Canada Thistle (*Cirsium arvense*): A Literature Review of Management Practices

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INTRODUCTION

Canada thistle (*Cirsium arvense* L.) Scop. was introduced to North America in the early 1600s and is now widespread throughout the northern United States and all provinces of Canada (Detmers 1927, Hodgson 1968, Moore 1975) where it is considered one of the most tenacious and economically important agricultural weeds. It is responsible for tens of millions of dollars in direct crop loss annually and additional costs for herbicides and other control practices (Hodgson 1968, Messersmith 1980, Wilson 1980). Canada thistle is also known to harbor destructive insects and plant pathogens, to cause infections in grazing animals, and to seriously complicate mechanical harvesting and processing of certain vegetables (Link and Kommedahl 1958).

Much has been written about Canada thistle but little has been applied to management of natural areas. Two particularly valuable reviews are by Hodgson (1968) and Moore (1975).

BIOLOGY

Description and Habitat. Canada thistle is in the family Asteraceae. It is a slender, branching, perennial herbaceous plant standing up to 1.5 m (Figure 1). Detailed descriptions are available in botanical texts (e.g., Steyermark 1963). Canada thistle has optimal growth with 50 to 75 cm annual rainfall and on irrigated land (Hodgson 1968). It is occasionally found in droughty areas, such as sand dunes (Moore 1975). It also occurs in wet areas such as stream banks, lakeshores, along ditches, marshes, or in muskeg (Moore 1975); however, several botanists have observed that high water tables or poorly aerated soils limit growth (Rogers 1928; Bakker 1960, Hodgson 1968, Moore 1975).

Canada thistle seedlings are vulnerable to shading with mortality occurring at light intensities 20% or less of full daylight, and development delayed in seedlings exposed to 60% to 70% of full sunlight (Bakker 1960). Shading and day length are apparently the most impo1xant factors determining the local distribution of Canada thistle. Canada thistle may flower under 18 hours of light per day, but produces few flowers in the range of 8 to 12 hours. (Link and Kommedahl 1958; Hodgson 1968). Moore (1975) observes that in shaded areas Canada thistle becomes tall and lax, producing few flowerheads. Bakker (1960) reports an average density of 39 shoots per m^2 with an average of 41 flower heads per shoot in open sites, and a density of 11 shoots per m^2 with an average of 18 flower heads per shoot in shaded areas. Patches of Canada thistle are characteristically found in disturbed areas such as agricultural land, roadsides, ditch spoil banks, gopher mounds, and overgrazed pastures (Moore 1975) where shade is absent.

Vegetative Reproduction. Vegetative reproduction is by rhizomes and creates the characteristic colonies or beds (Steyermark 1963). Seedlings first develop a fiberous taproot that thickens and produces lateral roots within several months. Nodes are produced at the lateral roots at 6 to 12 cm intervals and produce an aerial shoot and numerous small rootlets that act as absorption and storage sites (Moore 1975). Lateral root growth can exceed 6 m in one growing season (Rogers 1928, Hayden 1934) and vertical roots have been traced to 6.75 m depth (Rogers 1928). Thus, a single seedling can produce a large patch through vegetative propagation alone. Each clone can expand indefinitely, breaking into smaller patches.

Canada thistle also regenerates from root cuttings. Tests show that 14% of pieces as small as 3 to 6 mm thick and 8 mm in length could produce shoots, while 100% of pieces 12.5 mm long could produce shoots

