POTENTIAL BIOLOGICAL CONTROL AGENTS FOR *EMEX* SPP.

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Summary. Many prospects remain to be assessed for the biological control of doublegee, *Emex australis*, and lesser jack, *Emex spinosa*, in Australia. Two pathogenic fungi, *Phomopsis* sp. and *Colletotrichum gloeosporioides*, found on doublegee in South Africa are being tested for host specificity. Other potential fungal candidates are downy mildew, *Peronospora rumicis*, on lesser jack in the Mediterranean region and a rust fungus, *Uromyces rumicis*, on doublegee in South Africa. The weevils, *Coniocleonus excoriatus*, *Erythrapion miniatum*, *Perapion neofallax* and *P. violaceum*, on lesser jack in Morocco and Israel are also potential control agents. Parts of California and eastern Australia where *Emex* is naturalised, may harbour suitable agents among the native insects and fungi of these regions.

INTRODUCTION

The genus *Emex* contains two species, doublegee (three-cornered jack), *E. australis*, and lesser jack, *E. spinosa*. Doublegee is found throughout southern Africa although it is probably indigenous to Cape Province, South Africa (Scott, unpublished data). It has also been introduced into Australia, California, Hawaii, India, Kenya, Madagascar, New Zealand, Taiwan and Trinidad (2,3,6). It appears to be absent from Chile and the Mediterranean region, which both have climates similar to southern African. Doublegee is a serious weed in regions with Mediterranean climates in Australia (2) and in South Africa (4,30). In parts of California it is a minor weed (15).

Lesser jack is native to the Mediterranean regions of southern Portugal and Spain, northern Africa, the Levant and the Middle East (1). It has been introduced into Australia, Brazil, California, the Canary Islands, Hawaii and Kenya (1,3,6). Lesser jack is occasionally recorded as a minor weed (6).

The wide geographical distribution of both species of *Emex* indicates that there should be a number of possibilities for their biological control. Early attempts lead to the successful biological control of *Emex* in Hawaii by the weevil *Perapion antiquum* from South Africa (8). This weevil was released in Australia in 1974, followed in 1979 by another weevil, *Lixus cribricollis* from Morocco (8). Successful control of *Emex* was not achieved. Three other insects from South Africa, *Microthrix inconspicuella* (24,25), *Rhodometra sacraria* (19,23) and *Rhytirrhinus inaequalis* (18) were studied, but were found unsuitable for use as biological control agents. Despite this effort, doublegee remains one of the most serious weeds in Australia and further attempts at biological control are required. In this review we propose some potential biological control agents for *Emex* from regions of the world with Mediterranean climates.

CANDIDATE AGENTS FROM SOUTH AFRICA

The insect fauna on doublegee from Cape Province and Natal in South Africa has been thoroughly assessed and only *P. antiquum* was found to have potential as a biological control agent (20,22). The fungal pathogens on doublegee have also been assessed (11,12, Shivas, unpublished observations). Two fungi, *Phomopsis* sp. and *Colletotrichum gloeosporioides*, are under investigation by one of us (RGS). A third pathogen, *Uromyces rumicis*, causes leaf and stem rust on doublegee in South Africa (11). This rust also occurs in Europe on species of *Rumex*. It was shown to have potential for controlling curly dock, *Rumex crispus*, and is a candidate for introduction into the United States (7,21). The rust has been reported on glasshouse grown plants of fiddle dock, *R. pulcher*, and curly dock in Western Australia (27), but may not be established in the field.

CANDIDATE AGENTS FROM NORTH AFRICA AND THE NEAR EAST

The native distribution of lesser jack has not been systematically surveyed for biological control agents. Some information is available on the insect fauna found in Morocco (10), and in March 1988 one of us (JKS) made a survey of insects on lesser jack in Israel.

Four species of weevil were identified as possible control agents for lesser jack. Two of these, *Perapion neofallax* and *P. violaceum*, are from Morocco and Portugal respectively, although both are absent in Israel. Both species have larvae that feed in the stem. The only known host of *P. neofallax* is lesser jack. In contrast, *P. violaceum* is recorded from a wide range of *Rumex* species within its natural distribution, and will feed in laboratory tests on *Rumex brownii* which is indigenous to Australia (17). The third species, *Erythrapion miniatum*, was found in Israel. The larvae feed in the lower stem, crown and upper root of lesser jack. This insect has also been recorded from species of *Rumex* in Europe (5). The fourth species, *Coniocleonus excoriatus*, has larvae that feed externally on the subterranean part of the stems and crown, and adults that feed on the leaves. The host specificity of the four candidate weevils has not been studied, but all are likely to develop on doublegee and closely related species of *Rumex* in addition to their normal host, lesser jack.

