

Development of a Best Management Plan for Spreading Dogbane (*Apocynum  
androsaemifolium* L.) in Wild Blueberry Fields

by

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## Table of Contents

List of Tables .....	vi
List of Figures .....	viii
Abstract .....	ix
List of Abbreviations and Symbols Used .....	x
Acknowledgements .....	xi
Chapter 1.0 Introduction .....	1
1.1 Introduction to the Problem .....	1
1.2 Background on Wild Blueberry and Blueberry Production .....	2
1.3 Weeds in Blueberry Fields .....	5
1.4 Spreading Dogbane .....	6
1.5 Hemp Dogbane .....	11
1.6 Integrated Weed Management .....	12
1.6.1 Prevention .....	13
1.6.2 Cultural Techniques .....	13
1.6.3 Physical Techniques .....	14
1.6.4 Chemical Techniques .....	16
1.7 Response to Herbicides .....	19
1.8 Weed Biology and Ecology .....	21
Chapter 2.0 Modeling Spreading Dogbane Development in Wild Blueberry Fields ..	24
Abstract .....	24
2.1 Introduction .....	25
2.2 Materials and Methods .....	27
2.2.1 Study Sites .....	27
2.2.2 Data Collection .....	27
2.2.3 Air and Soil Temperature .....	28
2.2.4 Statistical Analysis .....	29
2.3 Results and Discussion .....	32
2.3.1 Meteorological Data .....	32
2.3.2 Spreading Dogbane Ramet Emergence .....	35

2.3.3 Spreading Dogbane Height.....	39
2.3.4 Spreading Dogbane Flowers.....	41
2.3.5 Basic Phenology .....	45
2.4 Conclusions .....	47
Chapter 3.0 Management of Spreading Dogbane with Herbicides.....	49
Abstract .....	49
3.1 Introduction .....	50
3.2 Objectives.....	52
3.3 Materials and Methods .....	53
3.3.1 Summer Broadcast.....	54
3.3.2 Fall Broadcast.....	55
3.3.3 Summer Spot Spray .....	56
3.3.4 Summer Spot Spray Versus Wiping and Hand Pulling.....	57
3.3.5 Data Collection .....	58
3.3.6 Statistical Analysis .....	59
3.4 Results and Discussion.....	60
3.4.1 Summer Broadcast.....	60
3.4.2 Fall Broadcast.....	64
3.4.3 Summer Spot Spray .....	65
3.4.4 Summer Spot Spray Vs. Wiping and Hand Pulling.....	68
3.5 Conclusions .....	69
Chapter 4.0 Conclusion.....	72
4.1 Overview .....	72
4.2 Overall Conclusions .....	72
4.3 Future Direction .....	76
References.....	78

## List of Tables

<b>Table 2. 1</b>	Parameter estimates for non-linear models describing spreading dogbane emergence timing at four sites in Nova Scotia in 2008 and 2009. ....	36
<b>Table 2. 2</b>	Confidence interval of each parameter comparison at four sites in Nova Scotia in 2008 and 2009.....	37
<b>Table 2. 3</b>	Parameter estimates for non-linear models describing spreading dogbane shoot height pattern at Salt Springs and Collingwood, NS sites in 2009. ....	41
<b>Table 2. 4</b>	Parameter estimates for non-linear models describing spreading dogbane flowering pattern at Salt Springs and Collingwood, NS sites in 2009. ....	42
<b>Table 2. 5</b>	Approximate timing for emergence, flowering, and seed set of spreading dogbane at Earltown, Salt Springs, NS in 2008 and Salt Springs and Collingwood in 2009. ....	46
<b>Table 3. 1</b>	Herbicide treatments applied POST in the summer and fall broadcast experiments in 2008 and 2009. ....	56
<b>Table 3. 2</b>	Herbicides evaluated for spreading dogbane control in summer spot spray experiments in Nova Scotia and Prince Edward Island, 2008 and 2009. ....	57
<b>Table 3. 3</b>	Summer broadcast herbicide efficacy on spreading dogbane and wild blueberry at Windham Hill and Salt Springs, Nova Scotia in 2008 and Oxford, Nova Scotia and Mt. Stewart, Prince Edward Island in 2009. ....	62
<b>Table 3. 4</b>	Spreading dogbane biomass following different herbicide combinations at Windham Hill and Salt Springs, Nova Scotia in 2008 and Oxford, Nova Scotia and Mt. Stewart, Prince Edward Island in 2009. ....	63
<b>Table 3. 5</b>	Blueberry floral buds count following different herbicide combinations at Windham Hill and Salt Springs, Nova Scotia in 2008 and Oxford, Nova Scotia and Mt. Stewart, Prince Edward Island in 2009. ....	64
<b>Table 3. 6</b>	Efficacy of fall broadcasts of herbicides on spreading dogbane and wild blueberry, Parrsboro, Nova Scotia, in 2008.....	66
<b>Table 3. 7</b>	Efficacy of herbicides spot spray on spreading dogbane and wild blueberry damage at Farmington and Collingwood, Nova Scotia in 2008, and Southampton, Nova Scotia and Mt. Stewart Prince Edward Island in 2009. .	67

**Table 3. 8** Effects of wiping and spot sprays on spreading dogbane and blueberry at Southampton, Nova Scotia and Mt. Stewart, Prince Edward Island 2009. ....68

**Table 3. 9** Effect of spot sprays and hand pulling on spreading dogbane at Salt Springs, Nova Scotia in 2008, Southampton, Nova Scotia and Mt. Stewart, Prince Edward Island in 2009.....69

## List of Figures

<b>Figure 1. 1</b>	Spreading dogbane blade (a) and leaves (b).....	7
<b>Figure 1. 2</b>	Spreading dogbane ramets (a, b), stems (c, d).....	8
<b>Figure 1. 3</b>	Spreading dogbane flower buds (a), flowers (b, c, d).....	9
<b>Figure 1. 4</b>	Spreading dogbane seed pods (a, b), and seeds (c, d).....	10
<b>Figure 2. 1</b>	Air temperature and precipitation data for Earltown, NS in 2008 (a), Salt Springs, NS in 2008 (b), Collingwood, NS in 2009 (c) and Salt Springs, NS in 2009 (d). .....	34
<b>Figure 2. 2</b>	Emergence model for spreading dogbane using a non-linear regression analysis combing data from Salt Springs 2008, Salt Springs 2009, and Collingwood 2009, and emergence model for data collected from Earltown 2008 only. For both models, $T_{base} = 6^{\circ} C$ .....	39
<b>Figure 2. 3</b>	Spreading dogbane shoot height as a function with Growing Degree Day at Salt Springs and Collingwood, NS 2009.....	40
<b>Figure 2. 4</b>	Spreading dogbane shoots with flower buds and flowers versus Growing Degree Day at Salt Springs and Collingwood, NS 2009.....	43
<b>Figure 2. 5</b>	Spreading dogbane flower buds and flowers as predicted by Growing Degree Day at Salt Springs and Collingwood, NS 2009.....	45



## **Abstract**

There is little information published on the phenology and biology of spreading dogbane (*Apocynum androsaemifolium* L.), a perennial weed that is considered a serious problem in wild blueberry fields. There is no known effective control technique for an established population. Therefore, a two year study was conducted to examine the growth dynamics of spreading dogbane in wild blueberry fields, and to monitor the suppressive effects of several herbicides and application techniques. The results show that spreading dogbane emergence at low GDD values and peak emergence occurred approximately 420 GDD. The optimal timing for POST herbicide application was predicted between 486 to 535 GDD. Result of this research also indicated that summer broadcasts of nicosulfuron with Merge, fall broadcast application of dicamba or dicamba plus nicosulfuron, spot spray with glyphosate, dicamba or primosulfuron and dicamba effectively controlled spreading dogbane with minimal blueberry damage as well as wiping with glyphosate and triclopyr.

