BEST MANAGEMENT PRACTICES FOR

Yellow Archangel

in the Metro Vancouver Region

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SERVICES AND SOLUTIONS FOR A LIVABLE REGION

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INVASIVE SPECIES COUNCIL OF METRO VANCOUVER

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In partnership with: The Invasive Species Council of British Columbia
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Requested by: Metro Vancouver's Regional Planning Advisory Committee – Invasive Species Subcommittee

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August 2021

Contents

CREDIT: ISCMV

Introduction

The impacts of invasive species on ecological, human, and economic health are of concern in the Metro Vancouver region. Successful control of invasive species requires concerted and targeted efforts by many players. This document – "**Best Management Practices for Yellow Archangel in the Metro Vancouver Region**" – is one of a series of species-specific guides developed for use by practitioners (e.g., local government staff, crews, project managers, contractors, consultants, developers, stewardship groups, and others who have a role in invasive species management) in the region. Together, these best practices provide a compendium of guidance that has been tested locally by many researchers and operational experts.

Yellow archangel[1] was introduced to North America from the temperate regions of Eurasia as an ornamental ground cover, prized for its unique silver variegated foliage and fast-growing nature. It has now escaped into natural habitats throughout Metro Vancouver and the Pacific Northwest, largely due to illegal green waste dumping, particularly from hanging baskets.

There are several cultivars and subspecies of *Lamiastrum*. The dominant invasive cultivar varies depending on location. In the Metro Vancouver region, the invader cultivar is 'Variegatum' within the subspecies *montanum* (Graham & Clements, 2003). In the Seattle area the cultivar is 'Florentinum' within the subspecies *argentatum* (Jacobson, 2003). The difference is likely due to what was historically available at nurseries in each region.

Academic institutions, government, and non-government organizations continue to study this species in British Columbia. As researchers and practitioners learn more about the biology and control of yellow archangel, it is anticipated that the recommended best management practices will change overtime and this document will be updated. Please check metrovancouver.org regularly to obtain the most recent version of these best management practices.

1 Yellow archangel (*Lamiastrum galeobdolon*) is also known by the common names lamium, false lamium, yellow lamium, silver beacon, and yellow deadnettle (Lilley & Page, 2010). Taxonomic updates place it in the genus *Lamiastrum* rather than *Lamium*.

REGULATORY STATUS

Although yellow archangel is an invasive plant of concern in the Metro Vancouver region, it is not currently regulated anywhere in British Columbia.

IMPACTS

Yellow archangel can grow up to one metre horizontally per year (Graham & Clements, 2003). This rapid growth makes it a favoured garden ground cover species and allows it to rapidly form dense populations in natural areas, climbing over stumps and smothering native herbs, mosses and low growing shrubs (Lilley & Page, 2010). It quickly out competes native vegetation, forming contiguous cover across the forest understory. The resulting reduction in plant diversity reduces food availability for local fauna and impacts local pollinator communities by limiting access to flowers in the spring (Invasive Species Council of British Columbia, 2017). In the long term, the presence of large populations of yellow archangel may prevent germination of native vegetation including tree saplings, reducing future canopy cover (Steele F., 2018).

All levels of government, non-profit organizations and private property owners spend significant resources managing yellow archangel in the Metro Vancouver region every year. In recent years, agencies represented on Metro Vancouver's Regional Planning Advisory Committee – Invasive Species Subcommittee together spent nearly $135,000 on yellow archangel control and volunteer stewardship annually. This figure does not include control costs for private landowners across the region or costs associated with education and awareness activities.

REPRODUCTION AND SPREAD

Yellow archangel is a perennial plant that reproduces both vegetatively and sexually. Fast growing horizontals stems called stolons (i.e., 'runners') are the primary means of spread (Graham & Clements, 2003). Each leaf node along the stolon can generate new roots and upright stems forming extensive ground cover from one individual plant. Fragments of roots and leaf nodes can develop into new plants (DesCamp, 2012).

A secondary form of dispersal is by seed. Plants can produce up to 800 seeds annually. Seed germination rates were found to be very low in controlled trials. Seeds can be carried by animals and humans passing through the vegetation. Seed dispersal is generally considered inefficient. However, ants can transport the seeds as far as 70 metres from the parent plant. Information available on sexually reproduction is based on populations in Great Britain (Packman, 1983). Trails and watercourses often seem to serve as a barrier to the spread of yellow archangel infestations (Steele F. , 2018).

Often labelled by the common name 'lamium', yellow archangel is commercially available as a popular ground cover and component of hanging baskets and ornamental container plantings. Consumers report being frustrated once they realize the aggressive plant has taken over their garden (Crosby, 2018).

