ELEMENT STEWARDSHIP ABSTRACT
for

Cardaria draba (L.) Desv.
Heart-podded hoary cress

Cardaria chalepensis (L.) Hand-Maz.
Lens-podded hoary cress

and

Cardaria pubescens (C.A. Meyer) Jarmolenko
Globe-podded hoary cress

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SPECIES CODE

SCIENTIFIC NAME

Cardaria draba (L.) Desv. is a member of the mustard family (Brassicaceae). It has had a number of botanical names. It was originally included in the genus *Draba* (Fernald, 1950), and more recently in the genus *Lepidium* (as *Lepidium draba* L.). Today, most sources place the species in the genus *Cardaria*. The genus name derives from the Greek word *kardia* (heart), and refers to the heart-shaped fruit of *C. draba* (Gleason, 1952). However, not all the fruit in this genus are heart-shaped.

A study by Bellue (1933) showed that the North American weed referred to as *Cardaria draba* actually consisted of three European and Asian species: *C. chalepensis* (L.) Hand.-Maz., *C. pubescens* (C.A. Mey.) Jarmolenko, and *C. draba* L.

The nomenclature for *C. chalepensis* (L.) is confusing. It is closely related to *C. draba*, and some authors reduce it to subspecific or varietal status, calling it *C. draba* subsp. *chalepensis* (L.) O.E. Schulz or *C. draba* var. *repens* (Schrenk) O.E. Schulz; furthermore, it is believed to hybridize with *C. draba* (Hickman, 1995; Mulligan & Findlay, 1974). *C. chalepensis* may also be referred to as *Lepidium chalepense* L. or *Lepidium repens* (Schrenk) Boiss. (Mulligan & Frankton, 1962). The specific epithet is frequently misspelled "*chalapensis*." *C. pubescens* is sometimes referred to as *Hymenophysa pubescens* C.A. Mey. (Robbins, *et al.*, 1952). In this Element Stewardship Abstract the three plants, *C. chalepensis* (L.) Hand.-Maz., *C. pubescens* (C.A. Mey.) Jarmolenko, and *C. draba* L. will be treated as separate species.

COMMON NAMES

Common names for mustards abound, and the same common names are often used for plants in other mustard genera. *Cardaria* species are commonly called hoary cress, white weed or white-top. Common names for *C. draba* are heart-podded hoary cress, whitetop (Fischer *et al.*, 1978), perennial peppergrass (Kummer, 1951) and Cranson dravier (Mulligan & Frankton, 1962). In England it may be referred to as whitlow pepperwort or Thanet weed (Robson, 1919), hoary pepperwort, chalk weed and devil's cabbage (Garrad, 1923). Common names for *C. chalepensis* include lens-podded hoary cress (Fischer *et al.*, 1978) and Cranson rampant (Mulligan & Frankton, 1962). Common names for *C. pubescens* include globe-podded hoary cress and Cranson velu (Mulligan & Frankton, 1962).

DESCRIPTION AND DIAGNOSTIC CHARACTERS

C. draba is a hardy perennial with stout, erect or procumbent stems that can grow 2-5dm tall. The plant is leafy below and branching above with grayish stems (Jepson, 1953). Plants are glabrous or nearly so at the top and densely hairy below (Mulligan & Findlay,

1974). In general, they have a gray-green, soft hairy appearance (hence the name 'hoary').

Seedlings are distinguished by their hypocotyl, which is dull brown-green, but green above. Seed leaves are 2.5x7-9mm, pale, dull gray-green, with a sharp, pepper taste. While young, the leaves are more or less opposite below but alternate above and obscure the stem. Leaves are rolled in bud (Kummer, 1951).

Mature *C. draba* leaves are blue-green, 1.5-7.5 (or even 10) cm long (Fernald, 1950), and are broadly ovate to obovate (Fischer *et al*., 1978). The lower leaves are long, slender, and taper to a short petiole (Robbins, 1952; Mulligan & Frankton, 1962). The margins are irregular, and may be either smooth or toothed. The leaf surface is weakly to densely hairy (Mulligan and Findlay, 1974). These leaves wither before the flowers open (Scurfield, 1962) and are shed as the seeds mature (Selleck, 1965). The upper leaves are shorter and broader (Fischer *et al*., 1978). They lack developed petioles, and clasp the stem. The leaf bases may have two sagittate lobes (Fischer *et al*., 1978; Mulligan & Frankton, 1962).