## List of Abbreviations and Symbols Used

°C	Degrees Celsius
cm	Centimetre
ha	Hectare
kg	Kilogram
g	Gram
a.i.	Active ingredient
l	Litre
v/v	Volume per volume
NS	Nova Scotia

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## **Chapter 1.0 Introduction**

### **1.1 Introduction to the Problem**

Lowbush blueberry (*Vaccinium angustifolium* Ait.), commonly referred to as the wild blueberry, is a perennial deciduous shrub native to North America (Eaton 2005; Vander Kloet 1978). It is cultivated commercially in Canada and the United States (Yarborough and Bhowmik 1989). The wild blueberry industry is a significant part of Nova Scotia's provincial heritage and natural vegetation economy (Sibley 1987). The industry produced 16,503 tons of blueberries and contributed over \$13 million to the farm value in Nova Scotia in 2009 (Statistics Canada 2010). However, factors such as weather patterns, weed pressure, foliar disease, insect pests and poor pollination can drastically decrease wild blueberry yields. For example, in 2007 blueberry yields were 14% lower than 2006 and 35% below the 5-year average (Statistics Canada 2008). Decreased yields were primarily attributed to winter kill and weed pressure. Weeds are traditionally the major yield-limiting factor in commercial blueberry production (Jensen 2003). They compete with blueberry for water, light, nutrients and space. They can restrict blueberry clone expansion and reduce berry yields and quality (Kinsman 1993).

Spreading Dogbane (*Apocynum androsaemifolium* L.) is a perennial herb that reproduces by underground rhizomes and seeds (Bergweiler and Manning 1998; Sampson et al. 1990; Woodson 1930). It is considered a serious weed in wild blueberry fields because it spreads rapidly once established and is difficult to control due to its vegetative reproduction (Sampson et al. 1990). Spreading dogbane is competitive and may decrease blueberry yield and profits (Yarborough and Marra 1997). Yarborough and Bhowmik (1989) reported that spreading dogbane was one of the most frequent weeds in blueberry

fields in Maine with 57% occurrence in fields surveyed. A survey of blueberry fields in Quebec showed a 87.5% spreading dogbane occurrence in the Saguenay–Lac-Saint-Jean region (Lapointe and Rochefort 2001). In Nova Scotia, 3.6% spreading dogbane occurrence was reported in a weed survey of 115 sampled blueberry fields (McCully et al. 1991). Recent grower reports throughout the province suggest that spreading dogbane is becoming more common in Nova Scotia.

Extensive research has been done on hemp dogbane (*Apocynum cannabinum* L.), a related species with a somewhat similar growth habit. It is a problem in corn, soybean, wheat or sorghum fields, where conservation tillage is adopted (Ransom and Kells 1998; Webster and Cardina 1999; Webster et al. 2000). However, very little data has been published on the phenology and biology of spreading dogbane. We know very little about the growth dynamics of spreading dogbane in wild blueberry fields and there is no known effective control technique for an established population. The purpose of this project is to: 1) enhance our understanding of the phenology and biology of spreading dogbane; 2) develop a ramet emergence, shoot height and flowering model for spreading dogbane; 3) monitor the impact of different herbicide applications on spreading dogbane; 4) compare different management techniques for spreading dogbane control, and 5) propose an integrated weed management plan for spreading dogbane.

## **1.2 Background on Wild Blueberry and Blueberry Production**

Wild blueberry is native to eastern and central Canada (Yarborough and Marra 1997). It is a perennial low spreading deciduous shrub about 10 to 25 cm tall. Plants grow in well-drained acidic soils, with a pH between 3.9 and 5.5 (Eaton and Nams 2006;

Kinsman 1993). Wild blueberry develops from native stands or abandoned hay fields (Barker et al. 1964; Kinsman 1993). It reproduces and expands primarily by the dormant buds present on underground rhizomes (Hall 1957). Rhizomes can grow up to 38 cm in one growing season in managed fields (McIssac 1997). Its flowers are usually bell-shaped and white to pinkish-white in color. Leaves are alternate and the inflorescence is usually a raceme (Barker et al. 1964; Vander Kloet 1988). Fruit have a sweet taste with variable acidity when mature (Hall et al. 1979). Wild blueberries are a good source of Vitamin C and dietary fibre (Hancock and Draper 1989). They also contain many organic acids and polyphenolic substances (Kalt and MacDonald 1996; Prior et al. 1998). Studies have shown that antioxidants in wild blueberries provide many health benefits (Berman et al. 1999, Prior and Cao 2000).

Due to high demand for blueberries, the wild blueberry industry has grown over the past 50 years from a small local market economy to a significant international frozen food export business (McIssac 1997). North America is the principal commercial producer of wild blueberries with production occurring in the US state of Maine and the Canadian provinces of Quebec, Nova Scotia, Newfoundland, New Brunswick, and Prince Edward Island. Atlantic Canada contributed approximately 38% of total North American production of wild blueberry from 2001 to 2005 (Yarborough 2007). Nova Scotia is the largest producer of wild blueberries in Atlantic Canada, with over 65% of the berries grown in Cumberland County (McIsaac and Reid 2000). In Nova Scotia, the wild blueberry is the number one fruit crop with respect to export sales and natural vegetation economy (Kinsman 1993; Sibley 1987). In 2006, total production of wild blueberries in

Nova Scotia was 13.9 million kilograms, with a farm value of \$23.2 million (Nova Scotia Statistical Review 2007).

Commercial wild blueberry fields are not planted but are managed intensely to encourage blueberry clonal spread, usually under a two year production cycle on commercial lands. This two-year production strategy promotes development of long unbranched shoots that ease harvests, and makes insect and disease control easier during the vegetative year when no berries are present. Yields from this cultural system are also higher than berries harvested every year because the plants store energy up for a year before forming fruits (Eaton and Nams 2006). The “sprout year” follows field pruning, which is followed by the “crop year”, when fruits are harvested (Yarborough 2004). Typically commercial wild blueberry producers manage their fields so that one half is in the sprout phase of production, and the other half is in the crop phase (Kinsmen 1993). Pruning is conducted in the late fall or early spring of the sprout year when blueberry buds start to break to stimulate vegetative stem growth from the underground rhizomes. The vegetative stem grows until tip dieback which generally occurs in July or August (Barker et al. 1964; Smagula and DeGomez 1987). Vegetative or flowering buds develop in the basal and upper axils at approximately the same time. Most agronomic and pest management activities occur in the sprout year (Barker et al. 1964; Kinsman 1993). In the crop year, plants flower in late May or early June and fruit maturation tends to occur in the middle of August (Aalders et al. 1972).