HABITAT AND DISTRIBUTION

Yellow archangel tolerates a wide range of light, pH, organic content and drainage conditions (Lilley & Page, 2010). It thrives in full shade and moist, rich soils of forest understory but can survive in drier conditions and partial shade (Invasive Species Council of British Columbia, 2017). It is often found in urban forests, ravines, and riparian areas (Lilley & Page, 2010).

Yellow archangel is currently found throughout the South Coast of British Columbia and it is particularly common throughout the Metro Vancouver region. Its presence in or adjacent parks can nearly always be attributed to escape from residential gardens, discarded hanging baskets or illegal green waste dump sites (Steele F. , 2009). Yellow archangel has also been reported at a handful of locations in the Kootenay Boundary, North Okanagan, Cariboo and Skeena-Queen Charlotte regions.

CLIMATE ADAPTATION

Climate modellers predict that the Metro Vancouver region will experience warmer temperatures; a decrease in snowpack; longer dry spells in summer months; more precipitation in autumn, winter and spring; more intense extreme events; and an extended growing season. In the past, our region had an average of 252 days in the growing season. In lower elevations 45 days will be added to the growing season by the 2050s, and 56 days by the 2080s, resulting in nearly a year-round growing season of 357 days on average. In higher elevation ecosystems the growing season length will increase by 50% to 325 days by the 2080s (Metro Vancouver, 2016). These changes will stress many sensitive ecosystems, increasing their vulnerability to invasive species.

No specific information on how yellow archangel will adapt to climate change was found in the literature, but it is speculated that it may benefit from our future climate in several ways:

- **Longer summer drought periods:** Unlike many native plants, yellow archangel can survive in dry conditions (Invasive Species Council of British Columbia, 2017).
- **Extended growing season:** Yellow archangel is an early blooming plant and can survive in a range of light conditions (Lilley & Page, 2010).

With its ability to thrive variable conditions, this species is more adaptable than native species and suggests that it will be able to withstand, and possibly thrive, with changing climate conditions.

Identification

The following identification information was collected from the Invasive Species Council of British Columbia (2017) and Washington State Noxious Weed Control Board (2005).

General: Perennial, vine, evergreen herbaceous plant that forms dense ground cover.

Stem: Erect, hairy and 4-sided (square) stems grow on average to 30 centimetres but may grow as tall as 60 centimetres. Forms 4-sided stolons.

Leaves: Oppositely arranged. The typical leaf is between 2.5 to 8 centimetres in length and up to 5 centimetres in width, with a petiole (stalk that attaches a leaf to the plant stem) up to 3 centimetres long. Leaves are hairy, serrated and ovate shaped, with rounded or cordate bases. Leaf upper sides are variegated dark green with distinctive silver or white pattern and a 'wrinkly' texture.

The following photos show yellow archangel plant parts.

Flowers: Flowers are bright yellow between 17 to 25 millimetres, with a helmet or hooded shape. They consist of five modified petals that form a two-lipped bloom. The lower petals have orange-brown markings. Between April and June, the flowers are produced as pairs of dense clusters between pairs of leaves on flowering stems.

Fruits: Four nutlets, each containing one seed.

Roots: Roots typically reach 30 centimetres in length and can grow 20 centimetres deep in the substrate.

Leaves

CREDIT: ISCMV

Flowers

CREDIT: BRENDA DOBBS, FLICKR

SIMILAR SPECIES

Yellow archangel has a unique appearance due to its silver-white markings and is therefore not easily confused with any other species (Lilley & Page, 2010), but a few of the similar species are described below.

NON NATIVE SPECIES

- Purple deadnettle (*Lamium purpureum*) has smaller leaves (2–4 centimetres) that are green to lavender in colour and do not have the characteristic silver-white markings of yellow archangel. It is an invasive plant of concern, although relatively rare in the Metro Vancouver region. It can grow in a variety of soil types on moist to dry sites and prefers full sun. Where disturbance has occurred, it has been known to invade sensitive dry ecosystems (e.g., Garry Oak and associated ecosystems). It can also be a weed in turf grass (University of Maryland Extension, N.D.). Purple dead nettle readily reproduces from seed, as well as stem and root fragments. The plant should be hand-pulled at the seedling stage, prior to flowering (Garry Oak Ecosystem Recovery Team, 2011).

