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Picking the target: A revision of McClay's scoring system to determine the suitability of a weed for classical biological control[1]

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Abstract:

A previously published system for ranking target weeds according to their suitability for classical biological control, using the size of infested area, environmental and biological aspects as criteria, is revised to make it applicable for use in other regions, and for weeds at the beginning of a biological control program or at any stage of its development. As examples, *Odontites verna, Matricaria perforata* and *Euphorbia esula* are ranked. Discounting the number of known potential biological control agents, leafy spurge (*Euphorbia esula*) ranked highest on account of habitat stability, lack of conventional means of control, toxicity and its status as a weed in its native range.

Introduction

A system for selecting the most suitable target weeds for classical biological control is needed because it takes up to 20 scientist-years to bring a biological control project to a successful conclusion (Harris 1979, Schroeder 1990). If the project fails, up to several million dollars may have been invested for little gain. Considering that many weeds are inadequately controlled, it is important to weigh all factors which impact on future success. McClay (1989) first produced a scoring system for selecting target weeds in Alberta. The purpose of this paper is to revise and supplement it so that it can be used by researchers and administrators in any jurisdiction, such as a country, province, state or even county when considering to target a certain weed for biological control. The system may be applied to a target weed in the beginning of its biological control program or at

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any stage in its development, such as when overseas field or literature surveys have already been carried out. Categories which were added or changed in the revised system, are presented, and also the categories left unchanged from McClay's original system to facilitate use of the entire system. Headings of the revised system are listed by Arabic numerals Categories of the original system are referred to by the Latin letters, which McClay (1989) had used, in brackets.

Revision of the system (Table 1)

The system includes 2 groups of criteria: economic and biological. Clearly, if the amount of damage of a weed, environmental and/or economic, does not warrant the cost of a biological control project, it should not be undertaken and there is no need to even score the biological criteria.

A. Economic aspects

1. Economic losses. McClay (1989) did not consider economic losses because such figures are often difficult to obtain. However, an assessment of yield losses and costs of conventional control measures, as well as damage to the environment, such as by the displacement of native flora, is needed in the first phase of any biological control project. If the damage caused by a weed, in excess of its benefits, is not larger than the cost of a biological control project, then such weed is not a suitable target for biological control. (see also category 6).

2. Infested area. (C. Extent of occurrence in Alberta). This category was modified so that it could be applied for use in ranking weeds of any region. For example, if the province of Alberta considers to contribute funds for the biological control of a weed in its region, that province will score the infested area of this weed in Alberta. On the other hand, the federal government would consider the infested area in all of Canada.

3. Expected spread. The range of a weed and corresponding damage may still be increasing. For example, Harris and Cranston (1979) estimated that *Centaurea diffusa* Lam. (Asteraceae) threatens 7.5 million ha of unimproved rangeland in western Canada. Such potential increase in damage should be scored.

4. Toxicity. Weeds toxic to livestock, such as leafy spurge (*Euphorbia esula* L.. *sensu lato*; Euphorbiaceae) (Lym and Kirby 1967) cause losses in 3 ways: displacing forage; inhibiting grazing on forage growing near the toxic weed; and direct toxicity. Biological control agents on toxic weeds avoided by cattle are little or not at all disturbed by grazing. This should further increase the points.

5. Available means of control. For example, chemical and cultural means to control perennial sow-thistle (*Sonchus arvensis* L.; Asteraceae) are acceptable albeit costly (Derscheid and Parker 1972). On the other hand, those available to control diffuse (*Centaurea diffusa* Lam.) and spotted knapweed (*C. maculosa* Lam.) (Asteraceae) are not acceptable in economic or environmental terms (Harris and Cranston 1979). Thus, need to find an alternate control is very urgent.

Table 1. A system for ranking target weeds according to their suitability for classical biological control.