### **1.3 Weeds in Blueberry Fields**

Any plant occurring in a wild blueberry field other than blueberry is considered to be a weed (Yarborough 1996). Weed pressure is one of the major factors inhibiting berry yields (Yarborough 2008a; Jensen 2003). Weeds compete with the blueberry plants for the resources necessary for adequate plant growth (Sampson et al. 1990). In 2007, the total production of wild blueberry in Nova Scotia dropped to 12 million kilograms, 14% lower than the record 2006 and 35% below the 5-year (2002-2006) average of 18.5 million kilograms (Makki 2008). This drop in yield was attributed at least in part to weed pressure. Weeds may also serve as alternate hosts for insects and diseases, hinder harvest, and contaminate blueberry packs (Jensen and Yarborough 2004). Weeds occurring in blueberry fields include surviving woodland species, annual and perennial grasses, and a composite of species from abandoned farmland (Jensen and Yarborough 2004).

Most difficult weeds to be controlled in the blueberry field are perennial, which live for more than two years (McCully et al. 2005). They reproduce by seeds, rootstocks and vegetative structures. Being a perennial, blueberries may have similar growth dynamics as these perennial weeds. Therefore, some production practices that promote blueberries growth and spread also promote those of these weeds. Herbaceous perennial weeds are traditionally the major problem in wild blueberry fields (Kinsman 1993; McCully et al. 2005). They are hard to control due to their vegetative reproductive structures and repeated treatments are typically needed to successfully control them (Ross and Lembi 1999). Perennial weeds can be effectively controlled at the seedling and early vegetative stages before they start to form reproductive structures (Ross and Lembi 1999).

The aggressive spread and persistence of perennials are likely due to the large



reserves of carbohydrates in the root and rhizome system (Becker and Fawcett 1998). After adequate aboveground photosynthetic structures develop, carbohydrates start to move downward to the underground structures. Therefore, the most effective time to implement chemical control is when the herbicide will move down with the carbohydrate into rhizomes, roots or other vegetative reproductive structures (Ross and Lembi 1999; McWhorter 1961a; McWhorter 1961b). This timing is reported to end at the early flower bud stage of the most perennial broadleaf weeds such as goldenrods (*Solidago* spp.) and black bulrush (*Scirpus atrovirens*) (Boyd and White 2009b).

#### **1.4 Spreading Dogbane**

Spreading dogbane, also known as wandering milkweed, rheumatism-wood or milkweed, is an herbaceous perennial in the family Apocynaceae. *Apocynum* is derived from Greek, with *apo* meaning “away from” or “bane”, and *kunon* meaning “dog”, implying that it was used as a poison for wild dogs and other animal pests in Greece (DiTommaso et al. 2009; Dalby 2004; Woodson 1930). Spreading dogbane is native to North America and is more frequently found on sandy or light soils (Hoeg and Burgess 2000). It usually grows in patches and reproduces by seed or vegetative buds on rapidly spreading rhizomes. All parts of spreading dogbane produce a milky latex sap. The following description is based on information taken from the literature (DiTommaso et al. 2009; Hoeg and Burgess 2000; Sampson et al. 1990; Woodson 1930), supplemented by observations made by the author.

**Leaves:** Spreading dogbane leaves are ovate or elliptic shape with a tapering point at the apex and the acute to round at the base. The margins are entire. Blades are bright to

dark green and smooth on the upper surface with a distinct white midvein and reticulate venation, while the underneath are whitish green and with downy hairs. Leaves are strongly drooping and opposite with short petioles. Leaves are largest near the middle of the stem and diminish toward the top and bottom, 5-9 cm long, 2.5-4 cm wide (Figure 1.1).



**Figure 1. 1** Spreading dogbane blade (a) and leaves (b)

**Stems:** Spreading dogbane stems are smooth and slender with a relatively lax, spreading habit. They can grow 20-100 cm tall. Emergence is generally late April to early May. The green stems often turn reddish-brown when mature, and the base of stems becomes woody as the shoot matures. Stems branch in the upper portions of the plant (Figure 1.2). Crown buds are located at the base of the stem, which are important for vegetative reproduction and begin growth each spring or following damage to the stem. In fall, the stems turn black and become hollow, dry and brittle.

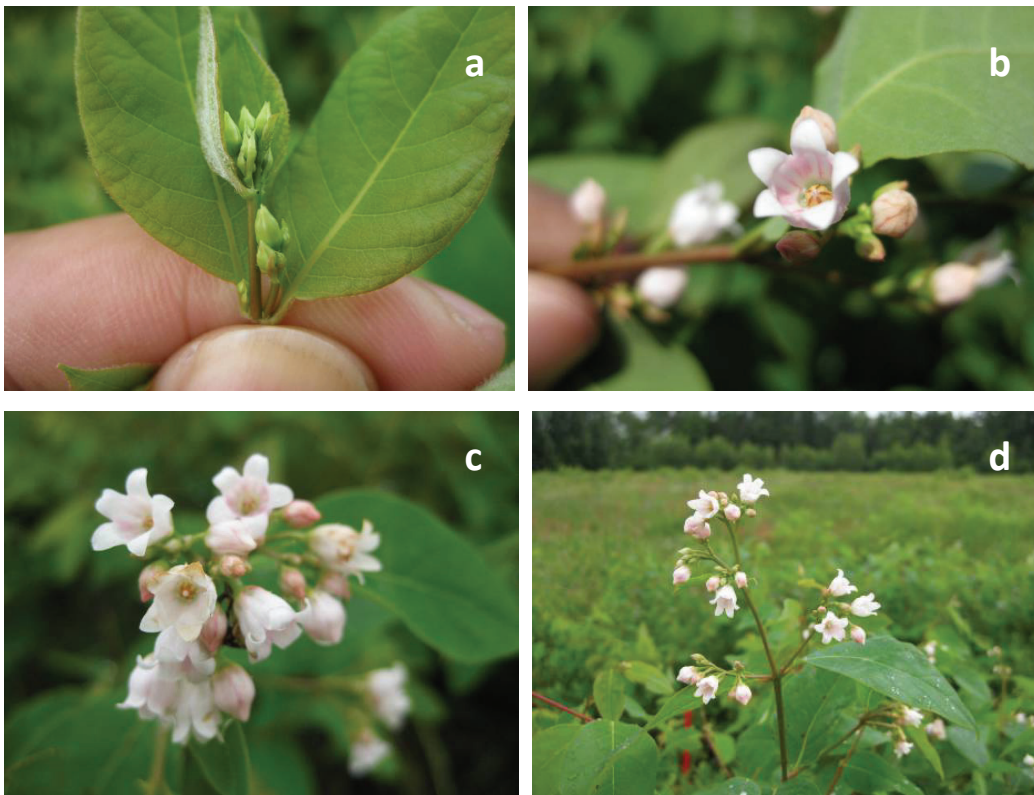


**Figure 1. 2** Spreading dogbane ramets (a, b), stems (c, d)

**Roots:** Spreading dogbane has an extensive, branched root system. It consists of a vertical primary and many lateral horizontal roots. A long horizontal rhizome with irregularly placed vegetative buds also develops from the initial taproot. New shoots may emerge from these buds forming on the horizontal roots and rhizomes. Vertical roots, which do not have buds, may penetrate the soil to a depth of 0.9-1.2 m.

**Flowers:** Spreading dogbane flowers are located in the upper leaf axils and form terminal cymes. They are small, greenish-white with pink stripes, and bell-shaped.