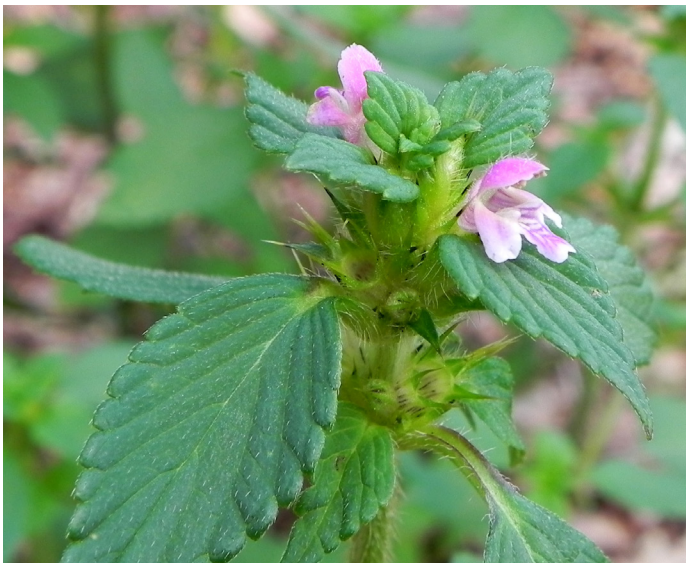
Purple dead-nettle

CREDIT: DANIEL J. LAYTON, WIKIMEDIA COMMONS

Purple dead-nettle

CREDIT: GAVIN SCHAEFER, WIKIMEDIA COMMONS

- Hemp nettle (*Galeopsis tetrahit*) has egg to lance-shaped leaves with rounded teeth, pointed tips and covered in bristly hairs. The leaves lack the characteristic silver-white markings of yellow archangel. Flowers can be purple, pink, white or pale yellow. The plant can grow up to 1 metre tall (Peace River Regional District, 2017) in moist to wet disturbed sites. Hemp nettle is invasive although generally considered an agricultural weed. It is best removed by digging or pulling when in flower bud stage (Wisconsin Department of Natural Resources, 2017).



Purple dead-nettle

CREDIT: DANIEL J. LAYTON, WIKIMEDIA COMMONS

Purple dead-nettle

CREDIT: GAVIN SCHAEFER, WIKIMEDIA COMMONS

- Herman's Pride (*Lamiastrum galeobdolon* 'Herman's Pride') has smaller, narrower and more coarsely serrated leaves than yellow archangel. It is slow growing, forming a 30 to 60 centimetres wide upright clump over time. It does not grow stolons. This plant is typically regarded as non-invasive and has not been observed to be invasive in the Metro Vancouver region (Steele F. , 2018). However, with the same genus and species names and similar silver variegated leaf pattern as yellow archangel, there is a risk of mis-identification.
- Goutweed/bishop's weed (*Aegopodium podagraria* variegata) is a member of the carrot family with its characteristic white flowers in umbel formation. Leaves are trifoliate (growing in groups of three) and either solid green or variegated. Variegated leaves are white around the edges and green in the center. Goutweed/bishop's weed is also considered locally invasive.

'Herman's Pride'

CREDIT: JAMES STEAKLEY, WIKIMEDIA COMMONS

Goutweed: non-variegated, flowering

CREDIT: ELI SAGOR, VIA FLICKR

Goutweed: variegated, flowering

CREDIT: ISCMV

Tracking

The Provincial government maintains the Invasive Alien Plant Program (IAPP) application (British Columbia Ministry of Forests, Lands and Natural Resource Operations and Rural Development 2017), which houses information pertaining to invasive plant surveys, treatments, and monitoring. Many agencies, including local governments, have their own internal invasive species inventory and mapping protocols that are used by staff, contractors and, in some cases, the public. For example, the City of North Vancouver has its own system called AlienMap. Agencies in British Columbia that do not enter data into IAPP are encouraged to check it regularly because it contains public reports and data from other agencies and it is important to consider as much data as possible when making management decisions. The Map Display module of IAPP is publicly accessible.

When carrying out a yellow archangel inventory it is useful to record the following information as it will later inform treatment plans:

- Size and density of infestation;
- Location in relation to the 10 metre Pesticide Free Zone adjacent to water courses;
- Location in relation to other water sources, such as wells;
- The suspected source of infestation (e.g., green waste dumping, spread from an adjacent private garden, etc.); and
- Proximity to non-target vegetation.

Reporting

Since yellow archangel is common throughout the Metro Vancouver region and does not pose an imminent health or safety risk, there is generally little value in reporting individual occurrences.

Prevention and Control Strategies

Effective invasive plant management may include a variety of control techniques ranging from prevention, chemical, manual, mechanical, biological and/or cultural methods. Each method is described below in order of effectiveness.

Yellow archangel can be effectively controlled through both manual/mechanical and chemical treatment techniques. The techniques used and the number of years required are dependent on the size, complexity of infestation and site characteristics. Chemical treatment is most efficient. However, it is not necessarily suited to all sites and efficacy is dependent on follow-up treatments. Manual/mechanical treatment can also be effective, but will generally be much more time consuming.