A. Economic aspects		
1. Economic losses:		
Very severe		30
Severe		20
Light		0
2. Infested area:		
Very large		10
Large		5
Small		0
3. Expected spread:		
Extensive		10
Small		0
4. Toxicity (health problems caused to humans and/or livestock):		
Very severe		10
Severe		5
None or small		0
5. Available means of control:		
Environmental damage	high	20
	medium	10
	low	0
Economic justification	low or not justified	20
	medium	10
	high	0
6. Beneficial aspects:		
None or small		0
Major		-15
Very major		-30
Biological aspects		
7. Infraspecific variation:		
Small (asexual, selfing, vegetative breeding system)		10
Medium (sexual, outcrossing breeding system)		5
Extensive (sexual, outcrossing breeding system)		0
Geographical area where the weed is native:		
Native only outside North America		30
Native to North America and other regions		10
Cosmopolitan or origin unknown		0
Relative abundance:		
More abundant/aggressive in area where it is to be controlled than in area of origin		10
Possibly more so not so		0
10. Success of biological control elsewhere:		
Under full biological control elsewhere		5
Under partial biological control elsewhere		2
Biological control not attempted		0
Biological control attempts failed elsewhere		-5
11. Number of known promising biological control agents:		
One score for each promising species		0-?
12. Habitat stability:		
High (i.e. rangeland, permanent pastures)		30
Moderate (perennial crops, extensive sources of infestation on waste land, roadsides)		
Low (damage virtually restricted to annual cropland)		0
13. Number of economic species in the same genus:		
0		3
1		1
>1		0
14. Number of economic species in the same tribe:		
0		4
1 to 3		2
4 to 8		1
>8		0
15. Number of ornamental species in same genus:		
0		2
1 to 5		1
>5		0
16. Number of ornamental species in same tribe:		
0		3
1 to 15		1
>15		0
17. Number of native North American species in same genus:		
0		2
1 to 20		1
>20		0
18. Number of native North American species in same tribe:		
0		4
1 to 40		2
41 to 120		1
>120		0
Maximum number of points, with no known biological control agents		179

6. Conflicts of interest. (J. Beneficial aspects or uses). This category was given more weight because benefits generated by a weed may be substantial, such as the value of *Echium plantagineum* L. (Boraginaceae) to the honey industry (Cullen and Delfosse 1985). Any benefits of a successful control may be decreased or even negated.

B. Biological Aspects

7. Infraspecific variation. (F. Infraspecific variation; G. Breeding System). The 2 original categories were combined because a clear difference between them is lacking. The greater the genetic variability of weed populations and the more open the recombination system, the smaller are the chances for successful biological control (Burdon *et al*. 1981, Crawley 1989).

8. Geographical area where the weed is native. (A). It is generally agreed that the likelihood of finding biological control agents for introduced weeds is greater than for native weeds (Andres *et al.* 1976). This category is changed only to the extent that native weeds are included as potential targets for biological weed control, because several such weeds have been controlled biologically, for example *Leptospermum scoparium* Forster (Myrtaceae) (Hoy 1949), *Opuntia dilenii* (Ker-Gawler) Haworth, *O. littoralis* (Engelmann) Cockerell, and O. *tricantha* Willdenow (Sweet) (Cactaceae) (Goeden *et al*. 1967, Julien *et al*. 1984). It should be noted, that 3 of the above weed species are cogeneric, and *L. scoparium* is controlled by the accidentally introduced *Eriococcus orariensis* Hoy (Pseudococcidae: Homoptera). The weight of this score was slightly reduced from a maximum of 33 to 30 points.

9. Relative abundance. (B). Weeds which were not weedy in the areas from where the biological control agents were imported, tend to be successfully controlled in the countries of introduction. Examples are *Hypericum perforatum* L. (Hypericaceae) and *Carduus nutans* L. (Asteraceae) (Harris and Maw 1984, Zwölfer and Harris 1984), There is evidence of a similar relationship with successfully controlled forest pests (Hulme and Green 1984). The weight of this category was increased from 5 to 10 maximum points.

10. Success of biological control elsewhere. (H). Successful biological control of a weed elsewhere improves the prospects for success (Crawley 1989) and was thus given a score of 5. Where biological control programs have been only partially successful (reduced spread and seed production, or control in some habitats only), a score of 2 is given. If biological control programs failed elsewhere, prospects are reduced, and a negative score of 5 is given.

11. Number of known promising biological control agents. (1. Surveys carried out in the area of origin). McClay (1989) gave this category a maximum of 3 points if an extensive or detailed survey had been carried out in the area of origin of the weed. However, even an extensive survey may produce few promising agents. Therefore, the score should reflect the number of promising agents found. One point is awarded for each promising agent found. Because the rust *Puccinia chondrillina* Bubac and Syd. (Uredinales) gave such spectacular control of skeleton weed (*Chondrilla juncea* L.; Asteraceae) in Australia (Cullen 1978), due to its millions of wind-dispersed propagules, it may be argued that disease organisms should carry more weight in the case of weeds of arable land.

