Why Do Weed Biocontrol Agents Fail to Establish or to Control Their Hosts?

ERIC M. COOMBS[1], PETER B. McEVOY[2], GARY L. PIPER[3], and BALDO VILLEGAS[4]

[1]Oregon Department of Agriculture, 635 Capitol St. NE, Salem, Oregon 97310, USA
[2]Entomology, Cordley Hall, Oregon State University, Corvallis Oregon 97331, USA
[3]Entomology, Washington State University, Pullman, Washington 99164, USA
[4]CDFA Biological Control, 3288 Meadowview Rd., Sacramento, California 95832, USA

This information is intended to help land management personnel increase the probability of successfully establishing biological control agents of weeds. Identifying and avoiding common errors will help. The causes of failure can be grouped into three general categories: abiotic, biotic, and procedural. Procedural errors (the human factor) are frequently the source of failures in biological control. Most reported biocontrol failures are attributable either to climatic or biological factors, or analyzed based on their taxonomic group. Each case should be individually appraised based on the relationship between the natural enemy and its environment (non-living and living) and the procedures used. Factors in one category can be influenced by those in another, and therefore failures can be attributed to multiple causes. Successes and failures are often reported by large-scale political units, but rarely confirmed by the ecosystem approach. Successes happen in stages: biocontrol agent introduction, recovery, establishment, redistribution, and suppression of the target host. Any stage of the process can fail, especially as it relates to the number of sites targeted. During the past decade, more agencies and other interested parties have elected to incorporate biological control into their integrated weed management programs. Because the number of personnel lacking expertise and experience involved in biocontrol has grown, local failures have increased. Fortunately, when natural enemies become abundant in several areas, failures at local sites becomes less important because additional releases can be easily and economically made. But ease of obtaining additional release organisms should not serve as an excuse for carelessness. Adequate training and provision of information to secondary users (those who receive biocontrol agents after they have already been established locally) will help improve the establishment and success rates of biocontrol agents.

Projects on Biological Control of Russian Thistle and Milk Thistle in California: Failures that Contributed to the Science of Biological Weed Control

RICHARD D. GOEDEN

University of California, Department of Entomology, Riverside, California 92521, USA

Projects on the biological control of Russian thistle (*Salsola tragus* and *S. paulseni*) and milk thistle (*Silybum marianum*) in California were cooperative ventures with the USDA/ARS Biological Control of Weeds Laboratory at Albany and the University of

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California at Riverside that began in the mid-1960's and continued off and on through the 1980's. During this period, 26 published scientific papers and book chapters were authored or co-authored by the speaker that documented all phases of these two projects, from preintroduction faunistic surveys of both weeds, to foreign explorations, natural enemy selection, preintroduction study, insect importations, colonization efforts, and evaluation studies of established natural enemies. Neither of these two biological control projects at the present time are considered to be successes; however, recent efforts, principally by USDA/ARS entomologists sponsored jointly with the California Department of Food and Agriculture, Biological Control Program, have identified additional natural enemies of Russian thistle that may see future use. According to a definition offered by my now-deceased colleague, Paul DeBach, to which I wholeheartedly subscribe, the field of biological control, of which biological control of weeds is a major sub-discipline, involves the "….*Study*, importation, augmentation, and conservation of beneficial organisms." Thus, only by studying, documenting, and publishing *all* aspects of *all* biological control of weeds projects, not just those events that precede the balleyhooed "successful establishment and successful" widespread distribution of natural enemies, and certainly not by locking away information as unpublished, in-house reports on introduced natural enemies that are deemed to be less than successful (indeed, that might even deserve the impolitic sobriquet, "failure"), can we ever hope to achieve the time-worn goal and overused, hackneyed admonition to become a "science" of biological weed control.

Disparity Between Laboratory and Field Spraying Systems - a Cause of Practical Failure of Mycoherbicides?