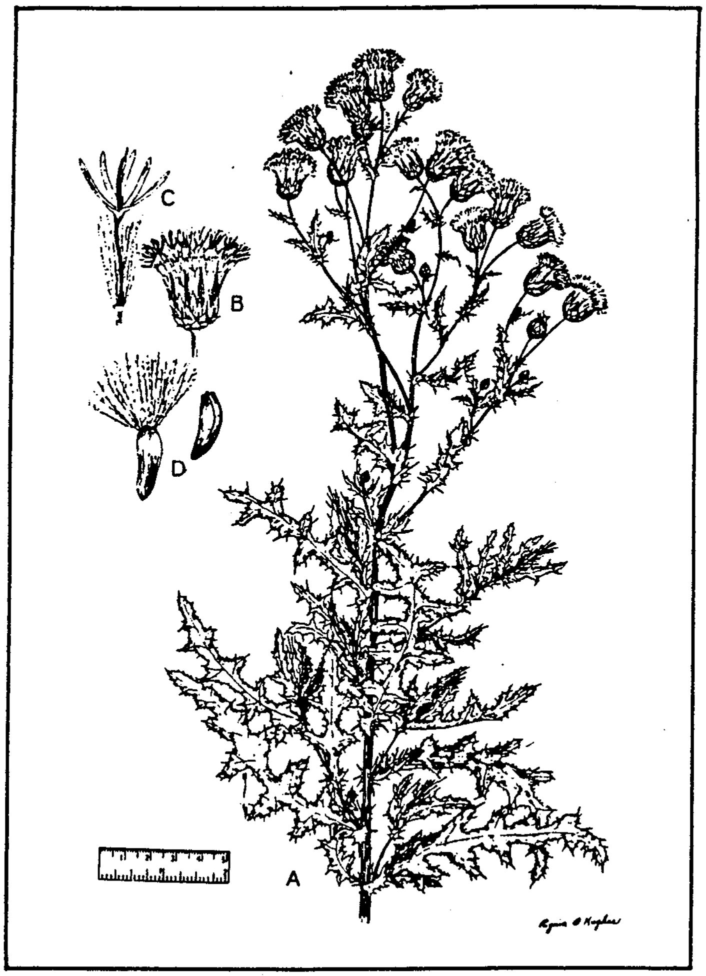

Figure 1. *Cirsium arvense*. A. Habitat; B. Head; C. Flower; D. Achnes
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(Prentiss 1889, Hayden 1934). Root segments 3 cm thick and 6 cm in length could regenerate shoots in as short an interval as 5 days (Sagar and Rawson 1964).

Seed Production and Germination. Canada thistle is dioecious. Staminate flowers are easily recognized in the field by abundant pollen, and pistillate flowers can be distinguished as the seed matures by the large pappus on the flower (Hodgson 1968). Cross-pollination success is a function of distance. Hodgson (1964) reports that a high proportion of seeds are produced when parent plants are 17 m apart. Seed production decreases as the distance between parent plants increases from 33 to 200 m (Hayden 1934) and only a small percentage of seeds are produced from plants up to 390 m apart (Amor and Harris 1974).

Pollination is mostly by honeybees (Detmers 1927) and wind pollination is limited (Derscheid and Schultz (1960).

Each carpellate head produces up to 83 seeds (Derscheid and Schultz 1960) and one plant can produce up to 5,300 seeds, with an average annual production of 1,530 seeds per plant (Hay 1937). Seed size varies among different ecotypes, ranging from 298,000 to 677,000 seeds per pound (Hodgson 1968).

Thistle germination studies report that maximum germination rates occur at a constant 30°C (Bakker 1960, Wilson 1979) or alternating temperatures of 20 to 30°C or 30 to 40°C (Wilson 1979). Germination rates are as high as 95% (Hayden 1934) and vary among different ecotypes (Hodgson 1964). Germination is inhibited at osmotic pressures greater than 5 bars, but 2% germination occurs even at 15 bars (Wilson 1979). Optimal pH for germination is 5.8 to 7.0 (Wilson 1979). Canada thistle seeds have remained viable in soil for more than 20 years (Goss 1924, Toole and Brown 1946). Canada thistle seeds retain viabililty after storage in water for four months, but viability declines greatly after this (Bruns and Rasmussen 1957).

