The potential of fungal pathogens to control *Hypericum* species in Australia

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Abstract

Two fungal pathogens that attack either St. John's wort (*Hypericum perforatum*) or tutsan (*Hypericum androsaemum*) are discussed. The fungus, *Colletotrichum gloeosporioides*, is host-specific and causes significant damage to *H. perforatum* populations in Nova Scotia in Canada. Its potential as a biological control agent in Australia is reviewed.

In October 1991, infestations of tutsan in the Otway Ranges of Victoria were found to be significantly attacked by the fungus *Melampsora hypericorum*. The rust had a devastating impact on the weed population, killing entire hillsides. A subsequent inspection in 1994 found only one live tutsan seedling. The tutsan rust fungus is possibly the most successful example of weed biological control ever witnessed in Victoria.

Introduction

St. John's wort (*Hypericum perforatum*) (Clusiaceae) is a perennial herb that originated in Europe, western Asia and North Africa; in Australia it now occupies more than 188 000 ha in New South Wales and 175 000 ha in Victoria (Parsons and Cuthbertson 1992). It has been found in all States of Australia except the Northern Territory where it invades poorly managed grazing land, sparse bushland, roadsides and neglected areas such as abandoned mine sites (Parsons and Cuthbertson 1992). St. John's wort contains hypericin, a compound that causes photosensitization in stock that ingest it. Symptoms develop on areas of skin directly exposed to light, such as ears and noses. Affected areas then become itchy and painful (Everist 1974). Animals become irritable, lose condition and in severe cases may develop convulsions and die (Kingsbury 1964).

Biological control of St. John's wort, *Hypericum perforatum*, by the fungus, *Colletotrichum gloeosporioides*

In 1984, a fungal pathogen, *Colletotrichum gloeosporioides* (Penz.) Penz & Sacc., was identified as causing substantial mortality to St. John's wort infestations in Nova Scotia, Canada (Hildebrand and Jensen 1991).

The *Colletotrichum* genus has been described (Barnett and Hunter 1972). The genus is part of the Imperfect fungi and has the following distinguishing features:

- Acervuli disc-shaped or cushion-shaped, waxy, subepidermal, typically with dark spines or setae at the edge or among the conidiospores,
- Conidiospores simple, elongate,
- Conidia hyaline, 1-celled, ovoid or oblong,
- Parasitic; imperfect states of *Glomerella.*

This genus differs from *Glomeosporium* in having spines, which may be absent under certain cultural conditions.

Colletotrichum pathogens have been successfully developed as mycoherbicides (Templeton 1987, Wymore *et al.* 1988, Makowski and Mortensen 1989, Templeton *et al.* 1989); some species have excellent qualities (host specific, consistent weed control under field conditions, low-cost of production, stable formulation with minimum shelf life of six months) for weed control (Charudattan 1989, Jackson *et al.* 1995).

K.I.N. Jensen (personal communication) described how *C. gloeosporioides* attacks St. John's wort. The pathogen generally attacks young stems but also infects leaves and flowers. It causes stem girdling lesions that are characteristic of *Colletotrichum* attack. Sporulating ascervuli commonly cause secondary infection. Given favourable conditions for sporulation, a single infection is potentially lethal to St. John's wort. Infected leaves turn a reddish colour, making infected plants easily identified. Seed from diseased plants produces diseased seedlings, though there is evidence that seed viability may outlast the seedborne pathogen. There is also circumstantial evidence that the disease can be transmitted by *Chrysolina* beetles feeding on infected plants and carrying the mucilaginous spores to new St. John's wort plants. In addition there are signs that the pathogen can survive as a weak parasite or saprophyte on plant species other than St. John's wort. Thus, symptomless carriers such as dandelion and clover may harbour dormant appressoria which become active only when leaves senesce after which the fungus becomes active in the necrotic areas, producing acervuli and often perithecia – the sexual stage.