C. draba blooms in early spring and looks like conspicuous patches of snowy white (Robbins *et al*., 1952; Fischer *et al*., 1978). The showy inflorescences consist of many white flowers in a flattened corymb of racemes. The flower pedicels (stalks) diverge slightly from the stem. Each flower is 2mm wide, and has four petals with long narrow bases, like a spoon (Robbins *et al*., 1952; Mulligan & Findlay, 1974). The sepals are green and 1.5-2.5mm long. Like other mustard species, there are six stamens and one pistil.

C. draba fruit is 3-4mm long and is shaped like an inverted heart. Each of its two chambers usually contains one or two seeds. The fruit is hairless and has a distinct beak (persistent style) on the upper end. As the fruit dries it deflates and the veins become distinct (Scurfield, 1962). The seeds are oval or round at one end and narrow to a blunt point at the other. They measure 2-3mm long by 1-1.5mm wide and are dark red-brown (Fischer, 1978; Robbins *et al*., 1952).

Distinguishing *C. draba* from *C. chalepensis* and *C. pubescens*

C. draba, *C. chalepensis*, and *C. pubescens* are easily confused, especially since they can occur in mixed stands (Bellue, 1933). The description of *C. draba* given above applies equally well to *C. chalepensis* and *C. pubescens*, except for details given below.

C. chalepensis is slightly shorter (20-40cm tall, as opposed to 20-50 cm for the other species). The fruit is oval to lens-shaped (Mulligan & Findlay, 1974), has a longer style, and does not narrow at the septum (*i.e*. where the two chambers of the silicle meet). The fruit remains inflated when mature and is not conspicuously veined once dry (Robbins *et al*., 1952). Hybrids of *C. chalepensis* and *C. draba* may occur, but the progeny has not been described (Mulligan & Frankton, 1962). Each fruit usually contains four seeds, while *C. draba* usually has two seeds per fruit, (Miller & Callihan, 1991) but this

characteristic is unreliable.

C. pubescens fruit and sepals are hairy and the fruit is taller than wide or globose and remains inflated when dry. Like *C. chalepensis*, the fruit of *C. pubescens* usually contain four seeds (Miller & Callihan, 1991). The flower pedicels of *C. chalepensis* are held closely to the stem, giving the inflorescence a cylindrical appearance. (Pedicels of *C. draba* are not held as closely to the stem.) Finally, *C. chalepensis* foliage has a purplish cast when flowering and in fruit (Robbins *et al*., 1952).

Distinguishing *Cardaria* from *Lepidium*

Species of *Cardaria* are often confused with those of *Lepidium*, but they can easily be told apart by both leaves and fruit characteristics. The upper leaves of *Lepidium* species clasp the stem to form a complete ring of tissue (*i.e*. they are perfoliate), while those of *Cardaria* do not. The fruit of *Lepidium* is flattened, keeled or winged while that of *Cardaria* is rounded or inflated. Finally, the fruit of *Lepidium* is dehiscent while the fruit of *Cardaria* is indehiscent (Mulligan & Frankton, 1962; Gray, 1970).

STEWARDSHIP SUMMARY

This ESA addresses three hoary cresses: *Cardaria draba, C. chalepensis* and *C. pubescens*. They were transported from southwest Asia near the beginning of the 20th century. *C. draba* and *C. pubescens* are more common in the United States, while *C. chalepensis* is more widespread in Canada.

These three perennial species have deep, long-lived taproots that store sugars. The plants can spread rapidly. Intact or damaged roots left behind after control efforts can resprout. The hoary cresses flower early in the season and form large white patches in fields.