Seed dispersal is poorly documented. The pappus, a modification of the calyx in composites, is an aid in wind dispersal of thistle seed. Bakker (1960) reports seed dispersal by wind. There is some evidence for seed dispersal by run-off in drainage ditches (Wilson 1979).

Canada thistle produces a succession of seedlings from a single crop of seeds. Some seeds germinate immediately, produce rosettes before winter, and emerge to flower the first spring. Other seeds germinate in spring and even later (Moore 1975). About 90% of all seeds germinate within one year after dispersal (Roberts and Chancellor 1979).

Heitlinger (pers. comm.) has observed that many of the Canada thistle patches on natural areas managed by The Nature Conservancy are on areas around ponds and wetlands where water levels fluctuate, areas around old haystacks that are burned off as part of prairie management, areas of soil erosion, gopher mounds, old fields and abused pastures, and areas impacted by deposition of a mixture of snow and dirt blown from agricultural fields during winter. On these types of disturbed sites, Canada thistle seedlings can grow rapidly, taking advantage of reduced competition in disturbed patches.

Canada thistle apparently cannot become established or spread in undisturbed or good to excellent condition pastures. Amor and Harris (1975) report no seedlings established from seed artificially sown in pastures, while 7% to 13% of seeds sown in bare dirt nearby emerged and 78% to 93% of these seedlings survived. Hodgson (1968) states that within spring wheat plots, Canada thistle increased in abundance by 192% in 4 years, while over the same interval it declined to 1% of its previous value in alfalfa fields mowed twice yearly for hay.

Phenology and Physiology.
Emergence time varies locally with different ecotypes (Hodgson 1968) but generally begins in early May when mean weekly temperatures reach 5° C. Rosette formation follows, with the period of most active vertical growth (about 3 cm per day) in mid-to-late June. Growth declines in July and is about zero in August. Flowering in Montana and South Dakota is from early June to August (Hodgson 1968, Van Bruggen 1976) and from mid June to September in western Canada (Moore 1975).

Minimal root carbohydrate reserves occur immediately prior to flowering. The amount of water soluble sugars in the roots declines from early spring until the onset of flowering (June), remains constant during flowering (June to August), and then increases in the early fall (September to October) (Bakker 1960). Root carbohydrates decline from emergence until the onset of flowering (late June), then increase from June to September, and remain about constant in the fall (Hodgson 1968).

Allelopathy. There is some evidence that Canada thistle produces allelopathic substances. Aqueous extracts from roots and shoots inhibit wheat (*Triticum aestivum*), flax (*Linum usitatissimum*) pigweed (*Amaranthus retroflexus*) and green foxtail (*Setaria viridis*) (Helgeson and Konzak 1950, Stachon and Zimdahl 1980). Species diversity in pastures declines as the relative frequency of Canada thistle increases (Stachon and Zimdahl 1980, Wilson 1981). Crop growth is inversely proportional to the amount of treated thistle residue in the soil and leaf leachate has an inhibitory effect on adjacent crop plants (Wilson 1981). Although the toxin has not been isolated, allelopathy may explain the absence of annual broadleaf plants from thistle patches (Stachon and Zimdahl 1980) and the absence of other species such as annual thistles (Bendall 1975). In addition, autotoxicity has been advanced as an explanation for the degeneration of patches of Canada thistle (Amor and Harris 1975).

MANAGEMENT

Thistle control problems on natural areas fall into two general categories (M. Heitlinger, pers. comm.). First, on high quality portions of a natural area, certain management practices, such as broadcast use of herbicides, are not desirable. Here, managers should consider low impact treatments such as fire, spot mowing, spot chemical or wick applicatians of herbicides and possibly biological control. A second category includes areas heavily infested with thistle, such as old pastures, ditches, or buffer lands. In these cases management practices used in agriculture may be the most cost effective treatment.