The *C. gloeosporioides hyperici* strain has been described as an 'orphan' mycoherbicide (Templeton 1992). It has been demonstrated to be effective in the field for specific weed control but has not been developed for commercial use. A low level market of potential in comparison to that of broad-spectrum chemical herbicides is a major reason for lack of commercial interest in this potential mycoherbicide (Templeton 1992).

Shepherd (1995) tested two Canadian isolates of *C. gloeosporioides* against three recognised Australian strains of *H. perforatum* (narrow-leaved, intermediate-leaved and broad-leaved; see Campbell *et al.* 1997) and untyped plants collected from various areas of Victoria, New South Wales and Canada. Both *C. gloeosporioides* isolates killed all strains of Australian St. John's wort but isolate S19 was more virulent than isolate DAOM. Both isolates were effective at killing field-collected St. John's wort (Figure 1). Virulence was influenced by dew period and inoculation concentration. It was concluded that if *C. gloeosporioides* were introduced into Australia, it could probably be used as a classical biological control agent.

Preliminary host specificity-testing has shown three out of twenty six test species were susceptible to attack by *C. gloeosporioides*. *Hypericum canadense* (in the field), *H. virginicum* (in laboratory trials) and tomato (*Lycopersicon esculentum*) (wound-inoculated in laboratory trials) were attacked (Hildebrand and Jensen 1991). Shepherd (1995) tested a further ten species and found no attack by *C. gloeosporioides*. However, even with these promising results, more testing is required before this fungus could be considered as a likely biological control agent for approval for entry into Australia.

Biological control of tutsan, *Hypericum androsaemum*, by the rust fungus, *Melampsora hypericorum*

Tutsan (*Hypericum androsaemum*) is an erect perennial shrub that originated in Europe, Asia Minor and North Africa (Parsons and Cuthbertson 1992). Tutsan was estimated to be infesting more than of 200 000 ha of Victoria in 1980 (Lane *et al.* 1980) and grew densely in the Otway, Strzelecki and Dandenong Ranges.

In October 1991, significant infestations of tutsan in the Otway Ranges of Victoria were found to be attacked by the rust fungus, *Melampsora hypericorum* (de Candolle) (Bruzzese and Pascoe 1992). The rust has since been observed attacking tutsan at Myrtleford (E. Bruzzese personal observation) and near Morwell in the Strzelecki Ranges (D.A. McLaren personal observation). It is not known how *M. hypericorum* entered Australia.