Follow-up monitoring and treatment will be required for several years regardless of the treatment technique.

STRATEGY COLOUR LEGEND

GREEN: RECOMMENDED

ORANGE: CAUTION

RED: NOT RECOMMENDED OR NOT AVAILABLE

PREVENTION: IMPERATIVE

Prevention is the most economical and effective way to reduce the spread of yellow archangel over the long term.

When working in or adjacent to yellow archangel, it is best to inspect and remove plants, plant parts, and seeds from personal gear, clothing, pets, vehicles, and equipment and ensure soil, gravel, and other fill materials are not contaminated with yellow archangel before leaving an infested area. Plants, plant parts, and seeds should be tarped or bagged before transport to an appropriate disposal site (see Disposal section).

It is best not to purchase, trade or grow yellow archangel, including plants in hanging baskets or containers. Instead, regional native or non-invasive plants should be used. The Invasive Species Council of British Columbia's 'Grow Me Instead' Program or Metro Vancouver's Grow Green website provide recommendations for non-invasive, drought-tolerant plants, and garden design ideas. All materials (e.g., topsoil, gravel, mulch, compost) should be weed-free. Healthy green spaces are more resistant to invasion by invasive plants, so it is also important to maintain or establish healthy plant communities.

If yellow archangel is already present in a garden, it is critical to prevent the plant from expanding and invading adjacent parks and natural areas.

MANUAL/MECHANICAL: RECOMMENDED

When determining the appropriate control method for a site it is important to consider the long-term impacts of repeated, intensive foot traffic that is often inherent with manual control methods (Crosby, 2018). The following manual/mechanical methods can be used to control yellow archangel.

- **Hand removal**: The plant can be hand pulled, although it is highly time consuming. Complete removal of the root systems, stems and stolons is necessary since any plant parts left behind can propagate new stems. Each individual plant should be gently pinched at the base and pulled out (Crosby, 2018). Sift through the soil to ensure no plant parts remain (Invasive Species Council of British Columbia, 2017). Attention to detail is key; plants can often be found under existing vegetation, so it is important to look beneath fern fronds, leaves and forest floor litter (Crosby, 2018).

  Hand removal is best done when soil is moist from fall to spring (Washington State Noxious Weed Control Board). Avoid pulling during wet periods when soil is saturated as muddy conditions make it difficult to find plant parts

and to keep track of which sections have been pulled (Crosby, 2018). Pulling is most effective in loose loamy soil; roots often break when pulled from clay or compact soils (Crosby, 2018). Using a hand tool like a pick to break apart hardpacked soil is useful; this will improve efficacy in follow-up treatments as soil will be looser. Roots will break if pulled during frost or snow periods (Crosby, 2018).

For large infestations that can be chemically treated, land managers in the region generally only use hand removal for follow-up control once the majority of the plants have died (Crosby, 2018) (Jarvis, 2018).

- **Soil grubbing**: Large scale mechanical removal of the forest organic layer and topsoil can effectively control yellow archangel since roots typically only penetrate 20 centimetres deep. This method could cause soil compaction and severe impacts to surrounding native vegetation. It would be most useful on accessible sites where little to no native vegetation remains and restoration is already necessary (Lilley & Page, 2010).
- **Cover**: Plants can be smothered by a cover treatment and mulch (Invasive Species Council of British Columbia, 2017). Thick layers of newspaper or cardboard with large overlaps can be used to ensure plants cannot find their way to the surface. A 10 centimetres layer of mulch (i.e., wood chips or composted mulch) should then be applied. The site should be monitored for plants creeping out, and mulch re-applied as needed. Landscape fabric can also be used with or without mulch. The fabric must be secured to the soil to ensure stems cannot grow out the edges or through holes (Washington State Noxious Weed Control Board). If a non-biodegradable cover is used, maintain the cover for one year minimum. Before removing the cover, test efficacy by uncovering only small portion and monitoring for spring growth for at least a few weeks. Mulching on its own has been found to be ineffective (Lilley & Page, 2010). A drawback of cover treatments is that it can be difficult to place covers around native vegetation. These gaps will allow the plant to poke through and re-establish (Lilley & Page, 2010). Begin covering treatment in early spring, when growth of the plants is at the peak.
- **Weed torching**: Weed torching is not recommended because it does not kill the roots and therefore must be repeated frequently to address re-growth. Fire hazard is also a concern.
- **Cutting or mowing**: Cutting and mowing are not recommended because the roots are left in place and will quickly sprout new growth. If the plant has been cut or mowed, all trimmings should be collected to reduce the risk of new plants regenerating from plant fragments (Invasive Species Council of British Columbia, 2017).