Cultivation. Cultivatian can be used to control Canada thistle, but plowed areas are susceptible to re-invasion. The most effective cultivation technique is to plow to a soil depth of 10 cm when new thistle shoots are 8 to 10 days old and to repeat this at 21 day intervals (Seely 1952) thus destroying all shoots so that no new food is stored in the root stocks (Hodgson 1968).

Mowing. Repeated mowing at 21 day intervals will weaken surviving stems and prevent seed production (Seely, 1952). Hodgson (1968) found that mowing alfalfa fields twice annually, at early-bud to preflowering stage (early-to-mid June in Montana) and early fall (September) reduces thistle to 1% of its initial value in four years. A single mowing at early-bud stage accomplishes top removal when Canada thistle root carbohydrate reserves are minimal (Hodgson 1968).

Grazing. There are no available data on the effect of different stocking rates or grazing intensities on Canada thistle. It seems likely that some grazing practices would encourage the spread of Canada thistle, both from the spread of seed and from the localized disturbances created by grazing, such as animal trails and wallows. Other thistle species (*C. lanceolatum* and *C. undulatum*) have been observed to increase with grazing (Tomanek and Albertson 1953, Ankle 1963, Hetzer and McGregor 1951). Additional information is needed to adequately determine the effect of grazing on Canada thistle.

Prescribed Fire. Olson (1975) contrasted the response of warm season dominated grassland to May and June burns. May burns produce short-term increases in Canada thistle compared to a control, but thistle abundance declines below that of the control within two growing seasons. Immediate reductions in thistle are found following June burns. In the same study, May burns in cool season grassland produced immediate reduction of thistles in comparison to a control.

Chemical Control. One problem in thistle control is that herbicide translocatian to the deep and extensive root system and numerous root buds is often insufficient to kill root buds (Mc Intyre and Hunter 1975, Baradari et al. 1980). When herbicides are applied to foliage, translocation in

Canada thistle is reduced toward shoots and roots below the area of application. The herbicide picloram tends to accumulate in shoot apices when applied through leaves or roots (Sharma and Vanden Born 1973). Burt (1974) observed that 14C-labelled atrazine moves with the transpiration system in the shoot but has only a slight effect on areas of the plant below herbicide application. Baradari et al. (1980) report similar results with 14C-labelled dicamba: about 32% of the foliar-applied herbicide is absorbed, but almost all of this remains in young growing leaves, with only 0.6% moving to the roots.

Improving herbicide translocation to root buds in Canada thistle has been a major focus for recent research. Lish and Messersmith (1979) report greater translocation of glyphosate plus 2,4-D to leaves and stems below the treated area when the herbicide is applied to stems instead of leaf surfaces.

Translocation to roots was greater when the herbicide was applied on the upper leaf surface. While translocation to the roots is not affected by herbicide concentrations on the treated leaf surface, translocation to plant parts above that surface increases with increasing herbicide concentrations and with increasing treated leaf surface area.

Plant age may have an effect on glyphosate translocation (Sprankle et al. 1975). In older plants, at bud to flowering stage, translocation was significantly less than in younger plants.

Drought stress also may affect herbicide absorption and translocation. Lauridson et al. (1980) conducted laboratory experiments on Canada thistle with 14C-labelled picloram, dicamba, and glyphosate at three moisture stress levels. Total plant absorption of glyphosate and dicamba decreases with increasing water stress, while picloram absorption remains constant. Translocation to apical meristems declines for dicamba with increasing water stress and remained constant for the other chemicals. Translocation to root buds declines for glyphosate with increasing water stress, while translocation of the other chemicals tested was not affected. Related field studies in Nebraska show that glyphosate effectiveness declines overall with increasing drought stress, while picloram and dicamba effectiveness were not as changed.

Baradari, et al. (1980) show that increased translocation of certain herbicides to the root buds of Canada thistle can be caused by growth regulators, such as morphactins, that act to inhibit auxin transport and thus stimulate lateral bud growth. Leaf absorption of dicamba is doubled (64% versus 32%) and basipetal translocation is increased more than 10 fold (9.0% versus 0.6%) with simultaneous addition of a plant growth regulator compared to application of dicamba alone.