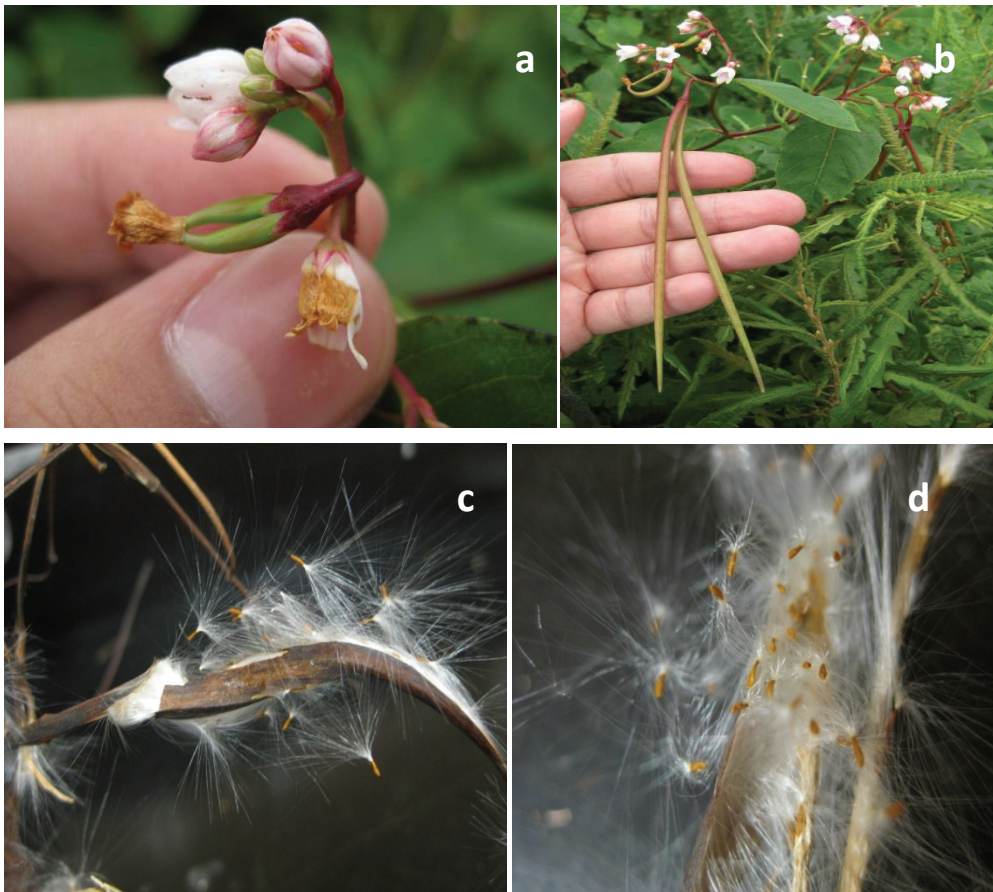
Flowers open from June to August. The flower is 5-10 mm long. The calyx is formed with 5 lobed sepals at flower base. It is usually about 1/3 as long as the corolla. Corollas are around 5.5-8 mm long, pinkish to white with dark pink veins, and are formed with 5 spreading, recurved petals. Within the tubular corolla, there are 5 tiny, triangular stamens. The arrow-shaped anthers unite around the stigma and slightly adhere to it (Figure 1.3). Two ovaries are located at the base of each flower and become follicle type fruits when mature.



**Figure 1. 3** Spreading dogbane flower buds (a), flowers (b, c, d)

**Fruits:** Each spreading dogbane flower produces slender, slightly curved, pencil-like follicles in pairs that are 5-15 cm long. The green pods turn reddish-brown and split in the front of the seed pod when mature. Seeds will release from these breaks. Each pod

contains numerous seeds. Seed of spreading dogbane is spike-shaped with silky white hairs at its end, 3-5.5 cm long. They are easily dispersed by wind. Seeds are 1.5-3mm long and 0.75 mm wide (Figure 1.4). Seeds are normally set in the late summer and mature in the early fall.



**Figure 1. 4** Spreading dogbane seed pods (a, b), and seeds (c, d)

Due to frequent hybridization and the extensive morphological variation between species in the genus, spreading dogbane is often confused with the closely related hemp dogbane (*A. cannabinum*). The leaves of hemp dogbane tend to be oblong to broadly lanceolate and are usually erect or slightly spreading from the stem, never drooping. Flowers are rarely axillary. The calyx is about  $\frac{1}{2}$  or more as long as the corolla. The corolla of hemp dogbane is shorter (2.5-4.5 mm) than that of spreading dogbane (5.5-8

mm). Five petals are erect or slightly spreading compared with strongly spreading or recurved of those in the spreading dogbane. There is no interior red marking on hemp dogbane's petals. Seeds of hemp dogbane are longer than 3 mm and bigger than spreading dogbane.

### **1.5 Hemp Dogbane**

Hemp dogbane (*A. cannabinum*) is a related species of spreading dogbane with a growth habit that is somewhat similar to it. Extensive research has been done on hemp dogbane and this information may contribute to our understanding of spreading dogbane. Hemp dogbane is one of the most troublesome perennial broadleaf weeds in corn (*Zea mays* L.) - soybean (*Glycine max* L.) rotations (Webster and Cardina 1999). It causes yield reductions in crops ranging from 0-10% in corn, 37-45% in sorghum (*Sorghum bicolor* L.) (Ransom and Kells 1998), and yield loss can exceed 55% in soybean at high hemp dogbane densities of 28 shoots per m<sup>2</sup> (Webster et al. 2000). In eastern and south-central Nebraska, a survey conducted in 1977 showed that nearly 96% of the farmers had hemp dogbane on their farm and 45% had had hemp dogbane over 20 years. In addition, 74% of the farmers responded that their infestations were still spreading under their present cropping systems and 70% responded that they have been spraying hemp dogbane 1 to 5 years to control it (Schultz and Burnside 1979a).

Control of hemp dogbane is difficult because of its persistent and extensive system of roots with adventitious buds. Reduced rates of triazine herbicides, the widespread use of herbicides with low efficacy on hemp dogbane, and relative low susceptibility to commonly used herbicides have contributed to the expansion of this weed (Webster and

Cardina 1999; Orfanedes and Wax 1991). Conservation tillage may help control perennial weeds by fragmenting roots and depleting root reserves (Robison and Jeffery 1972). However, intensive and repeated tillage may be necessary before achieving acceptable control (Orfanedes and Wax 1991).

Similar to hemp dogbane, spreading dogbane also occurs in patches, and spreads from seeds and rhizomes. It is commonly believed that spreading dogbane can also produce chemicals, which inhibit neighbouring plant growth (Hoeg and Burgess 2000). All of these characteristics make spreading dogbane a significant problem in many blueberry fields. A lack of susceptibility to herbicides and population persistence of spreading dogbane even under intense management is often reported in wild blueberry fields.

## **1.6 Integrated Weed Management**

Several management practices are used to increase blueberry cover and yield, including fertilizer management, pruning, pollination and control of insects, diseases and weeds (Kinsman 1993). In order to control weeds, effective weed management practices must be implemented (Yarborough 1996). It is important to remember that the use of one particular method, whether chemical or cultural, may inhibit some species while stimulating others. Changes in production practices over time may also result in an increasingly diverse weed flora. It is prudent to develop an integrated approach, combining multiple techniques so that weed populations can be reduced over time (DeGomez 1988). Blackshaw et al. (2005) noted that combining agronomic practices and herbicides improves weed management in wheat-canola rotations within no-tillage

production system. Harker et al. (2008) also reported that combining optimal agronomic practices can dramatically decrease weed infestations in barley production. It is reasonable to assume that similar results would occur in blueberry fields if integrated weed management approaches, including prevention, cultural techniques and herbicide application, are followed (Atlantic Comm. Fruit Crops 1999).