The various hoary cresses can be identified using hairiness and fruit-shape characters. The fruit of *C. draba* is heart-shaped, that of *C. pubescens* is globe-shaped and that of *C. chalepensis* is more oval or lens-shaped. The fruit and sepals of *C. pubescens* are hairy.

The three species grow in a variety of habitats, but thrive in disturbed or irrigated areas. They are less of a problem in undisturbed settings. The most successful control efforts combine several management practices such as herbicide application and physical removal by hoeing or tilling, followed by competitive species plantings. The most effective herbicides are 2,4-D and amitrol. Chemicals provide the most control when applied at the early bud or flowering stage. This is presumably when carbohydrates are moving from above to below ground and herbicides are more likely to be transported to the roots.

IMPACTS AND THREATS POSED BY THIS SPECIES

Although *C. draba* is found through the United States, it causes most of its trouble in the west (Robbins *et al.*, 1952). Hilgard (1890) branded it the most dreaded of the perennial

weeds. It reduces agricultural yields, particularly grain crops, alfalfa crops, and orchards (Chipping, 1992). It displaces valuable rangeland forage species and is toxic to livestock (Fischer *et al*., 1978). Managers of The Nature Conservancy consider *C. draba* to be a relatively easily controlled wildland weed that poses moderate threats to habitat and other plant species. It reduces native biodiversity and forage quality. Disturbed sites are the most threatened. Types of disturbance which promote colonization and spread include grazing (Carr, 1995), irrigation, and cultivation (O'Brien & O'Brien, 1994).

In the United States, *C. chalepensis* is less widespread than *C. pubescens* and *C. draba*, but in Canada it is the most troublesome hoary cress. *C. chalepensis* is particularly aggressive in irrigated areas (Mulligan & Findlay, 1974) although in central Asia it is also a problem on non-irrigated soils (Keller *et al*., 1934).

All three species are listed under the Seeds Act and Regulations in Canada as Prohibited Noxious Weed Seeds (Mulligan & Findlay, 1974). Commercial seed cannot be imported into the United States if it is contaminated with any of the hoary cresses (Rollins, 1967).

GLOBAL RANGE

Cardaria species are native to southwest Asia, although *C. draba*'s range extends into southeast Europe (Mulligan & Frankton, 1962).

C. draba is a widespread weed (Mulligan & Findlay, 1974). It is considered a serious weed in Afghanistan, Austria, Hungary, Italy, the former Soviet Union, and the United States; it is a principle weed in Greece, Iran, Jordan, and former Yugoslavia; it is a common weed in Canada, England, Germany, Iraq, Lebanon, Portugal, South Africa, Tunisia, and Turkey; it is present as a weed in Argentina, Belgium, Chile, Czechoslovakia, Guatemala, Israel, The Netherlands, New Zealand, former Rhodesia, and Tasmania (Holm *et al*., 1991). It is found throughout Europe as far as 65º N in Finland.

In the USA, *C. draba* is found in the west from Colorado and Wyoming to California (Fischer *et al*., 1978; Munz & Keck, 1959; Britton & Brown, 1970; Kummer, 1951), and in the east coast from Washington D.C., north towards (but not including) Nova Scotia (Fernald, 1950). Crons & Frankton (1952) report it in all the Canadian provinces except Prince Edward's Isle, Nova Scotia and Newfoundland.

C. draba probably traveled to the USA in ship's ballast or contaminated alfalfa (Mulligan & Findlay, 1974). It was first collected in North America in Yreka, California in 1876, and Ontario, Canada in 1878 (Robbins, 1940; Mulligan & Findlay, 1974). Other collections, such as in Napa, California (in 1893), a southwestern alfalfa field (in 1898), and New York City (also in 1898) firmly established its presence on the continent (Robbins, 1940; Robbins *et al*., 1952).

C. chalepensis was introduced to North America approximately 20 years after *C. draba* was, and probably arrived in alfalfa seed from Turkestan (Mulligan & Frankton, 1962).

Early collections were made in the USA in Chino, California (in 1918) and in Alberta, Canada (in 1926) (Mulligan & Findlay, 1974). Today, *C. chalepensis* is more widespread and persistent in western Canada than it is in the USA (Mulligan & Frankton, 1962).

