BIOLOGICAL CONTROL OF WEEDS

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Notes

I. General Considerations Concerning Weeds

A. Definition of weed: A weed is a plant growing where it is not wanted. In other places or times a weed species may be considered either neutral or of some benefit. Plants are able to establish themselves in almost every conceivable habitat.

B. There are ca. 2,200 weeds of importance in the entire U.S. More than half of the weed species were either accidentally introduced as seed, feed, or ship's ballast contaminants or purposely introduced as ornamentals which escaped cultivation.

C. Direct crop losses from weeds are estimated at 10 Billion dollars annually. Weed control costs 6.2 billion dollars/year of which $3.6 billion is spent on herbicides. Herbicides account for 57% of all pesticides sold. Weeds are the second most important agricultural and forest problem. The amount of losses is second only to soil erosion. Losses far exceed insect problems.

D. Types of losses due to weeds:

1. Quantity and quality of crop yields reduced due to weed competition for common resources;
2. Higher cultivation costs (machinery, fuel, manpower) used for weed control;
3. Reduced seed quality and increased costs for special seed and grain cleaning;
4. Loss in food quality due to off-flavor and color of agricultural products (dairy products especially);
5. Direct injury caused to man and livestock from internal and external poisoning, mechanical injury (thorns), and pollinosis (hayfever);
6. Blockage of waterways due to aquatic weeds which stop water flow, provide environments for mosquito breeding, ruin recreational activities, increase evaporation from reservoirs (through transpiration), and affect color and flavor of drinking water; and
7. Serve as alternate hosts for insect pests and plant pathogens.

II. Considerations in the Biological Control of Weeds:

A. Definition of BC of Weeds: The use of plant-feeding organisms or diseases to reduce the population of a plant species that has risen to the status of a weed. (Note that objective is reduction not eradication of weed species)

B. Some consider BC of weeds as inverse of BC of pests.

C. Theoretical considerations: Many of the worst weeds in the U.S. are of foreign origin. Their aggressiveness in the U.S. may not always be due to the absence of their phytophagous enemies. Aggressiveness of an alien weed in a new area may also be due to more favorable climatic and/or edaphic conditions or relative freedom from competition with other plants. However, the fact that many alien weeds have no or only a few insects specifically feeding on them in the areas of introduction as

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compared to their country of origin is the basis upon which the study of BC of weeds is based. Theoretically, the introduction of host specific phytophagous insects (minus the insects' own complements of natural enemies) should reduce the abundance of an alien weed.

D. Distinctions in BC of weeds:

1. Phytophagous species rather than entomophagous organisms are utilized
2. There can be "conflict of interest" problems
3. Necessity to apply extremely host specific organisms as BC agents

E. To date introduction of host specific weed feeding insects into regions invaded by alien weeds remains the major approach to BC of weeds. Insects constitute the largest group of natural enemies of weedy plants. Effective BC agents found in the orders: Hemiptera, Homoptera, Thysanoptera, Coleoptera, Lepidoptera, Diptera, and Hymenoptera. Organisms in other groups include plant pathogens, spider mites, fish, snails, ducks, manatee, and parasitic plants.

F. Insects have been used most in BC of weeds because:

1. There is great variety and number of species;
2. They frequently exhibit a high degree of host specificity;
3. They are intimately adapted to their host plants; and
4. There is a great range of natural enemies suited to particular ecological situations.

G. Recent increase in use of plant pathogens. These were once thought not to be host specific but turns out in some cases they are too host specific (will not attack different variety of same plant).

III. Preliminary Considerations to BC Projects on Weeds

A. Eradication of the weed may really be desired (i.e., weed toxic to livestock-may become dead stock), thus BC may not be the answer.

B. Biological control is selective and usually aimed at one species only. It is best used when weed is devastatingly abundant and aggressively spreading in dense stands.

C. Biological control is a relatively slow method. Usually it takes about 5 years between initiation of a project and importation of the first natural enemy. It may require several more years after the introduction of the first natural enemies to get control.

D. There may be risks involved in importing plant-feeding organisms and therefore BC of weeds is often resorted to only after other methods of control have failed or the weed covers large areas of land with (1) such low value (i.e., rangeland) or (2) such rough terrain that cultural or chemical treatments are precluded. However, potential agents are now screened for host specificity.

