RANGE

Operational Field Guide

to the propagation and establishment of the bioagent
Mecinus janthinus
(Toadflax stem-mining weevil)

May 2000

Province of
British Columbia
Ministry
of Forests

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Information contained in this Field Guide is comprised of fact and field observations as of May 2000. Site specific experiences may vary.

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(Toadflax stem-mining weevil)

May 2000

Forest Practices Branch
Range Section
Noxious Weed Control Program
British Columbia Ministry of Forests

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1. PURPOSE

This document summarizes information for the biocontrol agent *Mecinus janthinus* while it was classified as 'primary' and the responsibility of the Forest Practices Branch. The information is a combination of hard facts and field observations. Intended as a 'field guide' for those unfamiliar with *Mecinus janthinus,* yet responsible for the continuation of the program, the summary contains pertinent information for field propagation and establishment of the bioagent as well as a historical background of its introduction into British Columbia.

2. INTRODUCTION

The goal of the Ministry of Forests weed control program is to reduce target weed populations to ecologically and economically acceptable levels and to prevent their encroachment into new areas. The biological control portion of the program includes biocontrol agent screening, propagation, release, collection and monitoring.

Implicit in the use of biocontrol methods is the acknowledgment that weed eradication is not a goal. Rather, bioagent species and host weed species exist in predator-prey relationships with the weeds held at acceptable population levels and the insect populations self-sustaining.

The biocontrol program is cooperative among the Ministry of Forests, Ministry of Agriculture and Food, Agriculture and Agri-Food Canada, Centre for Agriculture and Bioscience International Institute for Biological Control (CAB IIBC) in Switzerland, and the BC Cattlemen's Association, Regional Districts, Montana State University, the US Department of Agriculture (USDA) and the Animal and Plant Health Inspection Service (APHIS).

3. *MECINUS JANTHINUS*

Coleoptera: Curculionidae
Common name: Toadflax stem-mining weevil

BIOLOGY

GENERATIONS PER YEAR: one

ADULT STAGE: Adults are black weevils which when lit by sunlight, often show a greenish-blue metallic sheen. They are on average 5 mm long and are elongate in shape (Powell et al. 1994). Adults emerge from diapause late April to mid-May. Prior to mating, the weevils feed on stems and leaves for a short period. The beginning of oviposition is weather dependent according to Jeanneret and Schroeder (1992). In the literature, weevils in Yugoslavia mate and begin egg-laying at the end of May and

continue until about mid-July. The oviposition period varied by approximately two to three weeks depending on the adult emergence date (Jeanneret and Schroeder 1992). The weevils feed throughout this time. Females chew holes in the stems into which they lay their eggs and then cover the holes with lids. The lids, in turn, are covered by a callous which appear as tiny round blemishes on the stems. Under laboratory conditions, females laid an average 1.15 eggs per day throughout the two month oviposition period (Jeanneret and Schroeder 1992).

LARVAL STAGE: Larvae hatch within 6 to 7 days and feed on the centre of the shoot. It takes 3 to 5 weeks for the larvae to develop to the pupal stage (23 to 34 days in the laboratory). The literature states the minimum shoot diameter for successful larvae development is 0.9 mm, although oviposition does occur in smaller shoots. Larvae mine the stems as they develop. The average mine is approximately 1 to 3 cm long but can reach up to 7.5 cm (Jeanneret and Schroeder 1992). Larvae development can cause the stem to swell and crack, the upper portion of which often dies (Powell et al 1994).

PUPAL STAGE: Pupation occurs in the stem over a span of 30 to 40 days (Powell et al 1994).

F1 ADULTS: Adults emerge from their pupal cases 2 weeks later but remain within their pupal cells in the stem until the following spring (Powell et al 1994).

DISPERSAL METHOD: The adult weevil both walks and flies to reach its mate and host plants.

Photo 1: *Mecinus janthinus* (adult)

RANGE

Native (European) Distribution

The literature states that *M. janthinus* resides in a wide range of habitat types. Generally it occurs from southern and central Europe and the southern USSR. It has been recorded to exist from just below the subalpine zone in the Alps to the "maritime lowlands in western and northern France and northern Germany" to the "Mediterranean climate of the Rome area in Italy" and to the "subcontinental, summer-dry regions of eastern and southern Yugoslavica and south-western Russia" (Jeanneret and Schroeder 1992). It is also believed to exist in "other parts of southern Germany, in Austria, Hungary and the Balkans" (Jeanneret and Schroeder 1992).

Additionally, *M. janthinus* attacks toadflax growing on a wide range of soil types. The weevil has been found on toadflax growing on: sandy-loamy soils on primitive rock; on diluvial and alluvial deposits of different composition; and on shallow top-soils on limestone (Jeanneret and Schroeder 1992).

See Appendix A for detailed information on Dalmatian toadflax (*Linaria dalmatica*) and yellow (common) toadflax (*Linaria vulgaris*).

Predicted North American Distribution

Based on its native distribution, *M. janthinus* was expected to establish in all habitats where yellow and Dalmatian toadflax exist in North America between the latitudes of 40^{o} and 52^{o} (Figure 1). In Canada this would entail south-central BC, southern Alberta and Saskatchewan as well as the maritime areas in eastern Canada. In the U.S. this would entail Washington, Oregon, Montana, northern California as well as the maritime areas in eastern US (Jeanneret and Schroeder 1992).

It has also been stated by Powell et al (1994) that *M. janthinus* prefers hot, dry conditions usually found in grassland or open forest with grasslands.