An examination of records at the Commonwealth Mycological Institute, Kew, showed that there are two fungal pathogens, *Cercospora tripolitana* and *Peronospora rumicis*, recorded on lesser jack in northern Africa. Morris (12) did not consider that the leaf spot pathogen, *C. tripolitana*, played a significant role in limiting natural populations of doublegee in South Africa. The downy mildew, *P. rumicis*, has also been recorded on *Fallopia convolvulus* and species of *Rumex* in Europe (29) and warrants further investigation as a potential biocontrol agent.

CANDIDATE AGENTS FROM AUSTRALIA

Most of the few native species of Polygonaceae in Australia are found in the eastern States (c.f. 14). Some of these species may harbour insects or fungi that could be used as biological control agents in areas where they are absent, but where *Emex* spp. are present. For example, the native Australian weevil, *Rhinoncus australis*, has expanded its host range within the Polygonaceae to include *E. australis* (9). *Rhinoncus australis* was the only organism causing consistent damage to *E. australis* in eastern Australia (9), but it is apparently not present in Western Australia. It warrants consideration for introduction into areas of Western Australia that have summer growing *Emex* populations, i.e. irrigated areas, since Julien and Matthews (9) found that *R. australis* was only abundant in spring and early summer.

The pathogens that have been recorded on doublegee in Australia are *U. rumicis* in Western Australia (28); *Botrytis cinerea* and *Puccinia ludwigii* in Victoria; *Ramularia* sp., *Rhizoctonia solani* and *Sclerotinia sclerotiorum* in Queensland; and an undetermined leaf spot (suspected bacterial) in New South Wales. There are no records of pathogens on lesser jack. More information is needed on the identity, host range, distribution and severity of damage caused by pathogens on *Emex* spp. in Australia.

CANDIDATE AGENTS FROM CALIFORNIA

Emex species have not become weeds of any importance in California (15). The climate appears favourable, but soil and competing plant species may restrict *Emex* populations. Native Californian insects and diseases may also limit the populations of *Emex* although there appear to be no records on either species of insects or pathogens. North America (along with Europe) is an area of evolutionary diversity of the Polygonaceae, particularly of the genus *Rumex* which is the nearest relative to *Emex* (13,14). In the Mediterranean region, genera of insects including potential biological control agents are shared between lesser jack and European species of *Rumex*. In California the native species of *Rumex* belong to the Section Axillares of the Polygonaceae. These plants are morphologically similar to *Emex* in that many branches develop from the crown of the plant. Potential biological control agents for *Emex* species may therefore be found here since the insect fauna and pathogens on other Polygonaceae in the region are well developed (e.g. lycaenid butterflies and rust fungi on *Eriogonum* and related genera in the Polygonaceae) (16,26).

DISCUSSION

South Africa is the only region that has been thoroughly surveyed for biological control agents for doublegee (10,11,12,20,22, Shivas, unpublished data). The result of these surveys has been that one biocontrol agent, the weevil *P. antiquum*, has been introduced into Australia and that two fungal pathogens, *Phomopsis* sp. and *C. gloeosporioides*, are presently under investigation in South Africa.

Further surveys for potential biocontrol agents throughout the native distribution of lesser jack, e.g. Tunisia, are desirable. Other areas of the world where *Emex* spp. are introduced, such as California, are less likely to have suitable agents, but should be surveyed if other possibilities prove unsuccessful.

Candidate biological control insects for *Emex* may also attack species of the closely related genus, *Rumex*. Five species, *R. acetosella*, *R. conglomeratus*, *R. crispus*, *R. obtusifolius* and *R. pulcher* are targets for biological control in Australia. It may be possible to combine *Emex* and *Rumex* as targets for biological control. The likelihood of some feeding on the eight Australian species of *Rumex* (14) will need to be considered in any future host specificity testing. No native species of *Emex* occur in Australia and plant pathogens specific to *Emex* may be found.

Biological control has been successful against *Emex* in Hawaii, but not as yet in Australia. We have shown here that there are further regions to be surveyed and that there are a number of candidates to be considered, some of which may lead to control of these serious weeds.

ACKNOWLEDGEMENTS

We thank J. Walker (Herb. DAR) and I. Pascoe (Herb. VPRI) for providing details of specimens in their collections. We also thank C. Kleinjan and M.J. Morris for their comments on drafts of the manuscript.

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