### **1.6.1 Prevention**

Preventative methods inhibit the dispersal of weed seeds or vegetative parts and stop the emergence of weed seeds, which are present in the soil (Yarborough 1996). It is important to know any activities that may lead to a buildup and spread of weed propagules. Boyd and Van Acker (2004) suggested that weed management practices should limit seed dispersal and discourage weed emergence during establishment periods. It is especially important in wild blueberries to clean field equipment, such as mowers, harvesters and tractors (Yarborough 1996). Harvesting equipment is a major vector of seed dispersal in blueberry fields and periodic cleaning of harvesting equipment between fields will help prevent the spread of weed seeds (Boyd and White 2009a).

### **1.6.2 Cultural Techniques**

Cultural practices may help to control weeds. Mulches change the environment at the soil surface and encourage blueberry rhizomes spread. Mulches can moderate soil temperature, reduce light intensity, increase soil moisture, reduce frost heaving and lead to a more efficient use of herbicides. Each of these factors may encourage clonal spread



(Chiasson and Argall 1996). Wood chips, sawdust or bark mulch could be used to encourage rhizome development and to cover bare spots within fields. Planting blueberry plants in bare spots also helps them fill in more rapidly and out compete weeds (DeGomez and Smagula 1990). Consistent blueberry cover will reduce weed establishment in open spaces (Yarborough 1996). Increased clonal growth of blueberry will result in greater yields by increasing plant stand densities. The presence of many clones in a wild blueberry field also provides a good fruit set by transferring pollen from different clones (Chiasson and Argall 1995a).

### **1.6.3 Physical Techniques**

#### **1.6.3.1 Pruning**

The primary purpose of pruning is to rejuvenate blueberry plants, but it also can control some weeds. Pruning is always conducted in the late fall of the crop year or early spring of the sprout phase of production when the plants are dormant (Rowe 1983; Warman 1987). Pruning can stimulate the growth of new stems from dormant buds on the rhizomes and thus increases yields.

Burning is a pruning technique used to improve productivity of wild blueberry fields (Penney et al. 1997). It encourages the new sprouts to grow, liberates nutrients for the growing plants; sanitizes the field by killing insects and pathogens, such as blueberry spanworm (*Itame argillacera* P.), blueberry flea beetle (*Altica sylvia* M.), blueberry sawfly (*Neopareophora litura* K.) and botrytis blight (*Botrytis cinerea* P.), (Chiasson and Argall 1995b). Pruning by burning can also eliminate some of weeds that spread by seeds

(Eaton and McIsaac 1997). Coniferous species and some shallow rooted grasses can also be controlled by burning (Atlantic Comm. Fruit Crops 1999).

However, pruning with fire is expensive and may negatively impact soil nitrogen and organic matter (Trevett 1956). Burning may also promote growth of underground root systems for many perennial weeds (Atlantic Comm. Fruit Crops 1999). Some rhizomatous perennial broadleaved weeds, such as spreading dogbane, bunchberry (*Cornus canadensis* L.), and goldenrods (*Solidago* spp.) survive low intensity pruning fires. Furthermore, these species often peak in the second or third year after burning which coincides with the crop cycle (Swan 1970). Proper prune burning destroys many weed seeds on the ground and creates open space for invaders such as fireweed (*Epilobium angustifolium* L.) and goldenrods (Jensen and Yarborough 2004; Rowe 1983).

Most commercial growers have replaced burning with mowing because the cost of mowing can be as low as one third of burning (Eaton and McIsaac 1997; Yarborough 2004). Stems chopped by the mower at ground level could reduce the hindrance to harvest by promoting growth of single vertical stems in the crop year and thus increasing the quality of the harvest (Chiasson and Argall 1995b). In addition to excellent weed control, the plant residue left on the soil surface improves water holding capacity, soil temperature and organic matter of the field (DeGomez 1988).

The disadvantage of mowing is the higher occurrence of disease and insects, and decreased yields from the presence of branched and unproductive plants if stems have not been cut properly (Chiasson and Argall 1995b). In addition, mowing does not destroy seeds that are on the soil surface and does not kill shallow rooted biennials and perennials

(Chiasson and Argall 1996). Repeated mowing is required to ensure permanent weed control (Atlantic Comm. Fruit Crops 1999).

### **1.6.3.2 Hand Pulling**

Hand pulling is an old but effective method of weed control. It can effectively control spot infestations of perennials when weeds are pulled before they form seed and the entire root system is removed (McCully et al. 2005; Yarborough 2008b). However, pulling is labour intensive and may release apical dominance if the vegetative system is not completely removed. It is also important to move weeds off the field, since many weeds can still produce seeds when lying on the soil surface (Marrs 1984).

### **1.6.4 Chemical Techniques**

Chemical control involves adopting different kinds of herbicides to manage weeds in the field (Yarborough 1996). Since the introduction of herbicides in the late 1940's, herbicides have been used as the primary methods of weed control in wild blueberry fields (Dill et al. 1998; Yarborough 1999). The widespread use of herbicides effectively controlled most common weeds and led to increased blueberry yields (Jensen 1985). Common herbicides used in blueberry fields are pre-emergence and post-emergence herbicides. Pre-emergence herbicides are mainly applied before blueberry and weed foliage emerge. These herbicides remain active in the soil for varying lengths of time and are taken up by plant roots. These herbicides are selective without blueberry injury when applied at the proper rate and time. Post-emergence herbicides include non-selective and

selective herbicides. Selective herbicides control specific weeds without causing blueberry damage when applied at right time and rate, while nonselective herbicides kill both weeds and crop plants. Therefore, extreme caution is needed to avoid contacting blueberry plants with non-selective herbicides (Jensen and Yarborough 2004).

Hexazinone, a pre-emergence selective herbicide, is the most widely used herbicides in wild blueberry fields. It drastically changed the weed flora in wild blueberry fields since its introduction in the early 1980s (Jensen 1985; Yarborough and Bhowmik 1989). It is a photosynthesis inhibitor that controls many grasses, sedges and herbaceous broadleaved weeds (McCully et al. 2005; Jensen 1985). Although hexazinone provides base level weed control, the long term effect of repeated hexazinone use also created several problems. The extreme water solubility and low sorption of hexazinone result in high soil mobility that can lead to surface and ground water contamination. Repeated use of hexazinone has also resulted in the development of herbicide resistance and the transition to tolerant populations (Yarborough and Bhowmik 1989). For example, spreading dogbane has developed hexazinone tolerance and is becoming increasingly common in many blueberry fields (Jensen 1985; Lapointe and Rochefort 2001). Other common registered pre-emergence herbicides used in wild blueberry include terbacil, which effectively controls grasses and some flowering herbaceous weeds and pronamide which effectively controls fescue species (*Festuca* spp.) and sheep sorrel (*Rumex acetosella* L.).