C. pubescens probably arrived in infested alfalfa seed from Turkestan (Mulligan & Frankton, 1962), and was first collected on North America in 1919, both in Alberta, Canada and Michigan (Mulligan & Findlay, 1974; Robbins *et al*., 1952). It is more common in the northwestern USA with a few occurrences in the mid-west (Mulligan & Frankton 1962).

HABITAT

They can grow in a variety of non-shaded, disturbed conditions, including roadsides, waste places, fields, gardens, feed lots, watercourses, and along irrigation ditches (Hickman, 1995; Fernald, 1950; Selleck, 1965). Preserve managers for The Nature Conservancy find *C. draba* in a variety of upland habitats including open grasslands and fields, but also at the edge of riparian habitats (O'Brien & O'Brien, 1994), and as a minor component of aspen/willow communities (Carr, 1995).

These species are not particular about soil type, and can grow in heavy (i.e. > 50%) clay, or light, sandy, or gravelly loams (Mulligan & Findlay, 1974; Robson, 1919; Scurfield, 1962). They are salt-tolerant, but *Cardaria draba* prefers non-acidic soils (Hickman, 1995; Scurfield, 1962). They are most aggressive in irrigated conditions or during moist years (Mulligan & Findlay, 1974). Selleck (1961) found that populations of *C. chalepensis* and *C. pubescens* increased when rainfall was higher than normal and decreased when rainfall was low. At many Kansas infestations, the water table was likely to be at or near the surface for some part of the growing season (Frazier, 1943).

BIOLOGY AND ECOLOGY

Phenology

In the United States *C. draba* flowers in late May or June, and fruits from mid-July into August (Gleason & Cronquist, 1991; Fischer *et al*., 1978). In California, *C. chalepensis* completes seed maturation before *C. draba* (Bellue, 1933).

In Saskatchewan, Canada, *C. pubescens* sown in October were 5-13 cm tall with 5-7 leaves by 18 May. On July 7, some flowers were open. Fruits were fully developed by July 14 and by July 20 seeds were immature but developed (Selleck, 1965).

In Colorado greenhouse and outdoor tests, *C. draba* cotyledons appeared 5-6 weeks after planting (Simonds, 1938). Fully developed basal rosettes formed after three weeks, lateral roots developed after 2-3 weeks, and aboveground branching began after 13-14 weeks.

Flowers, Seeds and Dispersal

C. draba and *C. chalepensis* can self-pollinate and produce up to 850 fruits per flowering stem. Each fruit contains approximately two seeds (Corns & Frankton, 1952). *C. pubescens* plants produce 30-560 fruits per plant (averaging 300 fruits) (Selleck, 1965).

Seeds germinate well. Germination rates are 93% for *C. draba* and 98% for *C. chalepensis* (Bellue, 1946). Seed viability decreases with age, especially rapidly for *C. draba*--germination rates for the three years after seeds were produced were 84%, 31%, and 0%. The seedbank for *C. chalepensis* is more persistent--after three years, 52% of *C. chalepensis* seeds still germinated. The optimal germination temperature for *C. draba* is between 20-30ºC.

Seeds can be transported a number of ways. They may be moved by water in drainage ditches. They can be inadvertently spread by human activity, since the seeds can contaminate crop seeds or the soil in root crops. In this way they are dispersed along roadsides and railways (Groh, 1940). Populations located along roads and ditches should be controlled to avoid dispersal of the seeds to other locations. *C. draba* is known to seed very freely (Robson, 1919).

Shoots

Cardaria grows most rapidly in the absence of competition. In Saskatchewan, Canada, *C. draba* grew to 3.7m in diameter in its first year. In following years, *C. draba*, *C. chalepensis* and *C. pubescens* expanded approximately 0.6-0.8m per year (Selleck, 1965). Meanwhile, infestations of all three species contracted when in competition with other species (particularly other perennials) and when not irrigated.

Roots

The hoary cresses can regenerate from their thick roots. These roots can grow a few meters or more deep (Garrad, 1923; Robbins *et al*., 1952; Selleck, 1965; Frazier, 1943; Corns & Frankton, 1952). Lateral roots grow for long distances and then produce more plants (Scurfield, 1962).