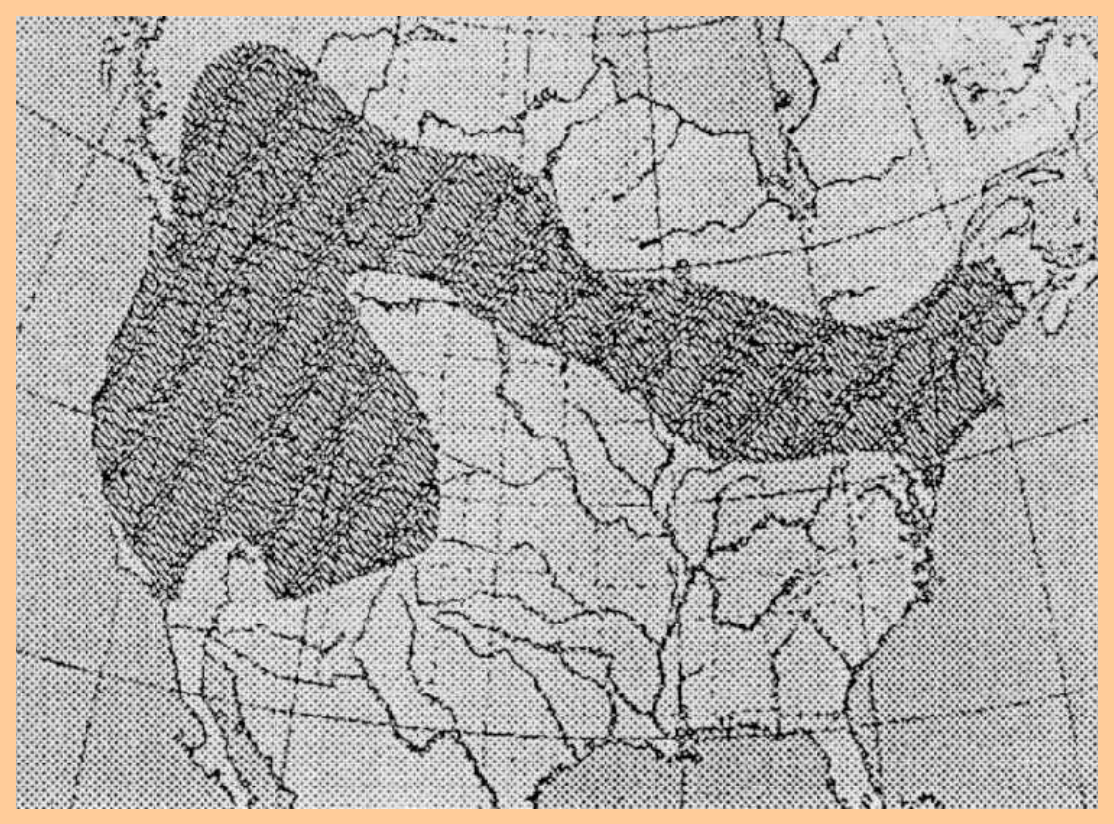

Figure 1: 1974 North American Dalmation toadflax distribution depicted by dark shaded area (Robocker 1974)

HABITAT

M. janthinus attacks both Dalmatian and yellow toadflax. To date, however, the focus of this agent's distribution has been on Dalmatian toadflax as this weed has been of greater concern than yellow toadflax for the majority of the province.

The weevil has been found to exceed its predicted distribution in B.C. A *M. janthinus* pair was found at a Terrace site (CWHws1) only one year following the release.

Terrace is located at latitude 54^{o} and 30 min or approximately 280 km further north than the predicted 52^{o} limit. Terrace, however, is influenced by the temperate climate of the Pacific Ocean.

Photo 2: Terrace site, (CWHws1) Prince Rupert Forest Region, 1997

Yet, Williams Lake is located at latitude 52^{o} and 8 min and is, therefore, at the northern edge of the predicted limit. This interior city is influenced by the cold climate of the coastal mountain range followed by the open Cariboo Plateau. The *M. janthinus* population at a Williams Lake site (R. Johnson property (IDFxm)) yields thousands of collectable weevils. Cariboo Region staff believe *M. janthinus* will survive anywhere in the region if enough weevils are released initially to allow for mortality by cold, parasites, etc.

Photo 3: Johnson site, Cariboo Forest Region, 1997 (before)

Photo 4: Johnson site, Cariboo Forest Region, 1999 (after)

A second release site in Williams Lake (Scout Island (IDFxw)) has not shown as high an increase in weevil population as the Johnson site, although weevils are present at the former site. These releases were made on the same day in the same year. The aspects of the two sites also are very similar (Scout Island faces southeast and Johnson faces south) so this is likely not the differentiating factor. However, a south aspect has proven favourable for insect establishment and increased numbers at several sites. It has been speculated that wind or large bird populations on Scout Island may have a negative affect on large population increases.

Photo 5: Scout Island site, Cariboo Forest Region, 1994

M. janthinus weevils are negatively affected by cold winter temperatures. It has been found that the weevils are not surviving winters where they are exposed to temperatures at or below –20^{o}C (DeClerck-Floate pers comm 1997). Survival of *M. janthinus* increases with snow pack. Stems within which the adults overwinter are insulated by snow and temperatures affecting the adults do not drop as low, nor do they fluctuate, as much as temperatures affecting adults in exposed stems. At some sites better survival has been observed at the base of stems, presumably where the stems are covered by snow for the majority of the winter or where cold winds would not reach as effectively.

M. janthinus weevils are also negatively affected by parasitoids, specifically ectoparasitoids which feed on the body of the larvae when it is inside its cavity in the stem. All parasitoids found to date on *M. janthinus* larvae are white in colour. A particular parasitoid found its way to North America on yellow toadflax. The

parasitoid has been attacking *Gymnetron netum*, a seed-feeding adventive insect, and has now moved on to Dalmatian toadflax and is attacking *M. janthinus*. High parasitism may occur at field sites. It may take several years for these parasitoids to increase in number and follow in a predator-prey cycle with *M. janthinus*, or they may not increase to devastating populations. This is not yet known.

Stems were sampled at the Johnson site in March 1998 for adult winter survival. Studies showed a 98% adult weevil mortality (91% mortality of weevils in all life cycle stages) and 2.7% of the weevils in all stages were found with parasitoids. The same studies in 1999 showed a 68% adult mortality (64% all life cycle stages mortality). This correlates with the temperature data. The coldest daily temperature in 1998 was –35^{o}C while in 1999 it was only –28^{o}C (DeClerck-Floate pers comm 2000). The site still has a large population of *M. janthinus* and in 1999 yielded approximately 6000 weevils to collection while a large portion of insects were left on the site for reproduction and research. To date, parasitoid populations at most sites are still low and appear to be stable at this time (DeClerck-Floate pers comm 2000). Only one site has had a large parasitoid population that may be the cause for the inhibited increase in residing *M. janthinus* numbers (DeClerck-Floate pers comm 2000).

M. janthinus has established in the Bunchgrass, Ponderosa pine, Interior Douglas-fir, Interior Cedar-Hemlock and Coastal Western Hemlock biogeoclimatic zones, primarily on sites characterized as xeric-hot to xeric-warm but also on sites ranging from xeric mild, dry hot, dry warm, dry mild, mesic warm and even on wet submaritime. *M. janthinus* is to date well adapted to B.C**.** In 1999, 18 (86%) of the 21 sites monitored in the Kamloops Region had positive establishment, two (100%) of the two sites monitored in the Cariboo Region were positive and 22 (92%) of the 24 sites monitored in the Nelson Region also were positive.