The diversity of weeds in blueberry is increasing with the repeat use of same herbicides, fertilizers, and changes of production practice (Jensen and Yarborough 2004). A weed survey conducted in Nova Scotia showed a doubling of species from 1984 to

2002 (McCully et al. 1991; Jensen and Sampson pers. comm.; Jensen and Yarborough 2004). Therefore, it is necessary to find post-emergence herbicides to control these new species. Some of the post emergence herbicides currently registered includes nicosulfuron/rimsulfuron and tribenuron methyl. Nicosulfuron/rimsulfuron is reported to control black bulrush (*Scirpus atrovirens* W.), at 0.031 g L<sup>-1</sup> water, in mid-summer with spot application (Jensen and Specht 2004). Broadcast application of tribenuron methyl, at 0.2 g L<sup>-1</sup> water with 0.2% v/v Agral, in spring of the sprout year is used for bunchberry control (Yarborough and D'Appollonio 2009). Spot application of tribenuron methyl at 2.5 g plus 20 mL Agral in 10 L of water can also control other weeds that are not controlled by hexazinone, such as: bracken fern (*Pteridium aquilinum* L.), yellow loosestrife (*Lysmachia terrestris* L.), common wild rose (*Rosa virginiana* M.) and speckled alder (*Alnus rugosa* L.) (Atlantic Food and Horticulture Research Centre 1998).

The three commonly used non-selective post-emergence herbicides are 2,4-D ester, dicamba and glyphosate. All of these herbicides provide good control of weeds but may injure blueberry plants. 2,4-D is a hormonal phenoxyalkanoic herbicide that effectively controls many woody and herbaceous broadleaf weeds. Dicamba can be applied alone or in combination with 2,4-D to control broadleaf weeds (Jensen and Yarborough 2004; Jensen and North 1987). Glyphosate is widely used today due to its broad range of weed control, providing control for many woody species and many herbaceous species, such as ferns, sedges and grasses. Control of woody species is improved with the addition of ammonium sulphate (Yarborough and Hess 2000). Due to severe crop injury with contact, selective means of applying non-selective herbicides are required to minimize crop contact and injury. Therefore, a number of different application techniques are employed.

Broadcast spray, the application of herbicides over a large area with a boom sprayer, is recommended for spraying a uniform rate of herbicide, or to treat large infestations of some species. Most pre-emergence and some selective post-emergence herbicides are applied in this way (McCully et al. 2005). Non-selective herbicides can be broadcasted if: i) the weed canopy is tall and dense enough to intercept most of the sprays, such as is the case of bayberry (*Myrica pensylvanica* M.) and sweet-fern (*Comptonia peregrine* L.) (Jensen and Yarborough 2004); or ii) spraying occurs in the fall or spring for the control of evergreen weed species, such as sheeplaurel and teaberry (*Gaultheria procumbens* L.) when blueberry is dormant. In mid-fall, blueberry foliage will have senesced so that herbicide cannot be translocated through the plant. These herbicides includes: dicamba and 2,4-D (McCully et al. 2005).

Spot sprays are applied with backpack or handheld sprayers or through wiper applications, which wipe herbicide to the foliage of weeds by an absorbent covered drum. Spot sprays are useful for weeds that are taller than blueberry plants. Wiping both sides of foliage improves coverage and results in better control. A commercially available “hockey-stick” applicator has been used widely for wiping (Jensen and Yarborough 2004). Both spot spray and wiper application can be adopted by non-selective herbicides to avoid injuring or killing blueberry plants through crop contact.

## **1.7 Response to Herbicides**

There is no published research on spreading dogbane susceptibility to herbicides, but several studies have been conducted on herbicide control of hemp dogbane. Although the herbicide efficacy may vary between these two species, this information still could be

used as a good starting point. The effectiveness of herbicide applications on hemp dogbane is not consistent due to different edaphic, climatic and biotic factors (Schultz and Burnside 1980)

**Glyphosate** Glyphosate is among the most efficacious herbicides for controlling hemp dogbane (Webster and Cardina 1999). The low foliar uptake may result in the limited control of hemp dogbane with glyphosate. Only 0.1% of applied glyphosate passes through the leaf cuticle of 5 to 6 week old hemp dogbane seedlings (Wyrill and Burnside 1976). But glyphosate can control hemp dogbane. Barnes and Brenchley (1972) reported that the isopropylamine salt of glyphosate [N (phosphonomethyl) glycine] gives 90% control at 3.4 kg a.i. ha<sup>-1</sup> when sprayed at the early bud stage of hemp dogbane and better control can be obtained by fall application of glyphosate to regrowth, following mowing or tillage earlier in the summer (DiTommaso et al. 2009; Curran et al. 1997). In contrast, Doll (1997) found that glyphosate application targeting the early and full flower stages was more effective at all rates used (630 -1680 g a.i. ha<sup>-1</sup>) than application against the vegetative and bud stages.

**2,4-D and dicamba** Schultz and Burnside (1979b) observed that hemp dogbane is sensitive to 2,4-D and dicamba when appropriate rates are used at the proper growth stage. Orfanedes and Wax (1991) found that 2,4-D applied alone (560 g a.i. ha<sup>-1</sup>) provided 79-89% control of hemp dogbane. The ester form of 2,4-D (40-140 g a.i. ha<sup>-1</sup>) worked better than the 2,4-D amine (70-280 g a.i. ha<sup>-1</sup>) (Schultz and Burnside 1978; Ransom and Kells 1998). Tank mixtures of 2,4-D (1120 g a.i. ha<sup>-1</sup>) and dicamba (280 g a.i. ha<sup>-1</sup>) suppress growth of hemp dogbane well, but additional application in the second year is needed to maintain suppression (DiTommaso et al. 2009; Ransom and Kells 1998).

**Nicosulfuron** The efficacy of nicosulfuron (35 g a.i. ha<sup>-1</sup>) for hemp dogbane control was as well as dicamba (560 g a.i. ha<sup>-1</sup>) (Glenn et al. 1997). Dobbels and Kapusta (1993) found that tank mixtures of nicosulfuron with dicamba or 2, 4-D controlled hemp dogbane well. Compared to either herbicide applied alone, tank mixtures of nicosulfuron with dicamba provided better control of hemp dogbane (Glenn and Anderson 1993; Kalnay and Glenn 2000).

**Primisulfuron** 80-90% control of hemp dogbane was obtained when primisulfuron (20 g a.i. ha<sup>-1</sup>) was applied to 12-30 cm tall plants (Doll 1994). Tank mixtures of primisulfuron and dicamba were found to provide > 85% control of hemp dogbane (Curran et al. 1997)

**Thiocarbamates** Schultz and Burnside (1979b) found that thiocarbamates can effectively control regrowth of hemp dogbane from crown and lateral roots, and also preplant application can be helpful for subsequent application of 2,4-D.

## **1.8 Weed Biology and Ecology**

Weed biological information is important in weed management. A good integrated weed management system requires a better understanding of weed biology and ecology (Ghersa and Holt 1995). Understanding the weed biology, life cycle, emergence patterns or seed production may allow us to predict the optimum timing for weed management, whether mechanical or chemical (Webster and Cardina 1999). Research has shown that herbicide applications in September provide better control of hemp dogbane (85%) than those applied in June and October (0 and 52%, respectively) because the sprouting and



regrowth of hemp dogbane is low in the early reproductive growth stage (Schultz and Burnside 1979b).

Plant modeling is a very useful tool to better understand weed biology. It provides a framework to predict establishment, growth, and competitiveness of weeds (Schreiber 1982). The time of weed development in the field is influenced by environmental factors, such as light, temperature, moisture, and soil structure (Forcella et al. 2000). Plant development related to thermal time accounts for the effect of temperature on development (Shirtliffe et al. 2000). Therefore, the cumulative effect of temperature, expressed as growing degree-days, has been widely used in plant modeling. It allows precise estimates of a plant's growth and development in varied temperatures. Growing degree day can be easily calculated by subtracting the base air temperature from the average of the maximum and minimum daily air temperatures (Robles et al. 2003).