These large root systems are produced quickly. A 25-day old *C. draba* plant will develop a taproot 25cm deep and 5-6 horizontal roots with numerous vegetative buds. At 100 days they have approximately 48 shots in an area within 30 cm of the plant, and an additional 80 root buds (Scurfield, 1962). Severed root segments only 1.3cm long can regenerate into new plants if they are left within approximately 7-10 cm of the soil surface (Scurfield, 1962).

Sugar production

The best time of the year to apply herbicides to *Cardaria* is late in the season, when the herbicide will be transported into the extensive root system and kill it. A Colorado study found that the roots accumulated sugars mostly during the period extending from late April-early May through late June-early July (Barr, 1942). Thus, the optimal time to

apply herbicide in Colorado was in early summer. Generally, accumulation of sugar in the roots coincides with the onset of flowering.

Cold Tolerance

C. draba is able to tolerate very cold climates. It grows in Finland, where the average temperature in July is 15-17ºC (59-63ºF) and the number of days with above freezing temperatures is 120-140 (Scurfield, 1962). *C. chalepensis* and *C. pubescens* are common agricultural pests in Canada as far north as 54º latitude (Mulligan & Findlay, 1974).

RESEARCH NEEDS

Information regarding control of any of the hoary cresses on wildlands is needed.

MANAGEMENT PROGRAM & RECOVERY POTENTIAL

Because they can regenerate from their extensive root systems, the hoary cresses readily re-establish after eradication measures. Therefore, control must be persistent, and requires at least 2-3 years of follow-up work (Blackman, *et al*. 1939; Garrad, 1923; Willis, 1950)**.**

Successful control is most likely achieved with a combination of approaches. Selleck (1965) used a combination of mowing and competitive cropping to control *C. chalepensis* and *C. pubescens*. O'Brien and O'Brien (1994)--managers for The Nature Conservancy--controlled *C. draba* by ceasing its irrigation, removing outlying plants, and increasing the general health of the grasslands they were managing. Other managers for The Nature Conservancy have decreased grazing (Carr, 1995), or developed restoration plans (Hill, 1995).

Prevent new infestations originating from seed sources. Seed may travel in contaminated hay, on farming equipment, and in fresh manure (Carr, 1995). Cardaria seeds have been eliminated from manure after one month of decomposition under very moist, warm conditions in late summer (Anonymous, 1970).

BIOLOGICAL CONTROL

No biological control agents are available for hoary cress (Miller & Callihan, 1991). Below is a list of potential bio-control agents for *C. draba*.

Insects found on *C. draba* in central Europe
Homoptera: *Brevicoryne brassicae* L., and *Myzodes persicae* Sulz. Lepidoptera*: Pieris brassicae* L., and *P. napi* L. Coleoptera: *Ceutorrhynchus turbatus* Schul. (larvae on silicles*), Phyllotreta namorum* L. (larvae on leaves) (Mulligan & Findlay, 1974), *Meligethes* spp., and *Nacerdes* sp. (Scurfield, 1962). Diptera: *Phytomyza horticola* Gour., and *Scaptomyza flaveola* Meig. (both larvae on leaves) (Mulligan & Findlay, 1974). Hymenoptera: *Halictus* spp. (Scurfield, 1962).

Fungus, parasites, and diseases found on *C. draba*
Cercospora bizzozeriana Sacc & Berl. (Mulligan & Findlay, 1974), *Albugo* sp. (Chev.) Kunth, and *Peronospora lepidii-sativi* Gaum. (Scurfield, 1962).

CULTURAL PRACTICES

The hoary cresses are most invasive in agriculture when they are irrigated. In less disturbed settings without irrigation, and in competition with other species (particularly perennial shrubs) they are relatively easily controlled. In moist conditions, alfalfa is a better competitor with *C. chalepensis* than perennial shrubs are, and in a combination of alfalfa cultivation and mowing 2-3 times per year will eradicate *C. chalepensis* within 5-6 years (Selleck, 1965). Other plants that compete well against C. chalepensis (at least in Saskatchewan, Canada) were *Rosa* spp., *Symphoricarpos occidentalis* (western snowberry), and the invasive exotic *Centaurea repens* (russian knapweed).