E. Biological control agents cannot be limited to an area, like chemical and cultural treatments, because living organisms will disperse from the introduction areas into adjacent areas. It must be agreed that everyone regards the targeted plant species as a weed. In some cases not everyone

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will feel that way. Then a "conflict of interests" arises. This especially happens when one wants wide spread control of a weed. Some might see weed as an ornamental or as in many cases as a valuable food for animals (prickly pear cactus, haole koa). Objections should be resolved prior to initiating the project. This may be done by arbitration (losses vs. gains).

IV. Methods used in BC of weeds (Classical BC, augmentation, conservation)

A. Steps in classical BC of weeds after objectives are defined.

1. Two surveys should be conducted prior to the foreign exploration. These include:

   a. A survey to obtain from the literature and specialists as much information as possible pertaining to the target weed and its natural enemies (refer to notes on foreign exploration - "Accumulation and evaluation of available information")
   b. A survey to determine what organisms are feeding on the target weed in the area for which control is desired. This survey is concerned with determining what native insects are already present on the target weed and the extent of the damage they cause. This is very important to do and can result in savings of funds and time. Effective local insects may be present or some insects may already have been introduced.

2. Most of the other steps in foreign exploration are similar to that conducted for natural enemies of arthropod pests (refer to earlier lecture notes mentioned above) until it is time to make the final selections for candidate species to import.
3. Selection of candidate phytophagous insects for importation are based on two criteria:

   a. The width of the range of host plants (none can be crop plants); and
   b. The plant structures attacked by the plant-feeding stages (larvae, nymphs, adults) that are vital to the plant (growing tips, stems, seeds, etc.).

4. After collection of phytophagous insects, studies can be divided into those conducted (1) abroad where insects were collected and (2) those conducted at the site of introduction (domestic studies)

   a. Studies Abroad. These should be conducted near the habitat of the target weed and its natural enemies. This allows the avoidance of the problem of crossing political borders with plants and insects. It also insures a ready supply of material for study and allows time for observations on natural enemy/plant relationships under

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natural conditions. Two types of laboratory studies should be conducted:

i. Starvation Tests: provide insect with only one type of plant and see if it will attack it or lay eggs.
ii. Multiple Choice Tests: Follows starvation tests and allows determination of insects' preference for test plants.

Types of plants used in testing include:

i. Representative economic and desirable plants to which the insects would be exposed in the target weed area.
ii. A systematically arranged spectrum of plants related to the target plant.
iii. Plants that are known to contain chemical constituents that are similar to those of the target plant.
iv. Plants from which the candidate insect has been reported collected or associated with in the literature.

After above information is obtained then permission is requested to import the candidate species into quarantine in the country of introduction.

b. Domestic Studies. After shipping to quarantine, complete host plant specificity testing is a major phase of work at the domestic laboratory. Additional studies conducted include feeding tests on:

i. Ornamentals, crop, and forage plants that would have been difficult to obtain or grow abroad

ii. Native plants in the vicinity of introduction that provide browse for domestic and wild animals, are necessary as food and shelter for wildlife, or have other redeeming qualities.

If any of the above plants were taken abroad they could potentially become a weed problem.

5. Domestic Release. When ready to release a phytophagous BC agent, accumulated data must be submitted to the "Working Group on Biological Control of Weeds" (Joint Committees of the USDA and the US Dept. of Interior (in charge of National Parks). If importation is approved by the "working group" then permits are sought from APHIS (USDA) and the associated state DOA's. When permits are obtained then BC agent can be released.

B. Manipulative methods (Augmentation and Conservation).

These methods involve the manipulation of the BC agents or their environment to enhance their effectiveness. Some work has been done in this area with inundative releases of native insects and pathogens.

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V. Evaluation of BC of weeds projects through 1984.

A. There have been 174 projects worldwide against 101 weed species. In all, 39% of the projects resulted in successful control and 48% of the 101 weed species were controlled in at least one project.

B. A total of 499 species of natural enemies have been released against the 101 weed species in 70 countries. Establishment of natural enemies occurred in 64% of the releases. Agents were effective in controlling the weed in 29% of all releases or 47% of the releases which resulted in establishment.

C. Releases of native natural enemies resulted in effective control in 62% of the cases compared to 29% when exotic natural enemies were used. This may result from native agents being used in inundative programs compared to exotic agents which are often released without any followup programs or additional aid.