M. P. GREAVES, J. LAWRIE, and N. M. WESTERN

IACR - Long Ashton Research Station, Department of Agricultural Sciences, University of Bristol, Bristol, BS41 9AF United Kingdom

Application of potential mycoherbicides to their target weeds in laboratory or glasshouse experiments is, almost without exception, achieved with some form of aerosol sprayer, applying sufficient inoculum suspension to induce run-off from the target. This applies something between 1000 and 3000 litres per hectare. In contrast, modern spray application practice in the field aims to reduce application volume to the minimum reliable volume, usually less than 250, and never exceeding 500, litres per hectare. Furthermore, the droplet spectrum generated from a field sprayer is markedly different from that produced by an aerosol, as is the retention pattern of the respective droplets and consequent coverage of the target by inoculum. This disparity will be illustrated by data and discussed in relation to assessing mycoherbicide efficacy.

Predation and Interference by Phytoseiid Mites on the Spider Mite *Tetranychus lintearius* (Acari: Tetranychidae), an Established Biological Control Agent of Gorse (*Ulex europaeus*)

PAUL D. PRATT[1], ERIC M. COOMBS[2], and BRIAN A. CROFT[3]

[1]USDA/ARS, Invasive Plant Research Laboratory,
3205 College Ave., Ft. Lauderdale, Florida 33314, USA
[2]Oregon Department of Agriculture, 635 Capitol St. N.E.,
Salem, Oregon 97301-2532, USA
[3]Oregon State University, Department of Entomology, Corvallis, Oregon 97331, USA

Gorse (*Ulex europaeus* L.), an introduced weed, infests coastal areas of the western USA. The spider mite (*Tetranychus lintearius* Dufour) severely damages gorse and has been introduced for weed control in parts of New Zealand, Oregon, California, Washington, and Hawaii. In most, if not all, natural plant ecosystems spider mites are regulated by natural enemies at levels far below those needed to suppress weeds. Therefore we questioned 1) if native predators were becoming associated with this biological control agent, 2) which major groups of predators were involved, and 3) what possible negative effect might they pose to biological control of gorse. Monthly surveys of gorse stands demonstrated that predaceous arthropods were present in *T. lintearius* colonies. The most common were the predaceous mites in the family Phytoseiidae, including specialist (i.e. *Phytoseiulus persimilis* A.H.) and generalist feeding (i.e. *Typhlodromus pyri* Scheuten) predators of spider mites. Laboratory feeding studies showed that most phytoseiid predators aggressively fed and reproduced on *T. lintearius*. Results show that phytoseiid mites can interfere with the biological control of gorse. The potential long-term effects of specialist and generalist phytoseiid predators on *T. lintearius* are discussed.

Failing to Make the Successful Leap from Small to Large Scale Application of a Fungal Pathogen of *Hydrilla verticillata* (L.f.) Royle

JUDY F. SHEARER

U.S. Army Engineer Waterways Experiment Station,
3909 Halls Ferry Road, Vicksburg, Mississippi 39180, USA

Mycoleptodiscus terrestris (Gerd.) Ostazeski, a fungal pathogen of hydrilla, has been undergoing formulation development as a bioherbicide for the past three years. In 1997, a prototype granular formulation that combined the fungus with an EPA approved biocarrier, Biocar 405, was efficacious in reducing hydrilla biomass in laboratory and greenhouse studies. In 1998, procedures and equipment were scaled-up to meet the requirements for field testing the formulation. Although it was realized that each change in the scale-up process had the potential to be concomitant with a change in viability and/or pathogenic-

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ity of the fungus, the rush to field test imposed in part by financial backers did not permit laboratory evaluation of the effect of the changes on formulation performance. The newly developed formulation was ineffective in reducing hydrilla biomass in pond and mesocosm studies. In comparison, the fungus applied as a slurry reduced hydrilla biomass by approximately 89% 3 weeks after treatment. One of the notable changes between the prototype and field formulation was in Biocar itself. In reevaluating the formulation process, we will begin by scrutinizing potential differences in lot numbers of Biocar and their effect on the fungal component and then proceed to other aspects of the formulation process.