holistic and integrated approach that would result in long-term, sustainable management has become apparent. A combination of biological control, grazing management and herbicides was investigated in an extensive field study in southern New South Wales. During the field trials, we monitored the impact of grazing and herbicide treatments on the weed and biological control agents, as well as on pasture composition. This IWM program was pioneering work in that it is one of the few IWM projects in the world that has a major emphasis on the biological control agents. An important focus of this study was therefore the compatibility and role of biological control in this IWM approach. Results showed that biological control can be successfully established despite limitations by grazing and herbicide treatments. At least at the spatial scale of this study, none of the other control measures impeded the efficacy of the biological-control agents. Management of biological control agents e.g. provision of refugia might be essential. We anticipate that biological control will be an important part of an effective long-term weed management together with herbicide and pasture management strategies.

Developing an integrated management program for kudzu

D. Jewett,[1] K.O. Britton[1] and J.H. Sun[2]

[1] US Forest Service, Southern Research Station, Athens, GA, USA
[2] Chinese Academy of Sciences, Institute of Zoology, Beijing, China

Kudzu is a perennial, semi-woody, climbing legume native to China. Since the late 1800s, it has been introduced deliberately to North America as an ornamental, as forage for livestock, for improving soil, and for preventing soil erosion. By 1946, over 121,406 ha of kudzu had been planted throughout the United States. Presently, extension agents report almost a half-million ha of it in 700 of 3,140 administrative districts from Florida to the Pacific Northwest. Commercial forests occupied by kudzu lose more than US$120 per ha annually, and it may be a reservoir of pathogens responsible for disease outbreaks in row crops. A variety of ways for managing small populations of kudzu exist, including herbicides, mechanical removal, and intensive livestock grazing. No existing strategy yields convenient and economical suppression over large areas, herbicides often are restricted in proximity to aquatic habitats and land of certain propriety (like some national parks), and the relief of areas occupied by kudzu is often considerable, making its eradication inconvenient, dangerous or both. For instances in which herbicide use is ill-advised, alternative strategies for managing kudzu are being considered, including biological control. In China, an abundance of natural enemies prevents, in part, kudzu from becoming either an important economic or environmental liability. Survey of populations there has revealed many insects and pathogens associated with kudzu, including a sawfly and a rust. Preliminary host-range testing of potential biological control agents has begun. Systematic resolution concerning kudzu and related taxa is incomplete, however, and must be refined before selection of biological control agents may proceed. In the field, several different plants are mistaken for kudzu, and it may hybridize with related taxa. Molecular tools for distinguishing among specimens are being tested, and are expected to help professionals match more accurately kudzu with its potential biological control agents.

Biocontrol of *Orobanche* spp. by inundative releases of *Phytomyza orobanchia* (Diptera, Agromyzidae)

Olaf Klein, Jürgen Kroschel and Abuelgasim Elzein

Institute of Plant Production and Agroecology in the Tropics and Subtropics (380), University of Hohenheim, 70593 Stuttgart, Germany

New approaches are necessary to control parasitic weeds of the genus *Orobanche*. The fly *Phytomyza orobanchia* (Diptera, Agromyzidae) is particularly suitable for biological control since it is oligophagous feeding only on *Orobanche* species. In total, of the 140 *Orobanche* spp. described, the occurrence of *P. orobanchia* is reported from 21 species. The use of *P. orobanchia* in biocontrol of *Orobanche* is based on

inundative releases at the time of *Orobanche* emergence. The larvae of *P. orobanchia* mine in *Orobanche* shoots and capsules and intervene at the sensitive reproductive stage of *Orobanche*. Hence, the reduction of *Orobanche* seed production prevents supplementary infestation and dissemination. The advantage of this control approach is its compatibility to all crop/*Orobanche* associations and that it can easily be combined with other control methods. In northern Morocco, the application of *P. orobanchia* in biocontrol of *Orobanche* spp. has been tested from 1995 until 1999. Under natural conditions, 48.9% of *Orobanche* seed capsules are infested by *P. orobanchia*. *P. orobanchia* is parasitized by nine hymenopterous species, but the total parasitization rate does not exceed 8.9% on average. For field releases of *P. orobanchia* adults, a formula for the calculation of the fly number per hectare based on the *Orobanche* infestation level has been developed. Inundative releases of *P. orobanchia* in field cages have shown that the natural efficiency of *P. orobanchia* can be increased considerably. Only 5.3% of viable seeds have been produced in comparison to 62.0% without inundative releases. Seeds are directly destroyed by the mining activity of *P. orobanchia* larvae as well as indirectly by the feeding damage to shoot tissues causing a degeneration of seed capsules. In highly infested fields (> 200 *Orobanche* shoots per m^2), an increase of the *Orobanche* seed bank in the soil could be still observed after inundative releases. In low to medium infested fields, releases of *P. orobanchia* alone are sufficient to reduce the *Orobanche* seed population to an acceptable level. An integrated control approach with tolerant and/or resistant cultivars, combined with mycoherbicides or other control methods is proposed.

Progress on the introduction, rearing and release of the ragwort plume moth, *Platyptilia isodactyla*, for the biological control of ragwort, *Senecio jacobaea*, in Australia

R.M. Kwong,[1,3] D.A. McLaren[1,3] and J.E. Ireson[2,3]

[1] Keith Turnbull Research Institute PO Box 48, Frankston, Victoria 3199, Australia
[2] Tasmanian Institute of Agricultural Research, 13 St. John's Avenue, New Town, Tasmania 7008, Australia
[3] Cooperative Research Centre for Australian Weed Management

Ragwort, *Senecio jacobaea* L. (Asteraceae), is a herbaceous, biennial plant native to Europe and western Asia. It was introduced into Australia during the mid 1800s and now occupies more than820,000 ha in the high rainfall areas of southern Victoria and at least 160,000 ha in Tasmania. Ragwort is an extremely invasive weed in pastures, particularly those grazed by cattle and horses, forestry plantations and natural ecosystems. Biological control of ragwort commenced in Victoria in the 1930s with the release of the cinnabar moth, *Tyria jacobaeae* L. (Lepidoptera: Arctiidae), and in the 1950s, the seed fly, *Botanophila jacobaeae* (Hardy) (Diptera: Anthomyiidae), was released. Neither of these insects established, despite repeated release attempts, probably due to disease, predation by native insects or an inability to adapt to the Australian environment. The flea beetles, *Longitarsus falvicornis* (Stephens) (Coleoptera: Chrysomelidae) and *Longitarsus jacobaeae* (Waterhouse), were introduced into Australia in the late 1970s and 1980s, respectively. In Tasmania, *L. flavicornis* is now widely established on ragwort and has caused significant reductions in plant vigour and density at many sites. In Victoria, flea beetle establishment has been less successful, with populations of *L. flavicornis* persisting only within the Strzelecki Ranges. The ragwort crown-boring moth, *Cochylis atricapitana* (Stephens), introduced in 1987, has established in both Victoria and Tasmania and has been shown to kill ragwort rosettes during autumn. The ragwort plume moth, *Platyptilia isodactyla* Zeller (Lepidoptera: Pterophoridae), is the latest biocontrol agent to be imported and was first released in Victoria in December 1999. This paper describes the release and establishment of *P. isodactyla* in south-eastern Australia.