Photo 6: Moody Creek (PPdh1), Nelson Forest Region, 1994

Photo 7: Barriere (IDFxh2), Kamloops Forest Region, 1997

Photo 8: Gilpin (PPdh1), Nelson Forest Region, 1997

Photo 9: Yalokum (PPxh2), Kamloops Forest Region, 1996

Photo 10: Lac Du Bois (BGxw), Kamloops Forest Region, 1997

Photo 11: Overton (PPdh1), Nelson Forest Region, 1999

4. HISTORY OF INTRODUCTION

Screening of *M. janthinus* occurred between 1988 to 1990. It was approved for release in North America in 1991 and the first shipments to B.C. occurred that same year.

Collection of *M. janthinus* from the MOF Propagation Facility (MOFPF) for field release began in 1994 while collection from the field began in 1996 at the Beaver Creek site in the Nelson Region. In 1997 weevils were collected from the Vernon site (Kamloops Region). Of particular concern to the Vernon site was a housing subdivision whose road cuts came within 4 m of the site. In 1998 and 1999, there were a growing number of field collection sites. The Johnson property site in Williams Lake (Cariboo Region) yielded several thousand weevils. In the Kamloops Region three sites within Kamloops District (Lower Aberdeen, Dufferin and Peterson Creek (west)) and one in the Lillooet District (Yalokom) have been added to the list. Construction, however, threatens the Lower Aberdeen site as well. China Creek has been added to the collection sites in the Nelson Region. Monitoring of field releases in the province has located additional field sites for potential collection of *M. janthinus*.

Photo 12: MOFPF *Mecinus janthinus* propagation tent

The MOFPF site 3 containing *M. janthinus* was dismantled in 1999 following field site monitoring, evaluation of the weevil in B.C. and the subsequent decision to change the status from a primary to a secondary agent. In September, Dalmatian

toadflax stems from the MOFPF were cut, tied into bundles and distributed. *M. janthinus* also infested two untented plots of yellow toadflax which were treated similarly. *M. janthinus* is no longer propagated at the MOFPF.

SUMMARY OF COLLECTIONS AND RELEASES

The following tables summarize collection and redistribution data.

Collection and release summary of *Mecinus janthinus* in B.C.[a]

	1991	1992	1993	1994	1995	1996	1997	1998	1999
Reared and collected			0	6,855	710	1,000	3,430	13,814	24,994 + infested stems
Released [a]	38	159	0	6,855	754	1,200	3,630	13,814	27,294 + infested stems

[a]*M. janthinus* weevils released in 1991 and 1992 were received from IIBC in Switzerland. Weevils released in 1995, 1996 1997 and 1999 in excess of numbers reared or collected in the province were received from AAFC laboratory populations.

Propagation Facility

Insects Reared in MOF Propagation Facility Tents

	1991	1992	1993	1994	1995	1996	1997	1998	1999[a]
Insects received for propagation tents (#tents)	40 (2)						48		
Reared at MFRPF				6,855	710	0	0	789	[a]2,630 + 109 DTF bundles + 2000 loose stems + 3 bundles YTF

[a]DTF = Dalmation toadflax, YTF = Yellow toadflax

Cariboo Forest Region

Field Collections

Insects

SITE	1999[a]
R. Johnston property	6,000
TOTAL	6,000

[a]Estimated number from sweep nets.

Field releases by district

Insects (# Releases)

DISTRICT	1994	1995	1996	1997	1998	1999
Williams Lake	1,611[a] (5)					6,000 (11)
100 Mile House		100 (1)		100 (1)	800 (3)	
TOTAL	1,611 (5)	100 (1)	0	100 (1)	800 (3)	6,000 (11)

[a]Estimate - releases made with insect infested stems and adult beetles.

Kamloops Forest Region

Field collections

#Insects

SITE	1997	1998	1999
Dufferin			3,464
Lower Aberdeen		620	
Peterson Creek (west)			200
Vernon	1,300		
Yalokum		1,600	
TOTAL	1,300	2,220	3,664

Field releases by district

#Insects(#Releases)

DISTRICT	1991	1992	1993	1994[a]	1995	1996	1997	1998	1999[a]
Clearwater									
Kamloops	38 (1)	92 (1)		340 (3)	410 (4)		868 (8)	300 (2)	(35)
Lillooet		65 (1)		900[b] (2)				1,600 (7)	(4)
Merritt				900[b] (3)		200[b] (2)	200[b] (2)	1,414 (6)	(18)
Penticton				200 (1)				2,000 (10)	(15)
Salmon Arm				200 (1)					(10)
Vernon				100 (1)			332 (1)		(14)
TOTAL	38 (1)	157 (2)	0	2,640 (12)	410 (4)	200 (2)	1,400 (11)	5,314 (25)	6,294 adults + infested stems (96)

[a]Estimate - releases made with insect infested stems and adult beetles.
[b]*M. janthinus* weevils released by Agriculture and Agri-Food Canada.

Nelson Forest Region

Field collections

#Insects

SITE	1996	1997	1998	1999
Beaver Creek	1,000	2,130	10,800	12,500
China Creek				200
TOTAL	1,000	2,130	10,800	12,700

Field releases by district

#Insects(#Releases)

DISTRICT	1994	1995	1996	1997	1998	1999
Arrow	683[a] (2)		200(1)		1,500 (4)	
Boundary	900[a] (3)		300 (2)	1,530 (8)	3,200 (8)	7,300 (8)
Cranbrook	700[b] (2)	49 (1)[c]		400 (2)	900 (3)	3,300 (11)[d]
Golden						
Invermere						
Kootenay Lake		95 (1)		200 (1)	200 (1)	1,400 (3)
Revelstoke						
TOTAL	2,263 (7)	144 (2)	500 (3)	2,130 (11)	5,800 (21)	12,000 (22)

[a]Estimate - some of these releases were made using insect infested stems.
[b]600 adults were released at two sites and an additional 100 at a site within the city of Cranbrook. This latter site was later destroyed.
[c]Supplementation of previous release with weevils from AAFC laboratory.
[d]2300 weevils released from AAFC laboratory for a research study in B.C.