VI. Examples.

A. *Lantana camara* L.: First major program for BC of weeds. In 1902, sugarcane planters in Hawaii were concerned with spread of weed. HSPA sponsored exploration for phytophagous BC agents in 1902. Albert Koebele searched for BC agents in Mexico. Attempted to introduce 18 insects into Hawaii, but only 8 species became established (problems encountered due to difficulties in transportation - slow rail and boat transportation). At that time no specificity tests were conducted and 2 of the released organisms fed on other plants (eggplant, pepper, and some ornamentals). Despite that, moderate control was achieved in the drier areas of the islands. More control was desired and from 1954-1970 (50 years later) 7 additional species were established in Hawaii. A noctuid moth, *Hypena strigata* F., was extremely effective in the drier areas of Hawaii during the cooler months. During the hotter months, the lace bug, *Teleonemia scrupulosa* Stal., was effective in the dry areas. It was one of the original 8 species released in 1902. In the wetter areas of the islands, 3 beetles appear to have reduced the problem somewhat. Two of the beetles (*Octotoma scabripennis* (Guerin-Meneville) and *Uroplata girardi* Pic.) are chrysomelids which mine the leaves. The other a cerambycid, *Plagiohammus spinipennis* (Thomson), bores into the stems of the plants.

Currently work in being conducted in Australia for control of Lantana. The lace bug has done quite well against some Lantana varieties in some areas, but complete control is still lacking.

Insects Introduced into Hawaii for Biological Control of Lantana (Established species only)

1. Original Introductions (1902--Koebele)

Lantana butterflies (Lycaenidae)
smaller - *Strymon bazochii gundlachianus* (Bates)
larger - *Thmolus echion* (L.)
Lantana lace bug (Tingidae): *Teleonemia scrupulosa* Stal
Lantana gall fly (Tephritidae): *Eutreta xanthochaeta* Aldrich
Lantana seed fly (Agromyzidae): *Ophiomyia lantanae* (Froggatt)

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Lantana plume moth (Pterophoridae): *Lantanophaga pusillidactyla* (Walker)
Lantana tortricid moth (Tortricidae): *Epinotia lantana* Busck
Lantana leafminer (Gracillariidae): *Cremastobomycia lantanella* Busck

2. Recent Introductions (1954-1970)

Lantana cerambycid, *Plagiohammus spinipennis* Thomson - 1960
Lantana defoliator caterpillar (Noctuidae), *Hypena strigata* (Fabricius) - 1957
Lantana stick caterpillar (Noctuidae), *Neogalea esula* (Druce) - 1955
Lantana leaf beetles (Hispidae), *Uroplata girardi* Pic - 1961; *Octotoma scabripennis* (Guerin-Meneville) - 1954
Lantana leaf-tier (Pyralidae), *Salbia haemorrhoidalis* Guenee - 1956
Second lantana lace bug (Tingidae), *Leptobyrsa decora* Drake - 1970

B. *Opuntia* spp., Prickly pear cacti: Greatest BC success with weeds. In early part of this century (1910 - 1920), prickly pear became extremely bad in Australia where it covered up to 60 million acres (the cacti excluded all grasses and shrubs).

Searches for natural enemies began in 1920 under the auspices of the Commonwealth Prickly Pear Board. A total of 150 species were discovered whose life cycles were restricted to *Opuntia* spp. The best insect found was the tunneling caterpillar, *Cactoblastis cactorum* (Berg) from Argentina. Releases led to almost complete control. It was ineffective in cooler regions where cochineal scale insects (*Dactylopius* spp.) are required for control. After the successes in Australia, *Cactoblastis* and the dactylopiid scales were introduced into South Africa, India, and Hawaii where partial to complete control was achieved in various areas.

C. *Hypericum perforatum* L., St. Johnswort or Klamath weed: First weedy plant for which insects were imported into the continental U.S. In 1952, ca. 2.3 million acres were infested in northern California plus 2.7 million acres in the surrounding northern states. USDA and the University of California established a joint research team in 1944. The first insect liberated in the field was the northern European leaf beetle, *Chrysolina hyperici*, in 1945.

The second species released was the southern European leaf beetle, *Chrysolina quadrigemina*, in 1946. The insects were obtained from Australia due to the political problems in Europe at the time (WWII). Immediate success was achieved with *C. quadrigemina* in sunny areas. Further control in shady areas was achieved with the introduction of a flathead borer, *Agrilis hyperici* whose larvae bore into the root crown and tap root of the plant.

Introductions into Hawaii for Biological Control of Weeds.