CUTTING

Cutting is somewhat effective in controlling *C. draba*. A combination of weed-whacking and applying 2,4-D from a backpack sprayer has provided 50% control at a preserve maintained by The Nature Conservancy (O'Brien & O'Brien, 1994). Meanwhile, a single late-April treatment of cutting plants back to the ground did nothing to control plants in England (Willis, 1950). Cutting in this way, combined with an herbicide application, was no more effective than using herbicides alone. If cutting is to be used, it clearly should be timed properly. Cutting before plants are flowering does little to control plants, while waiting for the plants to be in full flower will result in smaller plants and less seed production (McInnis *et al*., 1990). However, McInnis *et al.* 1990 recommend that cutting plants be combined with grazing as a primary or long-term solution for control of *C. draba*.

GRAZING

Sheep will eat *C. draba*, and especially like seedlings. Cattle that eat *C. draba* may have tainted milk (Scurfield, 1962)

DISKING AND HOEING

Cardaria root systems can be exhausted through repeated cultivation (Kott, 1966; Barr, 1942), resulting in complete elimination if the follow-up occurs within ten days of weed reemergence (Miller & Callihan, 1991). Hulbert *et al.* (1934) found tilling was a more economical way to remove *C. draba* than were herbicides. They recommended an initial deep plowing, followed by 10-13cm deep cultivations every five days for the first six to eight weeks of growth, and then less frequent tillings into October. Using this regimen, the plants were killed within two years. By tilling less frequently, Mulligan & Findlay (1974) killed Cardaria after three consecutive years. Even one cultivation before seed set reduced infestations.

Rosenthal and Headley (1944, as referenced by Mulligan & Findlay, 1974) successfully eradicated *C. pubescens* in one and a half seasons by hoeing every four weeks.

Cultivation is generally more successful when used with a competitive crop, as described above. On irrigated land Selleck (1965) controlled *C. chalepensis* in six years using summer fallowing combined with disking and planting mixtures of alfalfa and *Bromus* plants.

Cultivation machinery can spread *Cardaria* infestations, so all root fragments should be removed from machinery before it is used in other, uninfested fields (Pemberton & Prunster, 1940; Mulligan & Findlay, 1974; Scurfield, 1962).

MOWING

Mowing to control hoary cresses is controversial. Under non-irrigated conditions, mowing provides some control but also harms other species, especially perennials (Selleck, 1965), which are important to maintain as competitors.

CHEMICAL

Herbicide treatment for *C. draba* is effective, but in most cases a multi-year commitment is required (Blackman *et al*., 1939; Garrad, 1923; Robson, 1919; Willis, 1950). *Cardaria draba* can re-establish rapidly if control measures are stopped too soon (Willis, 1950). Even so, just a year of herbicidal treatment may help in restoration efforts where competitive plants are also being grown (Garrad, 1923).

The timing of herbicide application is important. Most recommend application of herbicides at the bud or flowering stage. In a very thorough study, Blackman *et al*. (1939) demonstrated that timing was important when using the herbicides MCPA (2 methyl-4-chloro-phenoxyacetic acid) and DCPA (2:4-dichloro-phenoxyacetic acid). Both herbicides were most effective when applied to flowering shoots but MCPA was more effective on plants still in bud (77% control) while DCPA was more effective on plants in full flower (69.4% control). Double spraying in one year did not improve control.

The three species of *Cardaria* differ in their susceptibility to herbicides, and *C. draba* is the most resistant. Jenkins & Jackman (1938) found that the application rate of carbon bisulfide to control *C. draba* was almost 2.5 and 2 times greater than that for *C. pubescens* and *C. chalepensis*, respectively. In Alberta, Canada, Sexsmith (1964) found that that the three species, *C. chalepensis, C. draba* and *C. pubescens,* differed in their responses to 2,4-D. Furthermore, he found that some strains of *C. chalepensis* were resistant (this may be because in Canada, *C. chalepensis* is frequently controlled using herbicides).