Thermal time models have been shown to predict emergence of a variety of annual weed species, but information for perennial weed species emergence is very limited. Notable examples of thermal models developed for perennial weed emergence include hemp dogbane in reduced tillage systems (Webster and Cardina, 1999), and johnsongrass (*Sorghum halapense* L.) in corn (Satorre et al. 1985), which was used to improve the timing of herbicide applications for johnsongrass control (Ghersa et al. 1990).

Very little data have been published on biology and phenology of spreading dogbane. It is not well known how spreading dogbane development in wild blueberry fields. Due to its importance as a weed, an effort should be made to quantify spreading dogbane growth and development with thermal units. By building thermal models for shoot emergence, shoot height and flowering, a phenology table can be created to decide the optimal timing

for spreading dogbane control. There is also no known effective means for spreading dogbane control. Although many researches have been done on hemp dogbane chemical control, whether these potential herbicides work on spreading dogbane in wild blueberry field is unknown. Therefore, screening trials should be conducted to determine the optimal options of herbicides and application techniques so that the best management plans for spreading dogbane control could be found.

## **Chapter 2.0 Modeling Spreading Dogbane Development in Wild**

### **Blueberry Fields**

#### **Abstract**

Spreading dogbane (*Apocynum androsaemifolium* L.) is a common perennial weed in wild blueberry fields. It is highly competitive and spreads rapidly once established. Emergence patterns, shoot height and timing of flowering of spreading dogbane were determined in 2008 and 2009 to develop models and predict optimum herbicide application timing. Spreading dogbane ramet dynamics and height were adequately described by a three parameter sigmoid nonlinear regression model and the flowering model was well fitted with a four parameter weibull nonlinear regression model. Results indicate that spreading dogbane ramets initiate emergence at low GDD. Peak emergence tended to occur at 420 GDD. Spreading dogbane reached peak height by about 558 GDD. The maximum number of flowers per plant was reached at approximately 750 GDD. In terms of management, the best time to manage spreading dogbane by post-emergence (POST) herbicides should be initiated between 486 to 535 GDD, when dogbane started to form flower buds and flowers.

## 2.1 Introduction

Spreading dogbane (*Apocynum androsaemifolium* L.) is a perennial herb that is considered a serious problem by wild blueberry growers in eastern North America (Yarborough and Marra 1997). It reproduces by underground rhizomes and seeds (Bergweiler and Manning 1998; Woodson 1930). Pencil-like seed pods contain many small seeds with tufts of white fiber, which are easily dispersed by wind. Spreading dogbane spreads rapidly once established due to its vegetative reproduction on spreading rhizomes and can decrease blueberry yields and field profitability (Sampson et al. 1990; Yarborough and Marra 1997). Yarborough and Bhowmik (1989) reported that spreading dogbane was one of the most common weeds in blueberry in Maine, occurring in 57% of fields. Lapointe and Rochefort (2001) found that in the Saguenay–Lac-Saint-Jean region of Quebec, spreading dogbane is in 87.5% of fields. A survey conducted in Nova Scotia in 1991 found that spreading dogbane was found in 3.6% of 115 blueberry fields (McCully et al. 1991), but recent grower reports suggest that it is becoming more common in Nova Scotia fields.

Plant modeling provides a framework to predict establishment, growth, and competitiveness of weeds (Schreiber 1982). Timing of plant development is influenced by a range of environmental factors including light, temperature, moisture, and soil atmosphere (Forcella et al. 2000), and plant development is largely explained by thermal time (Shirtliffe et al. 2000). Therefore, the cumulative effect of temperature, expressed as growing degree-days (GDD), has been widely used in plant modeling. It can be easily calculated by subtracting the base air temperature from the average of daily air temperatures (Robles et al. 2003). This model relates plant development to temperature

rather than calendar days, to avoid reducing accuracy in years with unusual weather conditions (Cardina et al. 2007; Lawson et al. 2006). Therefore, thermal model allows precise estimates of a plant's development in varied environments.

Thermal time models have been shown to predict emergence of a variety of annual weed species, but information for perennial weed species emergence is very limited. Notable examples of thermal models developed for perennial weed emergence include hemp dogbane (*Apocynum cannabinum* L.) in reduced tillage systems (Webster and Cardina 1999), Canada thistle (*Cirsium arvense* L.) in common wheat (*Triticum aestivum* L.) (Donald 2000), and johnsongrass (*Sorghum halapense* L.) in corn (Satorre et al. 1985). These models provide a better understanding of how environmental factors affect growth, competitive interactions of crop and weeds, and weed phenology (Robles et al. 2003). Phenological predictions allow more accurate estimates of timing of biotic events and thus allow developing more specific control methods, specifically improving the timing of herbicide applications (Ghersa and Holt 1995).

Little is known about the biology of spreading dogbane and there is no model or tool that can be used to predict spreading dogbane phenological stages. Such a tool could enable more effectively timed control measures for dogbane. The objectives of this research were to: 1) develop a model of spreading dogbane ramet emergence, shoot height, and flowering in commercial wild blueberry fields using growing degree days; and 2) develop a phenological table for spreading dogbane and estimate optimal timings for herbicide applications.

## **2.2 Materials and Methods**

### **2.2.1 Study Sites**

Study sites in 2008 and 2009 were located in commercially managed wild blueberry fields. In 2008, dogbane emergence was monitored in fields located at Earltown (45° 34' 39.94" N, 63° 8' 16.48" W) and Salt Springs (45°30'44" N , 63°00'40" W), Nova Scotia. Both fields were in the “prune year” of the wild blueberry production cycle. Soils at the Earltown sites were well drained sandy loams to gravelly sandy loams of the Westbrook Soil series (Nowland and MacDougal 1973). Soil at the Salt Springs site was an imperfectly drained gravelly sandy loam of the Millbrook soil series (Webb et al. 1991).

In 2009, the emergence of spreading dogbane was monitored in the “crop year” of production at Salt Springs and Collingwood (45° 36' 35.941" N, 63° 47' 09.797" W), Nova Scotia. Soil at the Collingwood site is a stony, well drained sandy loam of the Rodney soil series (Nowland and MacDougall 1973).

### **2.2.2 Data Collection**

Dogbane ramets were counted twice per week within in four 1 m<sup>2</sup> quadrats at each site throughout the summer until new shoots were no longer emerging. Quadrats were placed in the early spring in the areas that spreading dogbane were predicted to emerge, where dead spreading dogbane was existing. Total ramet number in each quadrat at each count was divided by the maximum number of ramets recorded in the quadrat in the

season to determine percent of maximum ramet emergence. Percentage of maximum ramet emergence in each site was used to reflect emergence timing at different sites.

In 2009, the height of spreading dogbane was measured throughout the growing season. The maximum height and timing of this event was also recorded. The number of shoots with flower buds and flowers was recorded in each quadrat. Total number of shoots with flower buds or flowers in each quadrat at each count was divided by the maximum number of shoots with flower buds or flowers recorded in each quadrat in the season to determine percent of maximum shoots with flower buds or flowers. Flower buds and flowers per plant were also recorded in three individual dogbane plants in each quadrat and counted the percent of maximum flower buds and flowers per plant in the same way.