Other Forest Regions

Field releases by region

#Insects(#Releases)

REGION	1998	1999
Prince Rupert		
Kalum	200 (1)	
Lakes	200 (1)	
Vancouver		
Campbell River		
Chilliwack		
Duncan		
Port Alberni		
Sunshine Coast		
TOTAL	400 (2)	0

[a]Estimate - releases made with insect infested stems and adult beetles.

Other Release Destinations

Distribution numbers recorded in this table are restricted to the releases given directly to municipalities, native Bands and a contractor by branch. Total field distribution numbers within this category will be higher since MOF regions and districts maintain relations with these and other groups and share a portion of their releases with them.

Field releases by organization

#Insects (#Releases)

	1994	1995	1996	1997	1998	1999
Native Bands					400 (1)	
City of Kamloops			500 (4)			
Agriculture Canada	181 (1)				600 (1)	
Alberta Agriculture	160 (1)					
University of Alberta		100 (1)				
Montana State Univeristy, Dr. B. Nowierski					500 (1)	3,000
TOTAL	341 (2)	100 (1)	500 (4)	0	1,500 (3)	3,000 (1)

5. REDISTRIBUTION

Redistribution of agents is a critical part of the biocontrol program. To ensure distribution throughout *M. janthinus*' potential provincial range, personnel must be able to recollect from field releases and make releases into new sites.

FIELD COLLECTION

What and where to collect

Field collection of *M. janthinus* involves aspirating, tipping stems over collection containers to collect falling weevils or visually locating adult weevils in a Dalmatian toadflax infestation and hand picking them from plants. Weevils can be observed on the plants in the spring, either on any of the stems, leaf axils and tips, or on lateral and terminal buds. When mating, the weevils can generally be found on the top 25% of the plant. Weather conditions have some effect on locating the weevils. The weevils are generally easier to find when it is warmer.

The following are suggested Collection Site Criteria*:

- Sites should be between 0.25 ha (2,500m^2) and 1.0 ha (10,000m^2) in size. Small sites may produce high insects/plant proportions faster than larger sites, yet, consideration must be given to longevity of the site. The insects may feed heavily and deplete the plants before need of the collection site is complete. Conversely, insects may disperse widely over larger sites, therefore, increasing collection time to attain desired numbers.

- The average estimated Dalmatian toadflax density of typical established sites ranges from 6 to 20+ stems/metre^2.
- Hot, dry, south to west facing aspects are best.
- Soils may be coarse to fine and uniformly textured but preferably well-drained.
- Sites receiving cold air drainage may be poor choices, especially if they are relatively flat, allowing cold air to pond.
- Preferably on Crown land with easy access within 100 km of regional or district offices.
- Sites should be easily traversed for collection.
- Adequate snow cover, especially where winter temperatures fall below –15^{o}C.

*These criteria also need to be kept in mind when establishing future collection sites (current release sites) to ensure a future population of *M. janthinus* in the field. See discussion under Field Release.

How to collect

M. janthinus weevils are generally collected either by aspirating the weevils directly from the plants or hand-picking. It is possible to sweep for *M. janthinus* but this is not preferable. The stems of Dalmatian toadflax plants are relatively stiff and when hit with a sweep net can either snap off or catapult the small weevils away from the sweep net opening. This latter was determined to be the case when large numbers of weevils were seen on stems prior to sweeping but low numbers of weevils ended up in the sweep nets.

Depending on experience the collection task can be accomplished several ways. Aspirating weevils directly from the plants works well as seeds, plant parts and other insects can be left at the site and the weevils are not jeopardized by storing them with spiders and other predators. Tipping stems over collection containers and tapping the stems to catch falling weevils works best at sites where large numbers of weevils exist per plant. These, in turn, may be emptied onto a flat, solid surface for counting and to eliminate seeds and other insects. Tipping the plant over your hand; or plucking the weevil off the plant from below to avoid the weevil dropping to the ground is also used although these methods are more time consuming. Avoid pulling a clinging weevil off a plant. They need to be gently persuaded to avoid injury. Plants need to be approached slowly when using these methods. If the weevils notice movement or the plant is shaken, they drop to the ground and lie motionless in the soil where they are difficult to see due to their small size. Contrary to collection of other biological control agents such as *Agapeta zoegana* or *Larinus minutus*, *M. janthinus* do not become extremely active when it is hot so it is not of much concern that the weevils will fly back out to the container when the lids are opened – instead they crawl quickly to the top. What ever the method used, beginner collectors may find it easier to crouch down at the plant level as it takes experience to develop ‘an eye’ for the weevils on the plants.

The weevils are placed into containers with a mesh opening in the lid. Mesh screen on the storage lids is critical to allow ventilation and to prevent a build up of

condensation that can drown the insects. Depending on care taken and experience the collection container may be free of any contaminants, but, it is good practice to check it and clean it if necessary before placing the weevils in the cooler or refrigerator. Dalmatian toadflax is placed in the containers to provide feed and a place for the weevils to cling (it also helps avoid weevils crawling over each other, fighting and injuring one another). Do not use plant material that is too lush as it produces a lot of condensation inside the containers that may drown the insects. Do not include seed heads in the container so as to avoid seed spread. Containers are kept cool and out of direct sunlight in a portable cooler with ice packs wrapped first in plastic bags and then in paper towels to absorb any condensation. Avoid contact between the containers and the wrapped ice packs as condensation still may occur.

In the lab, the numbers of weevils are confirmed. *M. janthinus* are not sexed for field purposes. If the weevils are to be kept for any length of time before releasing, they should be stored in quantities of 100 or less/container. Every two days the weevils must be transferred to clean containers and fresh Dalmatian toadflax added. When shipped, quantities of 200/container are used due to their small size.

M. janthinus may also be collected by harvesting infested stems in April, prior to adult emergence or fall, once the weevils have become fully formed adults within the stems. Prior to this time the larvae and pupae are too fragile for movement. Do not pull up plants when collecting if the intent is to maintain the infestation as a collection site. Cut the stems close to the ground and tie them in small bundles to be delivered to a release site. This method is more time consuming and there is a high potential to spread seeds from site to site. It is best to break off the thin stems containing seedheads prior to removal of stems from a site.

In order to obtain an estimate of the infestation and survival rates of the weevils, open the stems of several plants and calculate an average number of weevils per plant, percentage of stems infested or number of weevils per stem. In order to determine whether the weevils found inside stems are alive, they must be left long enough to revive. This can happen within a few minutes if the temperature is high enough. The weevils may have to be placed in a warmer environment (inside a vehicle or building) in order to revive if outside temperatures or the temperature of a hand are not sufficient.