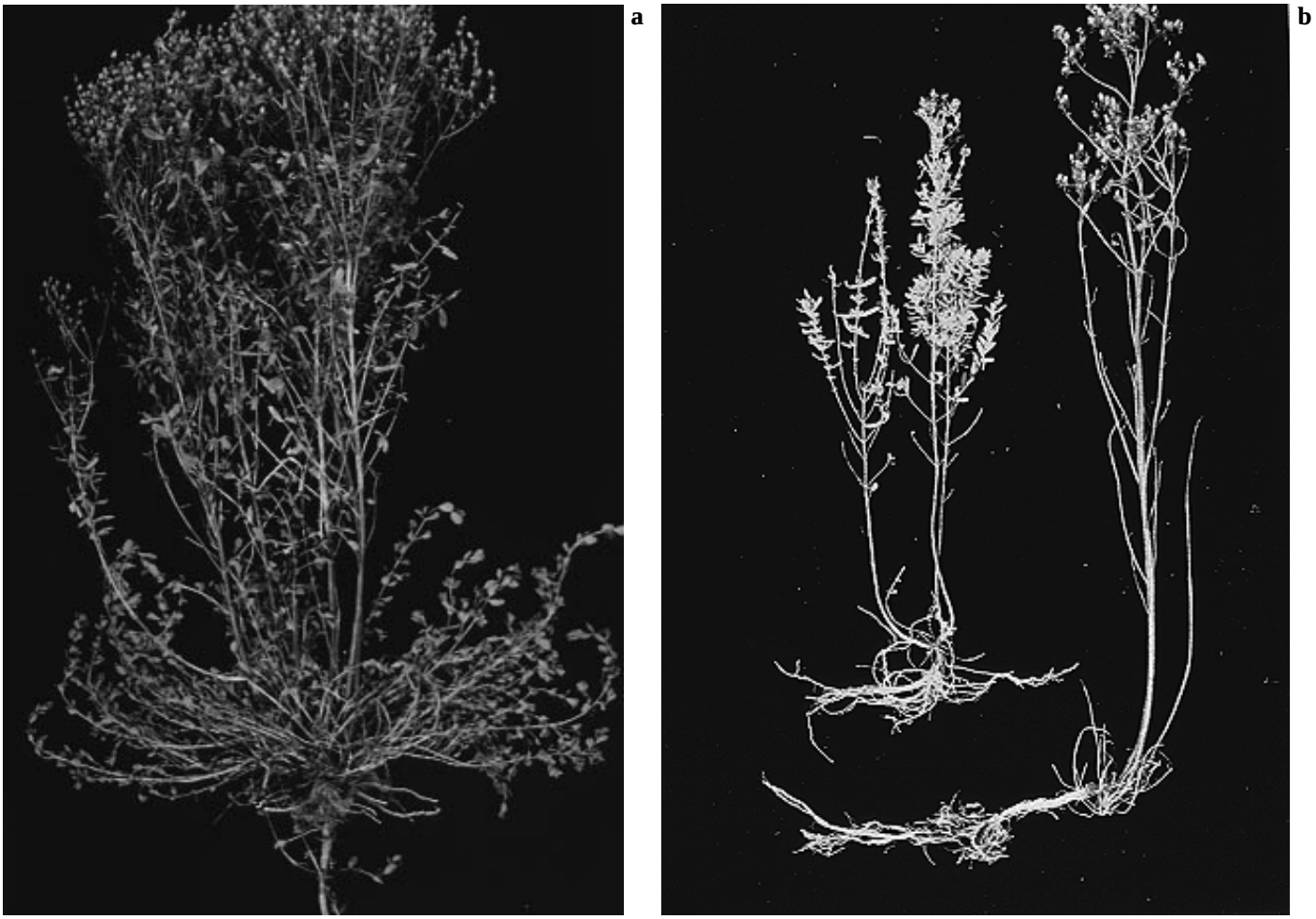

Figure 1. a) Control plant of St. John's wort plant and b) St. John's wort plant attacked by the fungus *Colletotrichum gloeosporioides*.

At Apollo Bay in the Otway Ranges of Victoria, tutsan was a dominant weed on hillsides, outcompeting native vegetation and invading pastures (M. Doueal personal communication). Since the rust was first found, it has been having a devastating impact on tutsan populations, with whole hillsides being killed. An inspection conducted in the Apollo Bay area in 1993 by two Government officers with twelve local landholders located only a single tutsan seedling after a full day's search (M. Doueal personal communication). The present situation in the Apollo Bay area is that the tutsan populations continue to be decimated with only the occasional seedling being found. These tutsan seedlings grow to only 10–15 cm before *M. hypericorum* infects and kills them (J. Turnbull personal communication). Initially, large areas previously occupied by tutsan were replaced by blackberry. However, since 1995, the blackberry rust fungus, *Phragmidium violaceum* (Shultz) has been defoliating the blackberry, thereby enabling replacement by native vegetation particularly blackwood, *Acacia melanoxylon*, to commence (J. Turnbull personal communication). Local landholders have been enthusiastic about the impact of biological control.

Samples of *M. hypericorum* collected from tutsan have been placed on St. John's wort but no sign of infection has been observed (E. Bruzzese personal communication). Similarly, a plant nursery at Apollo Bay containing numerous native and exotic species, including *Hypericum gramineum*, reported no sign of attack by *M. hypericorum*. This suggests that the tutsan rust fungus may be extremely specific (E. Bruzzese personal communication).