12. Habitat stability. (E). There is general agreement that the ideal target for biological control is an introduced weed dominating on land that is little disturbed (Andres *et al.* 1976, Harris 1975, Schroeder 1990, Reznik 1990). Almost all significant successes in classical biological control have been gained against weeds of uncultivated waste or range land. Exceptions are the perennial skeleton weed which has been mentioned above, and the annual *Tribulus terrestris* L. (Zygophyllaceae) which has been substantially reduced by seed-feeding weevils (Huffaker *et al.* 1983). Kovalev and Vechernin (1986) observed very high population densities of *Zygogramma suturalis* F. (Coleoptera: Chrysomelidae) which developed on land which was little or not at all disturbed and controlled the weed there. These masses of beetles moved into annual crops and gave control of the annual *Ambrosia artemisiifolia* L. (Asteraceae). If annually disturbed, however, populations of the beetle could not increase sufficiently, and they did not control the weed in most annual crops (Reznik *et al*. 1990). Insects have been predominantly used in biological weed control, but they often do not thrive in annually disturbed habitats (Panetta and Doff 1984, Peschken and Wilkinson 1981) or even if disturbed only by cattle grazing (Peschken *et al*. 1989). In unstable environments mainly species with *r*-selected traits (polyphagy, high reproductive rate, short generation time and high dispersal ability) survive (Ehler and Miller 1979). In biological weed control polyphagous insects cannot be used. Conservation tillage may increase the survival of biological control agents in annual crops (Stinner and House 1990). Based on the evidence of documented successes to date, weeds which cause most or all of their damage on cultivated land, receive the minimum number of points in this category.

13. and 14. Number of economic species in the same genus/tribe. (K. and L.). These 2 categories reflect the degree of taxonomic isolation of the target weed from economic plants grown in North America in the same ecozone as the target weed. All species listed as commercial crops and as ornamental species which are grown on a commercial scale such as carnations and poinsettia (Bailey and Bailey 1976), and important native range grasses are considered to be economic plant species. Tribes are defined as in Fernald (1950) or in Clapham *et al.* (1962). Families for which classification into tribes is not available are considered to consist of a single tribe.

15 and 16. Number of ornamental species in same genus/tribe. (M. and N.). These 2 categories similarly reflect the degree of taxonomic isolation of the target weed from ornamental plants grown in the same ecozone as the target weed in North America. Ornamental plants are considered those listed as such in Bailey and Bailey (1976).

17. and 18. Number of native North American species in same genus tribe. (O. and P.). These 2 categories reflect the degree of taxonomic isolation of the target weed from native North American plants. Native North American plants were taken to be those listed by Kartesz and Kartesz (1980).

McClay's original category "D. Life cycle of the weed" was not used in the revised system. Assuming that "arable agriculture" refers to the growing of annual crops, then only 3 such annual weeds were targeted for classical biological control (Julien 1987): *Salsola australis* R. Brown (Chenopodiaceae); *Ambrosia artemisiifolia*; and *Tribulus terrestris* L. (Zygophyllaceae). The latter 2 of these 3 weed species are partially controlled (Huffaker *et al*. 1983, Kovalev and Vechernin 1986). Therefore, the category "Life cycle of the weed" was not considered a suitable criterion.

Application of the scoring system to three weed species

The 3 weeds are in different stages of a biological control program. Red bartsia (*Odontites vema* [Bellardi] Dum. subsp. *verna;* Scrophulariaceae), is not presently a target for biological control but its biology and distribution, damage and control have been investigated (Meleshko 1988). Scentless chamomile is an official target weed, and aspects of the suitability of scentless chamomile (*Matricaria perforata* Mérat; Asteraceae) as a target for biological control have been investigated such as its distribution and candidate agents (Douglas 1989, Douglas *et al*. 1991, Peschken *et al.* 1990, Woo *et al.* 1991; Thomas, A.G., personal communication, 1990). Leafy spurge (*Euphorbia esula* L. *sensu lato;* Euphorbiaceae) has been a target for biological control and some released insects are locally reducing this weed below the economic level (Best *et al.* 1980, Gassmann *et al.* 1991, Harris 1991, Harris *et al.* 1985, Radcliffe-Smith 1985). Even discounting the number of known and promising biological control agents, leafy spurge and red bartsia rank highest (Table 2), mainly due to habitat stability, available means of control, toxicity and status as a weed in their native range.

Table 2. Points assigned to *Odontites vema* subsp. *verna, Matricaria perforata*, and *Euphorbia esula*.[1]

Category	*Odontites verna*	*Matricaria perforata*	*Euphorbia esula*
A. ECONOMIC ASPECTS			
1. Economic losses	30	30	30
2. Infested area	5	10	10
3. Expected spread	10	10	10
4. Toxicity	5	0	5
5. Available means of control			
Environmental damage	0	10	10
Economic justification	20	10	20
6. Beneficial aspects	0	0	0
B. BIOLOGICAL ASPECTS			
7. Infraspecific variation	5	5	0
8. Native range	30	30	30
9. Relative abundance	10	10	10
10. Success elsewhere	0	0	0
11. Number of known agents	0	4	30
12. Habitat stability	30	15	30
13. Economic species in genus	3	3	1
14. Economic species in tribe	4	2	2
15. Ornamental species in genus	2	1	0
16. Ornamental species in tribe	3	0	0
17. Native species in genus	2	1	0
18. Native species in tribe	4	1	1
Total	163	142	189

The main references on which these assessments are based are given in the text.

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