APPLYING MANUAL/MECHANICAL CONTROL METHODS IN RIPARIAN AREAS

Yellow archangel often grows in large contiguous patches right up to the edge of water courses. Consider the impact of control techniques and the resulting bare soil on the adjacent aquatic environment. Schedule removal works during a period of least risk to fish species, outside of the fish window. Adhere to Provincial and Federal riparian regulations. It is recommended to consult with a qualified environmental professional when working around water bodies.

CHEMICAL: RECOMMENDED

When alternative methods to prevent or control invasive plants are unsuccessful, professionals often turn to herbicides. Chemical treatment can be an effective and relatively inexpensive method to treat yellow archangel. However, this method should be used with caution for three reasons (Crosby, 2018):

1. Weather conditions greatly influence treatment efficacy;
2. Yellow archangel often grows in riparian areas where pesticide use is restricted; and
3. Native vegetation is often integrated with yellow archangel infestations (particularly true for salmonberry). Mortality of non-target plants should be expected. Sites with well established native shrubs layers should be considered as low priorities for chemical treatment.

With the exception of substances listed on Schedule 2 of the Integrated Pest Management Regulation, the use of herbicides is highly regulated in British Columbia. Site characteristics must be considered with herbicide prescribed, based on site goals and objectives and in accordance with legal requirements. This summary of the *Integrated Pest Management Act* provides an overview of the Provincial legislation.

PESTICIDE LICENCE AND CERTIFICATION

A valid pesticide licence is required to:

- offer a service to apply most pesticides;
- apply most pesticides on public land including local government lands[2]; and
- apply pesticides to landscaped areas on private land, including outside office buildings and other facilities.

Pesticides (e.g., herbicides, insecticides, fungicides) are regulated by the Federal and Provincial government, and municipal governments often have pesticide bylaws.

- Health Canada evaluates and approves chemical pest control products as per the *Pest Control Products Act*.
- The Provincial *Integrated Pest Management Act* sets out the requirements for the use and sale of pesticides in British Columbia. This Act is administered by the Ministry of Environment and Climate Change Strategy.
- Several municipalities have adopted bylaws that prohibit the use of certain pesticides.

Everyone who uses pesticides must be familiar with all relevant laws.

2 on up to 50 hectares/year by a single organization. Organizations looking to treat over 50 hectares of land per year are also required to submit a Pest Management Plan and obtain a Pesticide Use Notice confirmation.

ONLY companies or practitioners with a valid Pesticide Licence and staff who are certified applicators (or trained assistant applicators working under a certified applicator) may apply herbicide on invasive plants located on public lands in British Columbia. Applicators must be either the land manager/owner or have permission from the land manager/owner prior to herbicide application.

On private property the owner may obtain a Residential Applicators Certificate (for Domestic class products only) or use a qualified company. Residents do not require a Residential Applicator Certificate for certain uses of domestic class glyphosate including treatment of plants that are poisonous for people to touch, invasive plants and noxious weeds listed in legislation, and weeds growing through cracks in hard surfaces such as asphalt or concrete. Refer to the 'Pesticides & Pest Management' and 'Home Pesticide Use' webpages listed in the Additional Resources Section for more information.

Questions? Contact the Integrated Pest Management Program: Telephone: (250) 387-9537
Email: bc.ipm@gov.bc.ca

Pesticide applicator certificates can be obtained under the category 'Industrial Vegetation Management' to manage weeds on industrial land, roads, power lines, railways, and pipeline rights-of-way for control of noxious weeds on private or public land. Assistant applicator training is also available and the online course and exam are free.

It is best practice for personnel supervising or monitoring pesticide contracts to also maintain a pesticide applicator licence so they are familiar with certification requirements.

For more information on how to obtain a licence and the requirements when working under the Provincial *Integrated Pest Management Act* and Regulation, please review the Noxious Weed & Vegetation Management section on this webpage: gov.bc.ca/PestManagement.

HERBICIDE LABELS

Individual herbicide labels must always be reviewed thoroughly prior to use to ensure precautions, application rates, and all use directions, specific site and application directions are strictly followed. Under the Federal *Pest Control Products Act* and the Provincial Integrated Pest Management Regulation, **persons are legally required to use pesticides (including herbicides) only for the use described on the label and in accordance with the instructions on that label**. Failure to follow label directions could cause damage to the environment, poor control results, or danger to health. Contravention of laws and regulations may lead to cancellation or suspension of a licence or certification, requirement to obtain a qualified monitor to assess work, additional reporting requirements, a stop work order, or prohibition from acquiring authorization in the future. A conviction of an offence under legislation may also carry a fine or imprisonment.