The symptoms of *Melampsora hypericorum* and the fungus's cycle of attack on tutsan have been described by Baker (1955). The rust symptoms first appear in late spring or early summer. Yellow to red irregular blotches appear on the upper surface of tutsan leaves. Golden rust pustules (uredosori), 0.5–1 mm in diameter develop on lower leaf surfaces. First covered by the leaf epidermis, pustules later erupt, liberating powdery masses of uredospores. In New Zealand uredosori survive through the winter on the limited new growth produced on mature plants and seedlings. Under favourable conditions, many generations of uredospores may develop and kill host tissue, and blotched areas turn brown and shrivel. In severe infections the whole plant may be defoliated and killed. The impact of this rust was so great in Victoria, it was as though a fire had swept through the undergrowth and selectively browned, shrivelled, defoliated and killed the tutsan plants (D.A. McLaren personal observation).

The *Melampsora* family forms a characteristic sub-epidermal crust of sessile, laterally adherent, single celled teliospores near the surface of the infected host (Littlefield 1981). *Melampsora hypericorum* was described by Plowright (1889):

Uredospores – Sori orange, small, pulverulent, scattered, mostly hypophyllous. Spores globose or elliptical, finely echinulate, orange-yellow, 14–21 × 12–17 µ. Paraphyses absent.

Teleutospores – Dark brown, small, flat. Spores cylindrical, section polygonal, brown, 25 × 15 µ.

In Australia, McAlpine (1906) described *Melampsora hypericorum* attacking an Australian native *Hypericum japonicum* Thunb. However, recent examination has shown that the rust attacking *H. japonicum* as well as *Hypericum gramineum* G. Forster has been identified as *Melampsora kusanoi* (Pascoe, I.G.). In Europe, *Melampsora hypericorum* has been reported attacking twenty *Hypericum* species including tutsan

and St. John's wort, but not St. Peter's wort, *Hypericum tetrapterum* Fries. (Gaumann 1959).

Discussion

Both *Colletotrichum gloeosporioides* and *Melampsora hypericorum* hold great potential as additional biological control agents for St. John's wort. The observed attack by *C. gloeosporioides* on tomato, however, will make it extremely difficult to pass Australian Quarantine Inspection Service protocols for release in Australia. Further host specificity testing would need to be undertaken to prove that there was absolutely no risk of off-target attack by either *C. gloeosporioides* or *M. hypericorum*.

Melampsora hypericorum has had a massive impact on tutsan populations and is possibly the most spectacularly successful example of weed biological control ever witnessed in Victoria. From being a dominant plant species, within five years, tutsan populations are now insignificant. Some isolated tutsan populations still exist in Victoria which suggests that either the rust has not reached them or that there may be tutsan varieties that are resistant to the *M. hypericorum* rust.

The tutsan rust fungus has not been reported attacking any other plant species in either Australia or New Zealand, thereby suggesting that it is host specific. Given the outstanding success of *M. hypericorum* in controlling tutsan in Victoria, it would be advantageous if a biological control program were undertaken utilizing a strain of *M. hypericorum* that attacked St. John's wort. A search would need to be undertaken to identify a *M. hypericorum* strain that attacks St. John's wort in its area of origin. Once identified, the pathogen would have to undergo detailed host specificity trials both in Europe and Australia.

If additional biological control agents are required to control St. John's wort in Australia, then either of the pathogens described above could be utilized to complement the guild of biological control agents already released on St. John's wort. The introduction of these agents could make use of the agent distribution network that already exists for the St. John's wort mite, *Aculus hyperici* (CSIRO Final Report 1996).

References

Baker, S.D. (1955). Note on tutsan rust in New Zealand. *New Zealand Journal of Science and Technology* 36, 483-4.

Barnett, H.L. and Hunter, B.B. (1972). 'Illustrated Genera of Imperfecti Fungi'. (Burgess Publishing Company, Minneapolis).

Bruzzese, E. and Pascoe, I.G. (1992). *Melampsora hypericorum*, a rust fungus with potential in the biological control of tutsan, *Hypericum androsaemum*. Proceedings of the First International Weed Control Congress, Weed Science Society of Victoria, Melbourne, Volume 2, pp. 101.