Herbicide translocation is also stimulated by the simultaneous addition of nitrogen fertilizer. The application of 30 lbs. nitrogen and 100 lbs. phosphate per acre annually in combination with 0.75 to 2.0 lb/A of 2,4-D was more effective in controlling Canada thistle than the herbicide alone (Hodgson 1968). When Canada thistle is grown in a low nitrogen environment, a subsequent increase of nitrogen stimulates root bud growth and production of aerial shoots (McIntyre and Hunter 1975). Translocation of stored carbohydrates to the root buds at this time would make Canada thistle vulnerable to herbicides.

Numerous herbicides have been used for Canada thistle control. Some of the earliest chemicals used for thistle control were saline brines (Hodgson 1968) which are presently not used due to their expense. Other studies are summarzied in Table 1 [note the effectiveness of a rope-wick applicator to apply glyphosate (Poisson 1981)].

Biological Control. Moore (1975) and Maw (1976) review the native insect species found in Canada that might limit the spread of Canada thistle. There are at least 80 species of phytophagous insects as well as 51 species of visitors, parasites, and predators on Canada thistle. [The most important of these are the two beetles (*Cassia rubiginosa* Muell. Coleoptera: Chrysomelidae, and *Cleonus piger* Scop., Coleoptera: Curculionidae), a fly (*Orellia ruficauda* Fab., Diptera: Tephritidae) and the painted lady butterfly (*Vanessa cardui* L., Lepidoptera: Nymphalidae).] Maw reports that none of these are effective in controling Canada thistle in any area, even though *C. rubiginosa* can be numerous enough to defoliate the thistle in local areas, and *O. ruficauda* may destroy up to 70% of thistle seeds in some areas. In addition to these insects, the American goldfinch, as well as other birds, eat Canada thistle seed (Detmers 1927).

There has been an extensive search for natural control agents for Canada thistle in Europe and Asia. Peschken (1971) identified more than 80 insects that feed on Canada thistle in Europe. Attention has focused on four species. The gall fly *Urophora cardui* (Diptera: Tephritidae), the stem-mining weevil *Ceutorhynchus litura* (Coleoptera: Curculionidae), the flea beetle *Altica carduorum* (Coleoptera: Chrysomelidae) and the leaf weevil *Lema cyanella* (Coleoptera: Chrysomelidae). There is also interest in species of rusts of the genus *Puccinia*. The gall fly *Urophora cardui* is a native of Europe, ranging from Sweden to France to southern Russia. The life history has been summarized by Peschken et al. (1982). The female lays eggs in the growing tips of terminal or side shoots of Canada thistle. The larvae produce multilocular galls that have a thick nutritive layer which acts as a food source for the larvae. The mature