Unless otherwise mentioned, all entries for herbicide use apply to *C. draba*.

2,4-D

Apply 2,4-D LV ester or amine at 2.3-3.4kg acid equivalent/ha in non-cropland situations and 1.1kg acid equivalent/ha for selective treatment. Apply the herbicide early in the growth stage, before flowering. 2,4-D can be used in the spring, beforehand, when plowing, but respray new growth in the fall (William *et al*., 1998). Ester formulations should be sprayed only when the temperature is low, since they can evaporate at temperatures as low as 21ºC (70ºF) and harm non-target plants. Vaporization increases as the temperature rises (Hall *et al*., 1992).

A program of using a weed-whacker on flowering plants and 2,4-D applied using a backpack sprayer, several times during the growing season, resulted in approximately a 50% control rate (O'Brien & O'Brien, 1994).

In Saskatchewan, Canada, yearly 2,4-D applications at 2.2kg/ha, combined with competition from perennial grasses, eradicated *C. chalepensis* after three years (Selleck, 1965).

In England, 2,4-D provided 90% control when applied for two years at .85-1.1kg acid equivalent/ha. Contrary to most other studies, these plants were treated when only several cm tall, to flowering size. A competitive crop that is tolerant to 2,4-D should be used in the third year (Scurfield ,1962).

In Canada, 75-99+% *C. chalepensis* control is achieved with 2,4-D at 5.6-23kg/ha. *C. draba* and *C. pubescens* are controlled to between 90-99% at only 2.25kg/ha. Measurements made one year post-application (Sexsmith 1964).

Amitrol and Amitrol-T

Apply at .7kg ai/100 liters water for spot treatment before first flowers open. Wet foliage thoroughly (William *et al.,* 1998). Commercial use of amitrol is restricted as of 1985. It is not registered for use on crops or grazing lands.

In Canada, all three *Cardaria* species were controlled by 97-100% using Amitrol at 2.2kg/ha. Twice the application rate did not improve control. Measurements were made one year post-application (Sexsmith, 1964).

Ally

An application at 35gm/ha was effective (Carr, 1995).

Chlorsulfuron (Telar)

This is effective if applied at the pre-bloom to bloom growth stage, or to rosettes in the fall at 26-53gm ai/ha (William *et al*., 1998). Use this with an 80% ai surfactant. Apply only in sites not used for agriculture.

Metasulfuron (Escort)

This is effective if applied at the pre-bloom to bloom growth stage, or to rosettes in the fall at 21-42gm ai/ha (William *et al*., 1998). Use this with an 80% ai surfactant. Apply only in sites not used for agriculture.

MCPA (2-methyl, 4-chlorophenoxyactic acid)

In England, MCPA applied as a spray at 2.2 or 4.5kg/ha controlled *C. draba* by 96% in the first year (for both rates). Control for the two rates during the second year was 94% and 98%, respectively. If the follow-up control was not applied during the second year, control was only 85% for both rates (Willis, 1950).

In Victoria, Australia, applications at the early rosette stage of growth provided 42% (for 1.1kg/ha), 28% (for 2.3kg/ha), and 55% (for 5.6kg/ha). Applying at 5.6kg/ha for a second year increased control to 85%. An application rate of 2.8kg/ha may be sufficient if there is competition from other plants (Moore, 1953).

Trials at 0.09kg/100liters/ha (in England) were most effective when applied at the bud stage and for at least two consecutive years. This provided 96% control. Double spraying each year was ineffective and wasteful. A third year of treatment may be required but was not tested in this study (Blackman *et al*., 1939).

Sulfometuron Methyl (Oust)

This is effective if applied to pre- or post-emergent hoary cress at 0.16-0.27kg ai/ha or 0.21-0.35kg/ha. The best results are obtained if the application is made during early stages of growth. It can only be applied in non-crop areas, and with extreme care if near crops (Hall *et al*., 1992).

BURNING

No information available on burning as a control measure.

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