Herbicide labels include information on both the front and back. The front typically includes trade or product name, formulation, class, purpose, registration number, and precautionary symbols. Instructions on how to use the pesticide and what to do in order to protect the health and safety of both the applicator and public are provided on the back (British Columbia Ministry of Environment and Climate Change Strategy, 2011).

Labels are also available from the Pest Management Regulatory Agency's online pesticide label search or mobile application as a separate document. These label documents may include booklets or material safety data sheets (MSDS) that provide additional information about a pesticide product. Restrictions on site conditions, soil types, and proximity to water may be listed. If the herbicide label is more restrictive than Provincial legislation, the label must be followed.

HERBICIDE OPTIONS

The following herbicides can be used on yellow archangel (Miller, N.D.):

ACTIVE INGREDIENT (EXAMPLE BRAND NAMES)+	APPLICATION	PERSISTENCE	GROWTH STAGE	TYPE++	COMMENT
Glyphosate (many products)	foliar application	non-residual	early spring and late fall	non-selective	mixing with triclopyr or imazapyr improves efficacy, can impact trees with roots within or adjacent to the treatment area
Imazapyr (e.g. Arsenal™)	foliar application	residual	actively growing	non-selective	
Aminopyralid (e.g. Milestone™)	foliar application	residual	actively growing	selective, no effect on grasses	
Triclopyr (e.g. Garlon™)	foliar application	residual	actively growing	selective, no effect on grasses	
Metsulfuron (e.g. Escort™)	foliar application	residual	actively growing	selective, no effect on grasses	may affect shrub species

+ The mention of a specific product or brand name of pesticide in this document is not, and should not be construed as, an endorsement or recommendation for the use of that product.

++ Herbicides that control all vegetation are non-selective, while those that control certain types of vegetation (e.g. only grasses or only broadleaf plants) are termed selective.

Field trials undertaken in Washington State tested 32 different herbicides. The results showed that glyphosate and imazapyr provided the most effective, long-term control of yellow archangel (Miller, Halpern, Lucero, & Shaw, 2014). The Langley Environmental Partners (LEPS) has found that diluting the application rate of glyphosate to one tenth of the recommended rate is most effective (Dreves, Stewardship Coordinator, Langley Environmental Partners Society, 2018).

APPLYING PESTICIDE IN RIPARIAN AREAS

Provincial legislation prohibits the use of herbicides within 10 metres of natural water courses and 30 metres of domestic or agricultural water sources on public lands. On private lands herbicide labels need to be followed (which means for glyphosate products treatment can happen up to the water's edge) and other restrictions may apply (e.g., industrial sites, forestry sites, golf courses, etc.). On public lands, glyphosate is the only active ingredient that can be applied within the 10 metre Pesticide-Free Zone (PFZ)[3] in British Columbia in accordance with the *Integrated Pest Management Act* and Regulation and all public land Pesticide Management Plans (PMPs). A plant must be either a listed Noxious Weed (under the *Weed Control Act*) or appear in the *Forest and Range Practices Act* Invasive Plants Regulation to be treated within the 10 metre PFZ. **Yellow archangel is not listed and therefore glyphosate and other herbicides can only be applied on yellow archangel up to 10 metres away from the high water mark (HWM)[4].** The 30 metre no-treatment zone around a water supply intake or well used for domestic or agricultural purposes may be reduced if the licencee or PMP holder is "reasonably satisfied" that a smaller no-treatment zone is sufficient to ensure that pesticide from the use will not enter the intake or well.

When managing yellow archangel with herbicide in riparian areas:

- Observe and mark all PFZs while on site.
- The HWM should be determined by careful evaluation by the applicator.
- Distances in PFZs should be measured as horizontal distance.
- Herbicides restricted in a PFZ must not enter these zones by leaching (lateral mobility) through soil or by drift of spray mist or droplets.
- Treatments should be conducted when water levels are low (e.g., summer months) to reduce risk.
- Note that efficacy may be dependent on site conditions, including moisture in the soil.

3 The Pesticide-Free Zone (PFZ) is an area of land that must not be treated with pesticide and must be protected from pesticide moving into it, under the *Integrated Pest Management Act and Regulation*.

4 The High Water Mark (HWM) is defined as the visible high water mark of any lake, stream, wetland or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the lake, river stream, or other body of water a character distinct from that of the banks, both in vegetation and in the nature of the soil itself. Typical features may include, a natural line or "mark" impressed on the bank or shore, indicated by erosion, shelving, changes in soil characteristics, destruction of terrestrial vegetation, or other distinctive physical characteristics. The area below the high water mark includes the active floodplain (British Columbia Ministry of Environment and Climate Change Strategy, 2011).

APPLICATION METHODS

The preferred application method to minimize non-target damage and applicator exposure is **foliar application**, which involves using a backpack or handheld sprayer to completely cover the actively growing plant parts with herbicide.