Table 1. Summary of Herbicide Treatments for Canada Thistle

Herbicide	Application Rate	Locality	Date of Application	Effectiveness	Reference
2,4-D	1 to 2 lb/A	n.a.	early bud stage plus early fall	"control"	Bakke (1947)
2,4-D	2 lb/A	Montana	June 12 & Oct.12 (8 leaf rosette to early bud stage)	89% in 3 mo. 35% in 1 yr.	Hodgson (1968)
2,4-D	1 to 1.5 lb/A	n.a.	newly emerged (10 to 15 cm tall)	"control"	Sylvester (1974)
Glyphosate	1 kg/ha	Montana	June 10 (15 to 20 cm tall) June 24	80% "not as good"	Brattain and Fay (1980)
Glyphosate	2 kg/ha	Idaho	emergence	"control"	Belles, et al. 1980
Glyphosate	various	na.	various. early	"control"	Schumacher, et al. 1980
Glyphosate	1-2 lb./A	South Dakota	June & Sept.	92% 1st year. Came back strongly after second year.	Messersmith 1978
Alyphosate	20%-50% conc. sol. in rope-wick applicator	n.a.	n.a.	"control"	Poisson 1981
Amitrole	4 lb/A	Montana	June 12 & July 8	100% in 3 mos. 89% in 1 yr. 82% in 2 yr.	Hodgson 1968
Picloriam (plus 2,4 D)	1 + 1 lb/A	n.a.	n.a.	97-99%	Alley & Humburg 1979
Picloriam	0.5-1.1 lb/A	Montana	early July	90-100% over 2 yrs.	Hodgson 1968
Dicamba	0.5-1.0 lb/A	Montana	early July	80-94% first year but 10% 2nd year	Hodgson 1968
Dicamba	4 lb/A	n.a.	n.a.	"control"	Alley & Humburg 1979
3,6-dichloro-picolinic acid	0.1-0.2 kg/ha (3,6-DCP)	n.a.	rosette stage (5-25 cm tall)	"control"	Benndoin, et al. 1981 Lake & Bennett 1980
3,6-DCP	0.7 kg/ha	n.a.	early bud stage	"control"	Cagnieul, et al. 1981

larvae overwinter and pupate in the early spring inside the gall. The adults emerge in spring through channels prepared by the larvae the previous fall.

The effect of *U. cardui* on Canada thistle is reduction of shoot size and vigor (Peschken and Harris, 1975). Seedhead production is also inhibited (Laing, 1978). The net effect on the plant is determined by the size of the gall, which is correlated to the number of larvae in each plant. Unfortunately, studies in western Canada have shown that *U. cardui* tends to spread out before reaching a dense population. The same study found that even an average of 13 galls per shoot did not reduce thistle abundance in the absence of other factors (Peschken et al. 1982).

Host specificity studies have shown that *U. cardui* is strongly attracted to Canada thistle, but also will utilize *Cirsium vulgare* Ten. and *Carduus* *acanthoides* L. (Peschken and Harris 1975,. *U. cardui* has been released at different sites in Canada since 1975. It has become established in Ontario, Quebec and New Brunswick, but not in western Canada. Winter mortality in the west apparently does not entirely explain the failure of these colonies (Peschken et al. 1982).

The stem-mining weevil *Ceutorhynchus litura* is also European. The female lays eggs in the main vein of leaves in the rosette stage. When the larvae hatch, they mine from the veins into the stem and root collar. At one site in Ontario, *C. litura* reduced Canada thistle to 4% of the initial density within four years (Peschken and Beecher 1973), although part of this decline is attributed to the presence of the rust *Puccinia punctiformis* (Moore 1975). *C. litura* is established in the Canadian provinces of British Columbia, Alberta, Saskatchewan, Ontario, and New Brunswick (Peschken and Wilkinson 1981) and Montana (Story 1979). A related species, *C. trimaculatus*, has been imported for control of musk thistle (*Carduus nutans*) and also preys on Canada thistle to some extent (Kok et al. 1982).

The flea beetle *Altica carduorum* is a European species. The adult consumes leaves anly of certain *Cirsium* species including Canada thistle. The females lay eggs on the undersides of leaves along the edges of veins in June. The adults feed continuously on thistle leaves throughout the summer, and then overwinter in the soil. Some adults survive to emerge next spring and lay eggs (Schaber et al. 1975). *A. carduorum* has been introduced in Canada and South Dakota, but is not yet established. In South Dakota, high temperatures, low humidity, and predators limited the beetle (Schaber et al. 1975). In Canada, colonies survive only in situations where larvae are protected from predators by cages (Peschken, et al. 1970).