Weed species	No. Nat. Enemies Intro.	Estab.	Families	Intro Date	Status
Ageratina riparia (Regel) (Hamakua pamakani)	3	4*	Tephritidae Pterophoridae Fungus	1974 1973 1975	40-60% reduction in moist areas from 600-1200m.
Clidemia hirta (L) D.Don (Kosters curse)	2	2	Phlaeothripidae Pyralidae	1974 1972	effective in pasture, not in forests
Cyprus rotundus L. (nutgrass, purple nutsedge)	2	2	Curculionidae Tortricidae	1925 1925	no effects
Elephantopus mollis Humboldt, Borpland and Kunth. (elephants foot)	1	1	Tephritidae	1961	no effects
Emex spinosa (L.) Campdera	3	1	Curculionidae	1957, 1962	substantial to complete control from 600-1200 m.
Eupatorium adenophorum Sprengel (Maui pamakani)	2	2	Tephritidae (2)	1945, 1955	complete control in dry areas, stable in wet areas
Hypericum perforatum L. (Klamath weed)	3	3	Chrysomelidae (2) Cecidomyidae	1964 1965	excellent control mainly due to gall midge
Lantana camara L.	21	15	(see Table, p. 43)	1902–1970	partial to substantial control in dry areas
Melastoma malabothricum (L.) (Indian rhododendron)	3	2	Pyralidae	1958, 1965	no effects
Myrica faya Aiton (firebush)	1	1	Tortricidae	1956	no effects
Opuntia ficus-indica (L.) (prickly pear)	7	3	Cerambycidae Pyralidae Dactylopiidae	1951 1950 1949	excellent control below 900m.
Pluchea odorata (L.) Cassini (sour bush)	2	2	Tephritidae Gelichiidae	1959 1957	no effects
Rubus lucidus Rydburg (blackberry)	5	3	Tortricidae Tenthredinidae Heliodinidae	1964 1966 1963	no effects
Salsola australis R. Brown (russian thistle)	2	0	Coleophoridae (2)	1980	
Schinus terebinthefolius Raddi (christmas berry)	3	2	Bruchidae Tortricidae	1960 1954	no effects
Tribulus terrestris L. (puncture vine)	2	2	Curculionidae (2)	1962	complete control
Ulex europaeus (gorse)	2	0		1926, 1961	

* - a Tephritidae introduced to control Maui pamakani also attacks this weed species.

QUESTIONS

1. What is a weed? What special problems are commonly associated with biological control projects directed at weeds?
2. What types of losses result from weeds?
3. What types of studies are commonly conducted on phytophagous species selected to be biological control agents, prior to their importation into quarantine facilities in the country where the weed is a problem?
4. Discuss the biological control project directed against *Lantana camara* L. in Hawaii.
5. Discuss the biological control project directed against Klamath weed.

REFERENCES

Andres, L. A., C. J. Davis, P. Harris & A. J. Wapshere. 1976. Biological control of weeds. p. 481–499. *In* Theory and Practice of Biological Control (C. B. Huffaker and P. S. Messenger, eds.), Academic Press, New York. 788 pp.

Batra, S. W. T. 1981. Biological control of weeds: principles and prospects. p. 45–49. *In* Biological Control in Crop Production (G. C. Papavizas, ed.), Beltsville Symposia in Agric. Res. 5, Allenheld, Osmun and Co., Monclair, New Jersey, and Granada Publ., Ltd., London. 461 pp.

Frick, K. E. 1974. Biological control of weeds: introduction, history, theoretical and practical applications. p. 204–223. *In* Proc. Summer Institute on Biological Control of Plant Insects and Diseases (F. G. Maxwell and F. A. Harris, eds), Univ. Press of Mississippii, Jackson. 647 pp.

Goeden, R. D. 1978. Part II: Biological control of weeds. p. 357–412. *In* Introduced parasites and predators of arthropod pests and weeds: a world review (C. P. Clausen, ed.), USDA Agric. Handbook No. 480. 545 pp.

Grossman, J. 1989. Update: Biological control of weeds - What's happening, what's needed? IPM Practitioner 11(6/7): 1–11.

Julien, M. H., J. D. Kerr & R. R. Chan. 1984. Biological control of weeds: an evaluation. Prot. Ecol. 7: 3–25.

Van Driesche, R. G. and T. S. Bellows, Jr. 1996. Biological control. Chapman and Hall, New York. 539 pp.

READING ASSIGNMENT:

Chapter 5: pp. 78–91; Chapter 17: pp. 354–365, **Van Driesche, R. G. and T. S. Bellows, Jr. 1996.** Biological control. Chapman and Hall, New York. 539 pp.