Narrow Leaf Goldenrod (*Euthamia graminfolia* L.)

Common name: Narrowleaf Goldenrod, Grass-Leaved Goldenrod
Scientific name: *Euthamia graminifolia* L.
Family name: Asteraceae
Life-cycle: Herbaceous creeping perennial

Seedling description: Seedlings emergence as a rosette of oblong leaves that are entire (Werner et al. 1990).

Leaf shape and margins: Leaves are narrow, about 0.5 cm in width, entire and arranged alternatively along the stem (Newcomb, 1977).

Shoot structure: One shoot is produced per apical tip (Werner et al. 1990).

Root type and/or vegetative reproductive structures: Horizontal creeping roots that produce adventitious root buds (Werner et al. 1990).

Flower description and flowering time: Narrow leaf goldenrod has a corymb inflorescence that is flat or slightly convex (Price, 2003), multi-branched, with flowers produced in clusters of 20-25 (Sheahan, 2012). Flowers are pale to bright yellow after maturity in August and set seed from September to October (Siren, 1981).

Seed description: Creeping Herbaceous Perennial

A B C

Figure 1. A) Basal rosette, B) Shoot elongation, C) Flowering narrow leaf goldenrod (Photo taken by Lienna Hoeg, Nova Scotia 2019).

Weed Biology and Ecology

Floral biology:

Information for floral biology of narrow leaf goldenrod is limited, but some exists for its close relative Canada goldenrod (*Solidago canadensis* L.). *Solidago* spp. are pollinated by insects. These species are visited by honeybees, native bumble bees, soldier beetles and syrphid flies (Werner et al., 1980). The flowers of goldenrods are not self-compatible and require cross-pollination, and agamospermy and vivipary do not occur in this plant (Werner et al., 1980).

Seed production and dispersal:

Again, information is limited on seed production and dispersal for narrow leaf goldenrod specifically. Seeds of *S. canadensis* traveled 2.4 m from the parent plant when released from a height of 1 m (Werner et al. 1990). Narrow leaf goldenrod with a similar floral height may have a similar dispersal distance. Price (2003) determined seed viability of narrow leaf goldenrod seeds to be 0.006% suggesting limited importance of sexual reproduction for dispersal. Seeds of Canada goldenrod weigh an average of 0.0943 g per 1000 seeds (Gould et al., 2013).

Seed banks, seed viability, and seedling emergence:

There is limited knowledge of the seed bank, general phenology and emergence patterns exhibited by narrow leaf goldenrod and little knowledge of the seed bank dynamics or extent and occurrence of seedling recruitment of this weed species. It is known that the seeds of Canada goldenrod and a viability of 5 years (Gould et al., 2013). Seedling recruitment by creeping perennials has been reported as infrequent unless plants are establishing in a new area (Hakansson, 1982). Seedling emergence in other goldenrod species, such as *S. canadensis*, occurs in the spring and shoots begin to emerge from established rhizomes in late April (Werner et al., 1990). Further research is needed to investigate the phenology and seed dynamics of narrow leaf goldenrod.

Vegetative reproduction:

Narrow leaf goldenrod reproduces by seeds and vegetative reproduction. Creeping rhizomes produce adventurous root buds that give rise to shoots. After the first year of growth, *Solidago* spp. can reproduce by rhizomes. Each ramet can give rise to 2 - 6 daughter rhizomes, and each individual rhizome possesses the ability to produce one shoot from its apical growth tip (Werner et al., 1990). Seedling recruitment is important for Canada goldenrod (*Solidago Canadensis* L.*)* when invading a new area, but once seedlings become established, reproduction is primarily achieved via vegetative growth (Hartnett & Bazzaz, 1985). Seedling recruitment within established stands of narrow leaf goldenrod may be uncommon, but there is no data in the published literature on this subject.

Population dynamics:

Narrow leaf goldenrod can produce dense patches and out compete surrounding vegetation (Butcko & Jensen, 2002). Goldenrod can give rise to one generation per year, but emergence is season long (Werner et al. 1990). A study in 2018 indicated that mowing narrow leaf goldenrod in the floral bud stage can lead to a reduction in that season but does not maintain control in the following year (Farooq (2018). Goldenrod is quick to colonize recently disturbed areas. Established populations of *Solidago canadensies* have been thought to persist for at least 100 years (Werner et al. 1990).

Economic Importance

Detrimental effects:

The presence of narrow leaf goldenrod in Christmas tree lots can lower quality and yield of Christmas trees (McCully et al., 1991). Established stands of goldenrod can smoother seedlings, and increase competition for water, nutrients, and sunlight.

Beneficial effects:

There are some medicinal properties of some species of goldenrod. Goldenrod is able to populate and stabilize soils quickly after disruption, and narrow leaf goldenrod can be a reliable source of nectar for native pollinators (Werner et al. 1990).

Legislation:

Narrow leaf goldenrod is native to North America (Werner et al.,1990) and can be found from Nova Scotia to British Columbia and south into Florida, USA (Sheahan, 2012). Currently there are no Canadian Federal or Provincial Weed or Seed Acts that list narrow leaf goldenrod.