TREATMENT TIMING

For glyphosate, optimal performance has been observed during periods of mild temperature (approximately 15 to 22°C). Typically, in the Metro Vancouver region this corresponds to treatment in May to mid June and follow-up treatment from mid-September to early October (Crosby, 2018). Reduced efficacy has been observed when applying herbicide during hot weather, periods of drought or extended wet weather (Crosby, 2018) (Jarvis, 2018). Plants can take up to two weeks from chemical treatment before mortality is visible (Crosby, 2018).

CULTURAL: NOT AVAILABLE

There are no documented cultural control methods for yellow archangel. Miller, Tarasoff & Salmon (2021) researched the potential for targeted grazing as a control method for this species, but no information on palatability, toxicity to livestock, or the efficacy of this treatment method was found.

BIOLOGICAL: NOT AVAILABLE

The bank mole (*Clethrionomys glareolus*) preferentially consumes yellow archangel in Europe (Packman, 1983) but is not suitable for biological control in North America. No other biological control agents have been found to control yellow archangel in British Columbia at the present time.

CREDIT: ISCMV

CONTROL SUMMARY

The following table provides a summary and comparison of control methods for yellow archangel (adapted from Lilley & Page, 2010).

CONTROL STRATEGY	TECHNIQUES	APPLICABLE SITE TYPE	PROS	CONS
Mechanical	**Soil grubbing**	Highly disturbed sites with little or no native vegetation	Medium to high efficacy	Costly; high impact to ecosystems; access constraints
Manual	**Cover**	Environmentally sensitive areas in places with minimal native vegetation or other obstacles	High efficacy; low risk to environment	Challenging to implement around existing vegetation; access constraints
	Hand removal	Small sites (<5m^2), diffuse patches (e.g., after chemical control), environmentally sensitive areas	Selective; low risk to environment	Low efficacy in long term; large investment in time and labour
Chemical	**Foliar application**	Large, dense infestations except in environmentally sensitive areas and/or where herbicide use is restricted	Medium to high efficacy	Unintended environmental/ health impacts; high public concern; weather dependent; requires trained staff
Cultural	**No documented cultural controls**			
Biological	**No biological control agents are currently available in British Columbia**			

CONTROL SUMMARY COLOUR LEGEND

GREEN: RECOMMENDED

ORANGE: CAUTION

RED: NOT RECOMMENDED OR NOT AVAILABLE

Disposal

All manually removed plant parts should be collected in green waste bags or on tarps for off site disposal to prevent re-growth; this includes any plant parts hung up in other vegetation (Dreves, Stewardship Coordinator, Langley Environmental Partners Society, 2018). Plant material left on site on tarps to decompose has been found to continue to grow (Dreves, Stewardship Coordinator, Langley Environmental Partners Society, 2018). In cases where it is not possible to safely remove green waste from a site (e.g. the bottom of steep ravines), piles can be left on site to decompose. However, the piles must be turned (to ensure complete decomposition) and monitored for re-growth until plants are completely dead (Crosby, 2018).

Plants treated by herbicide should be left on site to die and decompose.

Yellow archangel should not be composted at home or at municipal works yards as the temperature may not be high enough to kill seeds. Yellow archangel readily regenerates from plant fragments, growing its way out of home composters.

OFF SITE DISPOSAL

When disposing off site, transport plant parts on tarps or in thick plastic bags to an appropriate disposal or compost facility. In the Metro Vancouver region, yellow archangel can be disposed at any regional green waste collection depot, as well as in residential green waste collection bins. Please consult this disposal facility list for current details.

PLEASE CONTACT ALL FACILITIES BEFOREHAND TO CONFIRM THEY CAN PROPERLY HANDLE THE MATERIAL.

CLEANING AND DISINFECTION[5]

Before leaving a site, all visible plant parts and soil from vehicles, equipment, and gear should be removed and rinsed if possible. When back at a works yard or wash station, vehicles should be cleaned and disinfected using the following steps:

- Wash with 180 °F water at 6 gpm, 2000 psi*, with a contact time of ≥ 10 seconds on all surfaces to remove dirt and organic matter such as vegetation parts or seeds. Pay special attention to undercarriages, chassis, wheel-wells, radiators, grills, tracks, buckets, chip-boxes, blades, and flail-mowing chains.
- Use compressed air to remove vegetation from grills and radiators.
- Sweep/vacuum interior of vehicles paying special attention to floor mats, pedals, and seats.
- Steam clean poor access areas (e.g., inside trailer tubes) – 200 psi @ 300 °F.
- Fully rinse detergent residue from equipment prior to leaving facility.

