periods of the year or some other reason. It is possible that the relative importance of hay as a vector for *O. ramosa* seed is being under-represented because much of that seed is being transported into conditions that are unfavourable for germination.

Soil None of the infested properties were linked to *O. ramosa* through the movement of bulk soil. However, there seems little doubt that *O. ramosa* seed can travel in soil. Infestations have been found on roadsides that were built or maintained using soil from fields now infested with *O. ramosa*. However, it is uncertain whether this seed travelled in the soil, on machinery used to build the roads or, since most of the infested roads are close to infested fields, via some other vector.

Analysis of relative importance of each vector to the dispersal of *O. ramosa* is difficult. There is no guarantee that the link identified between properties was the way that *O. ramosa* seed was spread. All infested properties were within 70 km of the quarantine area. Movement of possible vectors within this area is so frequent that it is not possible to conclude that the links identified represent the method of dispersal.

While more links were understandably found close to the quarantine area, the type of link was not affected by distance from the quarantine zone. A difference in the way that vectors are managed depending on whether they were short or long distance mechanisms may have had some influence on where *O. ramosa* was found. Machinery travelling short distances is usually associated with movement by share-farmers or contractors. Movement of this type will often result in less time being spent cleaning equipment than if the machinery was travelling over a greater distance as machinery would usually be thoroughly cleaned down before being sold to a new owner. Similarly, livestock moving over short distances are often simply walked along roadsides or loaded straight into a truck and moved to their new site. When moved over longer distances, livestock are usually mustered at least 1–2 days before market. The majority of *O. ramosa* seed moves through the gut of livestock within 48 h of ingestion (Crossfield unpublished data). Livestock that are destined for sale at public auction are often cleaned out 24 hours prior to travelling to make certain that they arrive to market in clean conditions. This would allow more time for *O. ramosa* seed to be passed from the gut of the livestock.

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