When to collect

Time of Year

The collection period is between mid to late May until mid-June with peak collection generally occurring in the fourth week of May and the first week of June. *M. janthinus* can be found toward the end of June, however, it is felt that collection needs to be terminated earlier than this (in mid-June) to allow for establishment on release sites. Eggs require time to hatch and pupae must develop in order for the adults to safely survive the winter contained within the stems. The dependence of emergence

and hence collection on the accumulation of enough heat units has not been observed or investigated.

In 1999, peak collection in the Nelson Region occurred on June 6 at Beaver Creek (490 m in ICHxw). Peak collection at site 3 at the MOAPF in Kamloops (345 m in BGxh2) occurred on May 26 while peak was achieved on June 3 at Dufferin (600 m in BGxw), also in Kamloops. The MOFPF is located on the valley floor and is hotter than the Dufferin site which is 255 m higher and in a different biogeoclimatic subzone.

It is unknown whether male *M. janthinus* emerge before the females from the stems in the spring to create an uneven sex ratio of newly emerged weevils. It is possible to identify male and female *M. janthinus* weevils but it has not been investigated as the size of the insect does not make this a practical field exercise. This fact, combined with the time period needed for the females' ovaries to mature, leads to the practice of leaving the first observed weevils in the field until the population increases and then collection occurs without determining the sex of the weevils.

Time of Day

Warm days have been found to be better for collecting than cooler days. Air temperature is a greater factor than cloud cover. Collecting takes place generally from 11:00 to 5:00 in the Nelson Region and 10:00 to 5:00 in the Kamloops Region. The temperature range during collection in the Nelson Region was from 22^{o}C to 31^{o}C. The early collection time in the Kamloops Region takes place on hot days with clear skies to avoid working in extreme heat. Some collectors have found that, within reason, it is best to work in the heat of the day. When the temperatures are high, the agents are more active and more apt to fly away, yet, there are also more in view, therefore, it is potentially faster to obtain large numbers and more weevils are available for collection. In very high temperatures, however, it has been observed that the weevils are more difficult to see, perhaps residing on the undersides of leaves or tucked in the whorls to avoid direct sunlight. Others have noticed (Agriculture and Agri-Food Canada technician Eva Pavlik) that the weevils do not leave the plant and so should be found in any weather conditions, save rain, when a person's eyes become trained for finding the agents. *M. janthinus* adult weevils can be found on terminal and lateral buds as well as on stems and leaf axils. During screening, a one day field study showed the weevils had a very active vertical migration (Jeanneret and Schroeder 1992). It has been observed that the sun draws the weevils to the tops of plants and leaf tips but cloud cover with warm temperatures may also have the same affect.

Caution should be taken when collecting the weevils following a rain shower. The weevils, although seen to be fairly hardy when caught in a rain drop, can either drown in small amounts of water or their elytra (wing covers) can be damaged when they get stuck to the wall of the containers. It is possible to tip the leaf whorls over paper

towel so the water will be absorbed leaving the weevils behind to be placed in containers, but, this is time consuming and must be factored into field priorities.

Additional considerations

The CAB IIBC September 30, 1994 Quarterly Report on Weeds notes that continual yearly collection of weevils from a site will cause a significant decline in their numbers. Unless collection activity is stopped early enough to allow sufficient ovipositing of remaining females, refraining from collecting for a year or more may be necessary to allow the population to recover. Depending on operational goals, size of weed infestation, and timing, it may be worthwhile to rotate collection sites from year to year to sustain their insect populations.

SHIPPING

Collected insects are shipped to new release sites in 1 litre bulk food containers. To ensure population establishment releases of a minimum of one container (200 insects) are recommended, particularly when confidence is high that the weevils will survive at the chosen site. When uncertain, larger release numbers should be used to allow for some mortality and acclimation, but only when *M. janthinus* has been released at more secure sites to satisfy program goals.

The containers must be well ventilated and contain sufficient Dalmatian toadflax to feed the weevils during transport. Containers are packaged into carefully sealed boxes to avoid insect escape during shipment. Cold packs are wrapped first in plastic bags to contain the majority of condensation and then in newspaper or paper toweling to prevent further condensation from building up inside the containers and damaging or drowning the insects. These are used to keep the weevils cool and reduce their activity if they are traveling any distance. Avoid contact between the containers and the wrapped ice packs by using packaging material as condensation still may occur. The agents are shipped quickly via courier or bus to release locations.

FIELD RELEASE

Potential release sites

A potential release site needs to meet certain criteria to ensure success and longevity. It must meet Ministry needs from a program and logistic standpoint i.e. travel distance, land tenure, accessibility. It must also be conducive to agent survival and establishment.

Below are suggested release site criteria and considerations. They are based on observations of past sites which have been successful.

Criteria

- Release sites should contain plants with stem diameters larger than 0.9 mm for complete larval development.

- In areas with cold winter climates, release sites should be able to accumulate a snow pack to insulate adult weevils residing in the stems from very low temperatures.
- Southerly or westerly aspects are preferred.
- Release sites should be large enough and contain enough toadflax to support a viable insect population with potential for natural dispersal (minimum 0.10 ha or 1,000m^2).
- Soils may be coarse to fine and uniformly textured, but preferably well-drained. Soils with higher water-holding capacities may allow for secondary growth to compensate the plant for loss of biomass due to insect feeding.
- Sites should not be shaded.
- Topographies of successful sites have varied. All have been able to accumulate heat units. A hot to warm climate is needed.

Considerations

- Releases at any elevation should be attempted. The highest recorded elevation where establishment has been successful is 944 m.
- Sites receiving cold air drainage may be poor choices, especially if they are relatively flat, allowing cold air to pond.

The following are suggested steps to take when making a site selection:

1. Plan release site locations prior to requesting agents. Release sites should be pre-selected the fall or spring prior to release of agents. This avoids 'drop and dash' releases and promotes overall weed management planning.
2. Determine tenure and stability of land management. Preferably a site will be located on Crown Land with MOF mandated as the steward and have a cooperative tenure holder. Other suitable locations may be land under the jurisdiction of other agencies with the goals of controlling weeds and establishing/maintaining working relationships. Release sites might be located in or close to relevant municipalities with the goal of future cost effective collection sites. An example of a release site is a municipal water reservoir which is long term and where most activity, particularly herbicide spraying, is prohibited.
3. Make sure the site will not be disturbed after release. Crown control of the site is preferred with future management known. Discuss future development plans for the site wherever it is located.
4. Check previous release records and maps to ensure no prior release of the agent has been made at a potential site. An unofficial rule states that a distance of 1 km constitutes a separate release.
5. Monitor plants at potential site to ensure the agent is not already present through natural dispersal.
6. Check the immediate vicinity of the proposed release site for ant hills and wasp nests to minimize predation.
7. Mark selected release sites with a stake so that it may be relocated to monitor insect progress and weed population decline.