* Appropriate self-serve and mobile hot power-wash companies in the Metro Vancouver region include: Omega Power Washing, Eco Klean Truck Wash, RG Truck Wash, Ravens Mobile Pressure Washing, Hydrotech Powerwashing, Platinum Pressure Washing Inc, and Alblaster Pressure Washing. Wash stations should be monitored regularly for yellow archangel growth.

5 Adapted from Metro Vancouver 2017 Water Services Equipment Cleaning Procedures and Inspection Protocols.

Follow-up Monitoring

Whatever control method is used, follow-up monitoring and maintenance treatments are components of an integrated management plan or approach. Initial treatments are rarely successful in removing or killing all roots and stolons of yellow archangel. It is almost guaranteed that some plants will be missed during each treatment pass and that re-sprouting will occur from fragments of plants left behind and from the seed bank.

Annual follow-up monitoring should take place following initial treatment for both chemically and manually treated sites. The number of years of monitoring required will vary depending on the control method(s) and site characteristics; the number of years is typically substantial for large patches treated solely by hand removal (Dreves, Stewardship Coordinator, Langley Environmental Partners Society, 2018). It is wise to assume monitoring will be required indefinitely into the future to preserve the investment of time and money put into control efforts (Crosby, 2018). Metro Vancouver Regional Parks staff have documented several patches that were chemically treated 2 to 3 times per year for at least 3 years. These patches will still require ongoing manual follow-up for several additional years before they are ready for restoration planting (Jarvis, 2018).

Restoration

Restoration is recommended to create competition, control yellow archangel regrowth, replace lost habitat, and for erosion control. Due to the capacity for yellow archangel to regenerate, restoration (including the application of mulch) is not recommended until successful control has been achieved (Lilley & Page, 2010). Sometimes there is enough existing native vegetation growing on site that restoration planting is not necessary (Crosby, 2018). However, after several years of chemical control, native vegetation is typically very sparse and therefore planting will be necessary (Jarvis, 2018). Examples of common competitive native species prescribed for sites within the Metro Vancouver region are summarized in the table below based on site moisture.

Replacement species should be chosen based on the ecology of the site by a qualified environmental professional. Local biologists, environmental professionals, agronomists, agrologists, native and domestic forage specialists, seed companies and plant nurseries are all good sources for localized recommendations for regional native species and regionally adapted domestic species, based on site usage. Native grass seed mixes are also available. Several science-based resources are available to guide restoration efforts, such as the South Coast Conservation Program's Diversity by Design restoration planning toolkit.

WET SITES	MOIST SITES	DRY SITES
SHRUBS		
Salmonberry	Salmonberry	Thimbleberry
Hardhack	Willow	Nootka rose
Willow	Red osier dogwood	Red flowering currant
Red osier dogwood	Red elderberry	Snowberry
Pacific ninebark	Vine maple	Tall Oregon grape
Sword fern	Indian plum	Oceanspray
Deer fern	Sword fern	
TREES		
Western red cedar	Western red cedar	Douglas-fir
Red alder	Red alder	Red alder

Revegetation of the site to a domestic or cultured non-native plant species composition may be considered in some circumstances. Often domestic species establish faster and grow more prolifically, which aids in resisting yellow archangel re-invasion.

Yellow archangel sites are often found in areas with existing, or potential, wildlife populations (e.g., deer, beaver, muskrat, vole, etc.) that can damage restoration plantings. Therefore, any revegetation plan must consider impacts from wildlife and utilize appropriate mitigation measures to protect the restoration and existing native plantings (tree wrapping, exclusion caging/fencing, vole guards, etc.).

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Additional Resources

For more information please refer to the following resources.

- BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Invasive Alien Plant Program (IAPP). www.gov.bc.ca/invasive-species
- E-Flora BC, an Electronic Atlas of the Plants of British Columbia. www.eflora.bc.ca/
- Grow Me Instead. http://bcinvasives.ca/resources/programs/plant-wise/
- GrowGreen Guide. www.growgreenguide.ca
- Invasive Species Council of British Columbia, yellow archangel Factsheet: https://bcinvasives.ca/wp-content/uploads/2021/01/Yellow_Archangel_TIPS_2017_WEB.pdf
- Pesticides and Pest Management. Province of British Columbia https://www2.gov.bc.ca/gov/content/environment/pesticides-pest-management

Acknowledgments

The project team would like to thank the following groups for their contributions related to the development and review of this document:

Janice Jarvis, Metro Vancouver, Parks and Housing Services

Kari Pocock, District of West Vancouver

Ken Crosby, City of Surrey

Lisa Dreves, Langley Environmental Partners Society

Melinda Yong, City of Burnaby

Metro Vancouver's Regional Planning Advisory Committee (RPAC) - Invasive Species Subcommittee

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