Management Opportunities

Monitoring:

To lower populations of problematic perennial weeds, methods to reduce seedling recruitment and vegetative reproduction are needed. Determining optimal treatment times requires an understanding of energy reserves and carbohydrate movement in perennials (Radosevich et al., 1997). When vegetative reproductive structures break winter dormancy and begin to sprout, carbohydrates are translocated acropetally from the roots to the new emerging shoots (Nkurunziza & Streibig, 2011). Concentration of stored carbohydrates in vegetative reproductive structures declines as shoot growth commences and carbohydrates are translocated upwards into the developing shoots (McAllister & Haderlie, 1985). This provides opportunity for herbicide application to newly emerged shoots as treatment can damage shoots and disrupt growth (Ross & Lembi, 2009). Upward translocation of carbohydrates continues until emerged shoots have enough leaf area to produce photosynthetic products for growth and respiration (McAllister & Haderlie, 1985). Carbohydrate reserves will begin to be replenished when basipetal movement of photosynthetic materials to vegetative structures begins (Nkurunziza & Streibig, 2011). This usually occurs as emerged shoots approach peak height or the flower bud stage and again in the autumn, at which time excess assimilates produced by the shoots will be translocated to the vegetative reproductive structures (Bradbury & Hofstra,1977). This provides another adequate timing opportunity for herbicide treatment, as the basipetal translocation of carbohydrates facilitates movement of herbicide through the plant (D'hertefeldt & Jónsdóttir, 1999).

Potential physical and mechanical control options:

Management of weeds relies on utilization of physical and mechanical, cultural, biological, and chemical methods of weed control. Physical and mechanical weed control consists of the use of strategies such as tillage, mowing, mulches, and flame weeding for weed control. Tillage is very effective for the management of perennial rhizomatous weeds and has been used to manage Canada thistle (*Cirsium arvense* L.), in conjunction with subsequent herbicide applications, in various cropping systems (Darwent et al., 1994). Use of tillage in Christmas trees, however, is difficult due to it being a perennial cropping system. Mechanical management of narrow leaf goldenrod includes manually pruning stems (Boyd et al., 2009). Farooq (2018) found that a single cutting at the floral bud stage led to significant reductions in narrow leaf goldenrod in the following year but does not maintain control. This approach, however, is not utilized widely by growers as it is time consuming and labor intensive.

Potential cultural control options:

Cultural weed management involves the use of crop rotation, fertility management, cultivar selection, and other strategies that increase crop competitiveness against weeds.

Cultural management practices encourage growth of Christmas trees while reducing weed occurrence. Use of mulches, a cultural and mechanical weed control tool, can increase lot density and potentially make the crop more competitive with weeds. Mulching aids soil fertility management in Christmas trees, and by maintaining soil fertility, vigor is increased (Kender & Eggert, 1966). Interplanting competitive fir cultivars could help reduce bare spots and increase genetic diversity within fields. As Christmas trees prefer acidic soil, applications can be used to lower soil pH. Maintaining proper soil pH contributes to decreased ground cover of broadleaf and grass weeds in Christmas tree lots.

Potential biological control options:

Biological control employs the use of beneficial organisms that target and reduce pests. Currently, this approach for weed management is limited. Ground beetle and field cricket have been observed consuming the seeds of common weeds such as sheep sorrel and hair fescue (*Festuca filiformis* Pourr.). Cutler et al., 2016 indicated these natural enemies may contribute to weed biocontrol. Ability of the dogbane beetle (*Chrysochus auratus* Fabricius) to reduce spreading dogbane (*Apocynum androsaemifolium* L.) populations has also been investigated (MacEachern-Balodis et al., 2017), though this insect did not establish large enough populations under field conditions to adequately control this weed. Natural enemies of narrow leaf goldenrod that could be utilized in a potential biocontrol program have not been assessed.

Potential chemical control options:

Chemical management of creeping herbaceous perennial weeds is generally very effective. These management strategies include the use of both soil-applied herbicides and foliar applied contact and systemic herbicides. Soil applied herbicides are applied to the soil prior to crop planting or applied as a pre-emergent treatment. After application, the herbicide persists in the soil and the plant absorbs the chemical through its roots. Herbicide is then transported acropetally to emerging shoots (Nishimoto, 1971). Hexazinone is widely used in Christmas tree management and is applied as a pre-emergent treatment and provides weed control in subsequent years. It is typically applied in the spring and is activated in the soil by rainfall (Boyd et al., 2009). Herbicides applied pre-emergence traditionally controlled most species of goldenrods (Jensen, 1985; Yarborough et al., 1986). Recent research trials, however, have shown reduced control of narrow leaf goldenrod by hexazinone (White et al. 2015). Other currently registered PRE herbicides for use in Christmas trees in Canada are generally ineffective on goldenrods (Anonymous, 2017; Smagula and Ismail 1981). Herbicides applied after emergence (POST-emergence), contribute to goldenrod management. POST herbicides with efficacy on goldenrods generally pose a risk of injury to established trees. Therefore, these herbicides generally need to be used as direct spot applications (Farooq et al., 2019). Alternative application timings that reduce injury risk to Christmas trees (e.g., after trees have hardened off) could be identified and evaluated with further research.

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