Insect release

Before any weevils can be released there is preparatory work that needs to be completed at the site. Make sure that all paperwork, photo's, site maps, measurements, etc. are completed before opening any lids, otherwise people will be treading on insects.

In the past, each release consisted of approximately 100 adults transported in a bulk food container, yet 200 adults in one or two containers is recommended.

Agents are released primarily by Ministry of Forest regional and district personnel and occasionally staff from the Ministry of Agriculture, and Food. Other people who may receive insects include Native Bands on reserve and private lands, private citizens, Ministry of Transportation and Highways and University staff.

The following are suggested steps to take when making an insect release:

1. Mark the release site with a semi-permanent stake to assist relocation efforts for follow-up agent establishment and weed impact monitoring.
2. Fill out the 'Biological Control Release Record' (see Appendix C) that is shipped with the weevils **accurately** and **completely**. Information on the form is fundamental to further analysis of the program. One completed copy of the Release Record is kept in the District office and one is returned to the MOF Regional office. The forms are then collated to create a provincial database.
3. Create accurate site maps complete with permanent tie points. This is essential for future monitoring of the release site.
4. Take photographs. They have proven to be a useful tool to both relocate the release site and to provide an ocular comparison of the site over time. A suggested method and form (EM-9) is outlined in the Habitat Monitoring Manual.
5. Gently release the weevils (once the paper work is completed) at one location by the stake. They will disperse themselves from this initial release point. It is more difficult for insects to propagate if they are spread over a large area.

Additional considerations

Initial releases for the season should be made in similar latitudes, further south or at lower elevations than collection sites to ensure temperatures are conducive to agent establishment. As northern or higher elevation release sites warm, they can receive insects. Once temperatures at these sites begin to drop, releases should be directed south or at lower elevations again to provide for the longest possible establishment season.

If more than one collection site is available, it is preferable to redistribute weevils into habitats similar to those they are acclimatized to.

If agent establishment at a release site is uncertain or the Dalmatian toadflax infestation is particularly large, re-release of agents may need to be considered.

Before re-releasing at a site the region/district plan needs to be reviewed, i.e. can agents be spared for re-release at a site that may or may not be conducive to the agents' survival when they could be placed at a new site?

6. MONITORING

Monitoring of field sites can be carried out to determine:
1. whether the agent has established at the release site;
2. the density of agents per plant or area;
3. how far the agent has spread from the release point;
4. the agent's preferred habitat and current range;
5. areas that are unsuitable to the agent;
6. any effects the agent has had on the weed population;
7. potential collection sites;
8. if collecting from the site has had any effects on plant or agent populations; and/or
9. agent life cycle information i.e. emergence dates, effects of weather.

Depending on the type of information being sought the monitoring technique will vary. Reconnaissance methods can be used to assess parameters such as site suitability, presence or absence of agents, dates of emergence etc. A suggested monitoring form ('Release Site Monitoring Form') detailing information to collect at each site can be found in the Appendix C. This form is intended for: assessing some site characteristics that may lead to a better understanding of bioagent preferences; assessing changes in the weed infestation; and comparing sites with known insect establishment for purposes of designating collection sites. Many details listed on this form can be found on the original release form. Some will not change over time and need not be duplicated if the information is already recorded, while other details, particularly the plant's dispersal description, may change.

A more rigorous method is needed for quantifiable information on insect and plant populations. It is suggested that this type of monitoring be planned at selected sites as dictated by the constraints of program planning, time and budget.

A suggested transect method is as follows:

1. Find the release stake or from the description on the release form, the closest position to the release stake. Mark a starting point.
2. Determine four directions from the starting point for running the transects. If cardinal directions cannot be used, determine 4 non-cardinal right angles. Pace out 25 m in each direction.
3. Or pace out three parallel transects at least 2 metres apart: two 33 m long and one 34 m long if the site does not allow for the previous transect design.
4. Or pace out two 50 m parallel lines lying side by side or staggered (as can be accommodated by the site). The intent is to monitor a uniform number of plants randomly, if the site does not allow for either of the above transect designs.

5. At each meter, select the plant closest to the toe and count the number of weevils visible on the plant. This same method can be used when cutting open stems longitudinally in the fall or very early spring prior to adult emergence. Stems cut in the spring would be those from the previous year's growing season.

A form for this method (Biocontrol Agent Monitoring Form) is found in Appendix C. The average number of agents may be calculated per metre and recorded.

An additional transect method is as follows:

1. Find the release stake or from the description on the release form, the closest position to the release stake. Mark a starting point.
2. With a timing device and a hand counter (if necessary) move in concentric circles away from the starting point counting the number of weevils found for a pre-determined time. Twenty minutes with one person or ten minutes with two people is recommended.

It is important to keep in mind that whichever monitoring method is used, it should be used for all sites of a particular insect to be consistent in order to have comparable results.

AGENTS

Sites can be monitored for the presence of adults from mid-May to generally mid-June but some sites may be monitored until the beginning of July. Weevils can be observed on the plants in the spring, either on any of the stems, leaf axils and tips, or on lateral and terminal buds. When mating, the weevils can generally be found on the top 25% of the plant. One speculation involved the possibility of an aggregation pheromone since the weevils were observed to occur in clumps within the infestation.

Contradicting observations have occurred regarding the condition of plants the weevils are concentrated on. One observation involves congregation of weevils on smaller plants. It was speculated that the stalks are more tender for chewing oviposition holes. Possibly the feeding of the weevils has suppressed the growth of these particular plants. Other observations have found the weevils on everything when the population is really high, however, later on in the season they are found primarily on the larger, robust plants.

Photo 13: *Mecinus janthinus* on plants

M. janthinus weevils remain concentrated near the release point for several years. Eventually they begin to disperse, perhaps due to feeding pressure.

Sites also can be monitored from September to April by cutting stems open longitudinally to expose adults in diapause.