Charudattan, R. (1989). Assessment of efficacy of mycoherbicide candidates. Proceedings VII International Biological Control of Weeds, 6–11 March 1988, Rome, Italy, ed. E.S. Delfosse, pp. 455-64.

CSIRO Final Report (1996). The establishment of a distribution network for the mite *Aculus hyperici* for the control of St. John's wort. Final Report to the Meat Research Corporation. Unpublished report, CSIRO Entomology, Canberra.

Everist, S.L. (1974). 'Poisonous Plants of Australia', pp. 363-6. (Angus and Robertson, Melbourne).

Gaumann, E. (1959). 'Beitrage zur Kryptogamenflora der Schweiz'. (Kommissionsverlag Buchdruckerei Buchler and Co., Bern).

Hildebrand, P.D. and Jensen, K.I.N. (1991). Potential for the biological control of St. John's-wort (*Hypericum perforatum*) with an endemic strain of *Colletotrichum gloeosporioides. Canadian Journal of Plant Pathology* 13, 60-70.

Jackson, M.A., Schisler, D.A. and Bothast, R.J. (1995). Conidiation environment influences fitness of the potential bioherbicide, *Colletotrichum truncatum*. Proceedings VIII International Symposium on Biological Control of Weeds, 2–7 February 1992, Lincoln University, Canterbury, New Zealand, eds. E.S. Delfosse and R.R. Scott, pp. 621-6. (DSIR / CSIRO, Melbourne).

Kingsbury, J.M. (1964). 'Poisonous Plants of the United States and Canada', pp. 171-5. (Prentice-Hall, Englewood Cliffs, NJ).

Lane, D.W.A., Riches, K. and Combellack, H. (1980). A survey of distribution of the noxious weeds in Victoria. Unpublished report. Department of Conservation and Natural Resources, Keith Turnbull Research Institute, Victoria.

Littlefield, L.J. (1981). 'Biology of the Plant Rusts – An Introduction'. (Iowa State University Press, Ames, Iowa).

Makowski, R.M.D. and Mortensen, K. (1989). *Colletotrichum gloeosporioides f.* sp. *malvae* as a bioherbicide for round-leaved mallow (*Malva pusilla*): Conditions for successful control in the field. Proceedings VII International Biological Control of Weeds, 6–11 March 1988, Rome, Italy, ed. E.S. Delfosse, pp. 513-22.

McAlpine, D. (1906). 'The Rusts of Australia – Their Structure, Nature and Classification'. (Government Printer, Melbourne).

Parsons, W.T. and Cuthbertson, E.G. (1992). 'Noxious Weeds of Australia', pp 387-91. (Inkata Press, Melbourne).

Plowright, C.B. (1889). 'A Monograph of the British Uredininee and Ustilaginee'. (Kegan Paul, Trench and Co., London).

Shepherd, R.C.H. (1995). A Canadian isolate of *Colletotrichum gloeosporioides* (Penzig) Penzig & Saccardo as a potential biological control agent for St. Johns wort (*Hypericum perforatum* L.) in Australia. *Plant Protection Quarterly* 10, 148-51.

Templeton, G.E. (1987). Mycoherbicides – achievements, developments and prospects. Proceedings of the Eighth Australian Weeds Conference, Sydney, Australia, pp. 489-97.

Templeton, G.E. (1992). Some 'orphaned' mycoherbicides and their potential for development. *Plant Protection Quarterly* 7, 149-50.

Templeton, G.E., Smith, R.L. and DeBeest, D.O. (1989). Perspectives on mycoherbicides two decades after discovery of the Collego® pathogen. Proceedings VII International Biological Control of Weeds, 6–11 March 1988, Rome, Italy, ed. E.S. Delfosse, pp. 553-8.

Wymore, L., Poirier, C., Watson, A.K. and Gotlib, A.R. (1988). *Colletotrichum coccodes*, a potential bioherbicide for control of velvetleaf. *Plant Diseases* 72, 534-8.