The leaf-eating beetle *Lema cyanella* is widespread in Europe, Siberia, Mongolia, and Manchuria (Peschken and Johnson 1979). The life history has been summarized by Peschken and Johnson (1979). The female lays eggs on both sides of thistle leaves while in the rosette stage. The larvae hatch in 8 to 17 days and feed on both sides of the leaves. The larvae pupate in the soil in a cell constructed of soil particles cemented together. Pupation lasts 8 to 21 days, and *L. cyanella* overwinters as an adult. Host specificity studies in North America reveal a strong preference for Canada thistle, but other species that are eaten include *Silybum marianum, Carduus nutans, C. crispus, Cirsium undulatum, C. flodmanii, C. occidentale, C. quercetorum, C. brevistylum*, and *C. foliosum*. Further studies will be conducted before any releases (Peschken and Johnson 1979).

There are a number of rust species having all stages of the life cycle occur on the same host that are co-extensive with Canada thistle. Turner et al. (1981) found that different ecotypes of Canada thistle had different resistance levels to the rust *Puccinia obtegens*. Because Canada thistle patches often consist of a single ecotype, infections have been proposed as a way to reduce field populations. Turner et al. (1981) found that Canada thistle inoculated with urediospores produces only small, localized pustules. Inoculations using teliospores prevented seed production and reduced the competitive ability of adult plants (Ososki et al. 1979). Watson and Keogh (1981) inoculated Canada thistle with the rust *P. punctiformis*. Almost 100% of the plants died after inoculations with urediospores of this rust, and secondary infections were observed on all healthy plants adjacent to those which were diseased.

INTEGRATED PEST MANAGEMENT AND SUMMARY

Many researchers have stated that no single control method is effective for Canada thistle. This species is a prime candidate for an integrated pest management (IPM) program where a combination of management treatments is designed to magnify the strengths and minimize the weaknesses of each treatment.

There are three important characteristics of the biology of Canada thistle that help in designing an IPM program. First, carbohydrate reserves are minimal in the time interval from early-bud stage to immediately prior to flowering. This is the time top removal treatment (mowing, prescribed fire) would most stress Canada thistle. Second, herbicide translocation to root buds is stimulated by the simultaneous addition of nitrogen fertilizer, or the addition of plant growth regulators, such as Chlorflurenol (a morphactin). There are a number of factors to consider about herbicide application, such as drought stress, method of application, and target treatment areas on the plants. In general, there is greater translocation to the root buds during the rosette stage (approximately 5 to 25 cm tall). Third, shading can prevent seedling establishment of Canada thistle, and may inhibit the spread of established patches (Hodgson 1968). Good grassland management is a key to reducing Canada thistle. This observation may modify some control practices. For example, as discussed in the section on prescribed fire, areas dominated by cool-season grasses might be better burned in May than June. Although this is not the time of minimal root carbohydrates for Canada thistle, it will be less stressful on the co-occurring grasses than a June burn.

Integrated pest management programs for Canada thistle in agricultural areas involve a combination of plowing to 10 cm depth in the spring or fall, treatment with a post-emergence herbicide, and fall cultivation (Warner 1974). Alfalfa planted as a cover crop and mowed for hay in spring and fall is extremely effective in thistle control (Hodgson 1968).

Management methods for infestations of high quality portions of natural areas are less well known. In general, these would include fire, hand cutting, spot application of chemicals through a backpack sprayer or wick applicator and possibly biological control programs. One possibility is spot application of a herbicide (glyphosate or 3,6-DCP) applied when Canada thistle is at rosette stage, a prescribed burn to accomplish top removal when Canada thistle reaches early-bud to preflowering stage, and hand cutting in late summer to early fall to control regrowth. If herbicides are used, simultaneous application of plant growth regulators (morphactins) which have been shown to increase herbicide translocation to root buds may increase effectiveness. The needed information about interfacing biological control programs with the other methods discussed is not available.

Canada thistle is a tenacious weed that may resist any single control practice. Good grassland management inhibits the spread of Canada thistle, and a well-designed IPM program, using mowing, fire, herbicides, and biological control agents, may reduce Canada thistle infestations.

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