Photo 14: *Mecinus janthinus* adults inside stems

PLANTS

A method needs to be developed for measuring responses of the host weed population. Useful parameters to monitor would be: height, density, biomass production, seed production, cover, and frequency.

Observations have shown that the majority of feeding takes place in the top 25% of the plants. Between feeding by *M. janthinus* adults and subsequent mining of the larvae in the stems, the plants are noticeably weaker, generally shorter, often wilt and droop and frequently do not flower. The terminal point even dies back from the top. When insects numbers are high, pressure on existing plants can cause complete stem die-back.

Photo 15: Dalmatian toadflax terminal droop caused by *Mecinus janthinus* feeding

Photo 16: Dalmatian toadflax terminal die-back caused by *Mecinus janthinus* feeding

It is important to distinguish between feeding by *M. janthinus*, by *Calophasia lunula*, an introduced defoliating moth which feeds on both Dalmatian and yellow toadflax and by the Checkerspot butterfly (*Euphydryas anicia* in the Family Nymphalidae), a native insect which feeds on toadflax. Check for the existence of these insects in past records and while viewing the site.

Photo 17: *Calophasia lunula* larva

Photo 18: Checkerspot butterfly (native)

Photo 19: Checkerspot butterfly pupae and webbing

Photos from Morrissey Creek, a 1994 *M. janthinus* release in the Nelson Region, show a significant decrease in the Dalmatian toadflax infestation.

Photo 20: Morrissey Creek, Nelson Region, 1996 (before)

Photo 21: Morrissey Creek, Nelson Region, 1997 (before)

Photo 22: Morrissey Creek, Nelson Region, 1998 (after)

Photo 23: Morrissey Creek, Nelson Region, 1998 (after)

RESULTS

To date, monitoring has found that *M. janthinus* can establish in the Bunchgrass, Ponderosa pine, Interior Douglas-fir, Interior Cedar-Hemlock and Coastal Western Hemlock biogeoclimatic zones, primarily on sites characterized as xeric-hot to xeric-warm but also on sites ranging from xeric mild, dry hot, dry warm to dry mild and even on wet submaritime. Specific site parameters are more difficult to summarize and analyze. However some generalities have been noted previously in the suggested criteria for site collection and release.

With the differences in latitude, future monitoring information may be best analyzed on a Region or District level. Dispersal information is best presented in map form.

APPENDICES

Appendix A - HOST WEEDS

Dalmatian toadflax (*Linaria dalmatica*)

- A short-lived perennial herb, introduced as an ornamental in the USA in 1894. Originates from the Mediterranean region from Yugoslavia to Iran and was cultivated as an ornamental in Europe in the 1500's (Robocker 1974). Spreads by seed and creeping root stock. The root system consists of a large, rough-surfaced tap root which may be up to or longer than 180 cm and possibly branched, and the long, (up to 3 m or longer) branching lateral roots whose buds produce new vegetative growth. Mature plants are 60 to 120 cm tall. The stems, several per plant, are smooth and light-green. Leaves are also light green and are heart-shaped, dense, alternate and individually clasp the stem. The flowers are 'snapdragon' shaped: double-lipped, bright yellow and tinged with orange on the inner lip. The flowers have long spurs projecting from their bases and the entire structure can reach 4 cm in length. Up to 500,000 seeds have been recorded from a single plant under good growing conditions. Seeds, sharply angular and 1-2 mm long, remain viable up to 10 years and are dispersed mainly by wind and browsing animals. The plant, like all *Linaria* spp., is toxic to livestock, however, cattle tend to avoid grazing in toadflax infested stands.

Habitat

- Widespread throughout BC including the Skeena, Nechako, Cariboo, Thompson, Okanagan, Similkameen, Fraser Canyon, East Kootenay and Boundary areas. It has also been observed on Galeano Island, one of the Gulf Islands.

Growing conditions

- Stress tolerant plant able to grow in conditions of low temperatures, coarse textured soils and summer drought. Soil types range from sand to gravelly loam and silt loam. Possibly extremely competitive with annual vegetation, other

perennial herbs and even its own species. Living Dalmatian toadflax roots have a possible allelopathic effect (Robocker 1974). Found to out-compete other vegetation mainly by its ability to attain soil water from limited supplies. Toadflax seedlings do not compete effectively for soil moisture with fast maturing winter annuals and established perennials (Robocker 1974). Dalmatian toadflax, therefore, seldom becomes established in healthy, closed plant communities but is located in disturbed soils, cultivated fields, waste areas, gardens, open grassland and transitional forest-grassland. Mainly occurs in the biogeoclimatic zones of Bunchgrass, Ponderosa pine and Interior Douglas-fir.

Photo 24: Dalmatian toadflax (*Linaria dalmatica*)

Yellow toadflax (*Linaria vulgaris*)

The plant

- A short-lived perennial herb, introduced into New England before 1672. Originates from south-western Asia, western Europe and the steppes of south-eastern Europe. Spreads by seed and creeping root stock. The root system consists of a tap root, which may extend more than 1 m, and lateral roots. Mature plants are 20 to 30 cm and sometimes up to 80 cm tall. The stems, several per plant, are generally unbranched, hairless and green. Leaves are also hairless and green and are numerous, narrow, pointed, alternate and attach one per node to the stem. They range in size from 25 to 75 mm long but are 40 mm on average. The flowers are 'snapdragon' shaped: double-lipped, bright yellow with an orange (rarely whitish) center. The flowers have long spurs projecting from their bases and the entire structure can reach 25 mm in length. Seeds are black or dark brown, winged and 2 mm in diameter. Seed production and viability are variable. They are dispersed mainly by wind, water, birds, rodents and other wildlife. However, it has been observed that during a growing season over 80% of the mature seeds fell within a 0.5 radius of the parent plant. Yellow toadflax, like all *Linaria* spp., is toxic to livestock, however, cattle tend to avoid grazing in toadflax infested stands.

Habitat

- Found in the Thompson, Okanagan, Similkameen, Boundary, East Kootenay, Cariboo, Peace River, Skeena and Bulkley areas. The North American latitude range extends as far north as 55 to 65^{o} and elevation range extends from sea level up to 2800 m.

Growing conditions

- Able to quickly colonize open sites, it is found in cultivated fields, waste areas, gardens, open grassland and transitional forest-grassland. The vegetative reproduction allows yellow toadflax to take advantage of less hospitable sites such as subarctic areas or pastures or orchards where regular herbicide application or fire occur. Preferred soils include coarse, fertile and relatively summer moist grassland soils and it is limited by wet or dark conditions. Mainly occurs in the biogeoclimatic zones of Bunchgrass, Ponderosa pine and Interior Douglas-fir.

Photo 25: Yellow toadflax (Linaria vulgaris)

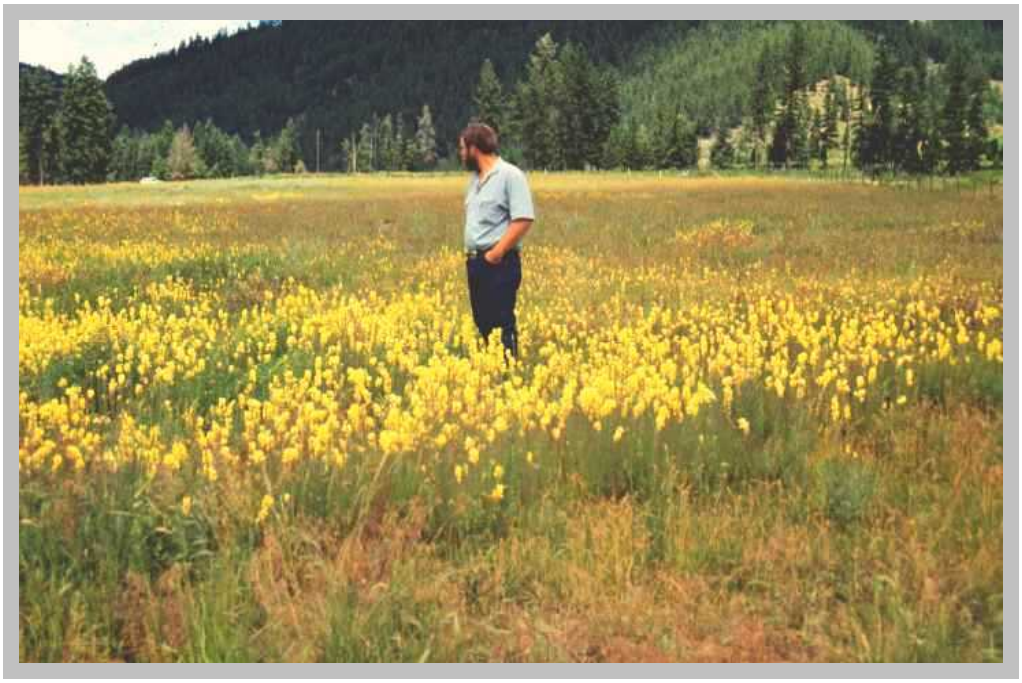

Photo 26: Yellow toadflax (Linaria vulgaris) infestation

Appendix B - LITERATURE CITED

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Appendix C – RELEASE AND MONITORING FORMS

BIOLOGICAL CONTROL RELEASE RECORD

SITE NUMBER: D __ __ /___ ___ ___ ___ /___ ___ /___ ___ ___

BIOAGENT: _____/_____ **WEED SPECIES: ___ ___ ___ ___ / ___ ___ ___**

SOURCE: _____ **STAGE:** ADULT PUPA LARVA EGG OTHER

COLLECTION: __ __ / __ __ / __ __ **RELEASE: __ __ / __ __ / __ __** **TIME: __ __ : __ __**

YY/MM/DD YY/MM/DD

#RELEASED _____ **JURISDICTION _____** **RELEASED BY: _____**

DISTRICT: _____ **RANGE UNIT NAME: _____**

PRIVATE LAND **Owner: _____** **Phone: ( ) ___ ___ ___ - ___ ___ ___ ___**

ADDRESS: _____

LOCATION:_____

_____

BCGS MAP: __ __ __ __ __ __ __ **UTM :** |__|__| |__|__|__|__|__|__| |__|__|__|__|__|__|__| _____

ZONE EASTING NORTHING DATUM

WEED DENSITY: <1 plant/m^2 2-5 plants/m^2 6-10 plant/m^2 >10 plant/m^2

SIZE OF INFESTATION: < 100 m^2 101-400 m^2 401-2500 m^2

2501-5000 m^2 5001-10000 m^2 >1 ha.

WEED DISTRIBUTION: Continuous Stand: Scattered Patches: Distribution Code (1-9):_____

SLOPE %: _____ **ASPECT ^{0} : _____** **ELEVATION m : _____** **BIOGEO UNIT: _ _ __ _/_ _ _**

MONITORING for ESTABLISHMENT

Date Monitored

Y M D

Yes No Photo

__ __ / __ __ / __ __

Yes No Photo

__ __ / __ __ / __ __

Comments

_____

_____

_____

_____

_____

_____

RELEASE SITE MONITORING

DATE: **AGENT:**

SITE NUMBER: **SITE NAME:**

MAP NO.:

WEED DENSITY:

<1 plant/m^2	____	2-5 plants/m^2	____
6-10 plants/m^2	____	>10 plants/m^2	____

SIZE OF INFESTATION:

<100m^2	____	100-400m^2	____
400-2500m^2	____	2500-5000m^2	____
5000-10000m^2	____	>1 ha	____

WEED DISTRIBUTION:

Continuous Stand____ Scattered Patches ____

ACCESS TO SITE:

Easy ____ Difficult ____

Describe if necessary.

SITE TOPOGRAPHY:

Flat	____	Bowl Shaped	____
Forest Openings	____	Close to River/Lake	____
Terraced	____	Hillside	____
Other (describe)	____		

TRAVERSABILITY OF SITE:

Easy ____ Difficult ____

Describe if necessary.

SOIL DESCRIPTION:

Moss covered	____	Gravel	____
Clay	____	Silt	____
Compact	____	Loose	____
Sandy	____	Other (describe):	____

SLOPE (%): ____ ASPECT (^{o}): ____ ELEVATION (m): ____

BIOGEOCLIMATIC CLASSIFICATION: _____

DISTANCE FROM KAMLOOPS (km): ____

LAND OWNER:

RECOMMENDATION:

COMMENTS:

BIOCONTROL AGENT MONITORING FORM

SITE NUMBER: _____ DATE: (YR/M/D) _____
AGENT: _____ LOCATION: _____
RELEASE DATE: _____ TARGET PLANT: _____

METERS	NORTH	SOUTH	EAST	WEST
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
MAX DIST.				

PERCENT ATTACK: _____

COMMENTS: _____