### **2.2.3 Air and Soil Temperature**

Hourly temperature data was collected with a HOBO Pro v2® temperature logger placed 75 cm above ground and the soil probes was placed 2.5 cm below the soil surface at each site. Initial counts occurred on May 6 (Julian Day 127) at Earltown, May 14 (Julian Day 134) at Salt Springs in 2008 and in 2009 on April 29 (Julian Day 119) at Collingwood and on May 13 (Julian Day 133) at Salt Springs.

The biofix date, which is the start date for determining cumulative GDD, was set at April 1 (Julian Day 92 in 2008 and Julian Day 91 in 2009) because GDD are rarely accumulated before this date (Martinson et al. 2007). Air temperature data prior to logger establishment was obtained from the Environment Canada (EC) weather stations located

closest to each site. Air temperature data for Salt Springs was obtained from the EC weather station located at Caribou Point, Nova Scotia (45° 46.200' N, 62° 40.800' W, elevation of 2.4 m) in 2008 (Julian Day 92 to day 133) and 2009 (Julian Day 91 to day 132). This weather station is located 27 km north of Salt Springs. Data from the EC weather station at Debert, Nova Scotia (45° 25.200' N, 63° 28.200' W, elevation of 37.5 m) was used for Earltown in 2008 (Julian Day 92 to day 126). The station is 49 km southwest of Earltown. Air temperature data for Collingwood was obtained from the EC weather station located at Nappan, Nova Scotia (45° 45.600' N, 64° 14.400' W, elevation of 19.8 m) in 2009 (Julian Day 91 to day 118). The station is 29 km northwest of Collingwood.

GDD were calculated using the equation:

$$GDD = \sum (T_{\text{aver.}} - T_{\text{base}}) \quad [1]$$

where  $T_{\text{aver.}}$  is the average daily air or soil temperature, and  $T_{\text{base}}$  is the base temperature for a specific plant species to occur biochemical reactions (Hacault and Van Acker 2006).

#### 2.2.4 Statistical Analysis

Ramet emergence, shoot height and flowering data were analyzed in SAS using Proc NLIN to fit non-linear models (SAS Institute 1999). Emergence at different times was expressed as the average of percentage of the maximum ramet emergence in the season in each site and represented as a function of cumulative growing degree days. A sigmoid, 3 parameter model was fitted to the data:

$$y = a / (1 + e^{-(x-x_0)/b}) \quad [2]$$



where  $y$  is the dependent variable (percent of maximum ramet emergence),  $x$  is cumulative air GDD, and  $e$  is the base of the natural logarithm. The parameters  $a$ ,  $b$ ,  $x_0$  are nonlinear parameter estimates, where  $a$  is asymptote (the estimated value of maximum emergence),  $b$  is a curve shaped parameter,  $x_0$  is the GDD at 50% emergence.

Spreading dogbane height at different times during the season was expressed as an average of the percentage of the maximum height per quadrat and fitted with sigmoid, 3 parameter model as well. In this model,  $y$  is percent of maximum dogbane height and  $x$  is cumulative air GDD. The parameter  $a$  is the estimated value of maximum height and  $x_0$  is the GDD at 50% height.

Flowering data at different times were also expressed as an average of the percentage of the maximum shoots with flower buds or flowers in the season in each site, and the percentage of maximum flower buds or flowers per plant. A peak, weibull 4 parameter model was fitted to the data:

$$y = a \left( \frac{c-1}{c} \right)^{\left( \frac{1-c}{c} \right)} \left[ \left( \frac{x-x_0}{b} \right) + \left( \frac{c-1}{c} \right)^{\left( \frac{1}{c} \right)} \right]^{c-1} e^{- \left[ \left( \frac{x-x_0}{b} \right) + \left( \frac{c-1}{c} \right)^{\left( \frac{1}{c} \right)} \right]^c + (c-1)/c}$$

[3]

where  $y$  is the cumulative percentage shoots with flower buds and flowers, or the cumulative percentage flower buds and flowers at cumulative GDD,  $a$  is the asymptote (theoretical maximum for  $y$  normalized to 100%),  $b$  and  $c$  are the location parameter and curve shaped parameter, respectively, and  $x_0$  is the GDD in the midpoint.

The residual sum of squares and corrected total sum of squares from the nonlinear regression analysis were used to calculate the coefficients of determination ( $r^2$ ) between

the predicted model and the observed field data. Standard errors of parameters estimates, a measure of confidence, are presented to indicate variability of the mean.

The model parameters of emergence pattern at four sites (Earltown-08, Salt Springs-08, Salt Springs-09 and Collingwood-09) were compared by forming six pairs (Earltown-08 vs. Salt Springs-08, Earltown-08 vs. Salt Springs-09, Earltown-08 vs. Collingwood-09, Salt Springs-08 vs. Salt Springs-09, Salt Springs-08 vs. Collingwood-09, Salt Springs-09 vs. Collingwood-09) and completing extra sum of squares analysis on the corresponding nested nonlinear regression with incremental parameters model stated as:

$$y = (a + \Phi_1 Ind) / (1 + e^{-(x - (x_0 + \Phi_3 Ind)) / (b + \Phi_2 Ind)}) \quad [4]$$

Where  $\Phi_1, \Phi_2, \Phi_3$  are the incremental parameters and  $Ind$  is an indicator variable. For example, to compare Earltown-08 and Salt Springs-08, the data from the two were combined, and the values of  $Ind$  were set at zero whenever the data were from Earltown-08, and the values of  $Ind$  were set at one whenever the data were from Salt Springs-08. Therefore, in model [5], parameters for Salt Springs-08 are  $a + \Phi_1, b + \Phi_2$  and  $x_0 + \Phi_3$ , respectively. A null hypothesis  $\Phi_1 = 0$  is equivalent to testing whether the models for Earltown-08 and Salt Springs-08 have the same 'a'. The other incremental parameters were interpreted the same way. After completing the analysis of the individual and nested sigmoid models, and using the NLIN procedure of SAS, the difference between each parameter comparison were determined.

For height and flowering data, the model parameters of the Salt Springs-09 and Collingwood-09 sites were compared in the same manner along with an extra sum of squares analysis on the corresponding nested nonlinear regression with an incremental

parameters model. Since height model used the same model as emergence data, the incremental parameters model for height was exactly same as formula [4]. The model for flowering data was stated as:

$$y = (a + \Phi_1 Ind) \left( \frac{((c + \Phi_3 Ind) - 1)}{(c + \Phi_3 Ind)} \right)^{\frac{(1 - (c + \Phi_3 Ind))}{(c + \Phi_3 Ind)}} \left[ \frac{((x - (x_0 + \Phi_3 Ind)) / (b + \Phi_2 Ind))}{\left( \frac{((c + \Phi_3 Ind) - 1)}{(c + \Phi_3 Ind)} \right)^{\frac{1}{(c + \Phi_3 Ind)}}} \right]^{(c + \Phi_3 Ind) - 1} e^{-\left[ \frac{((x - (x_0 + \Phi_3 Ind)) / (b + \Phi_2 Ind))}{\left( \frac{((c + \Phi_3 Ind) - 1)}{(c + \Phi_3 Ind)} \right)^{\frac{1}{(c + \Phi_3 Ind)}}} \right]} + \frac{((c + \Phi_3 Ind) - 1)}{(c + \Phi_3 Ind)} \quad [5]$$

Where  $\Phi_1, \Phi_2, \Phi_3, \Phi_4$  are the incremental parameters and  $Ind$  is an indicator variable, the incremental parameters and indicator variable are interpreted in the same way as the emergence data.

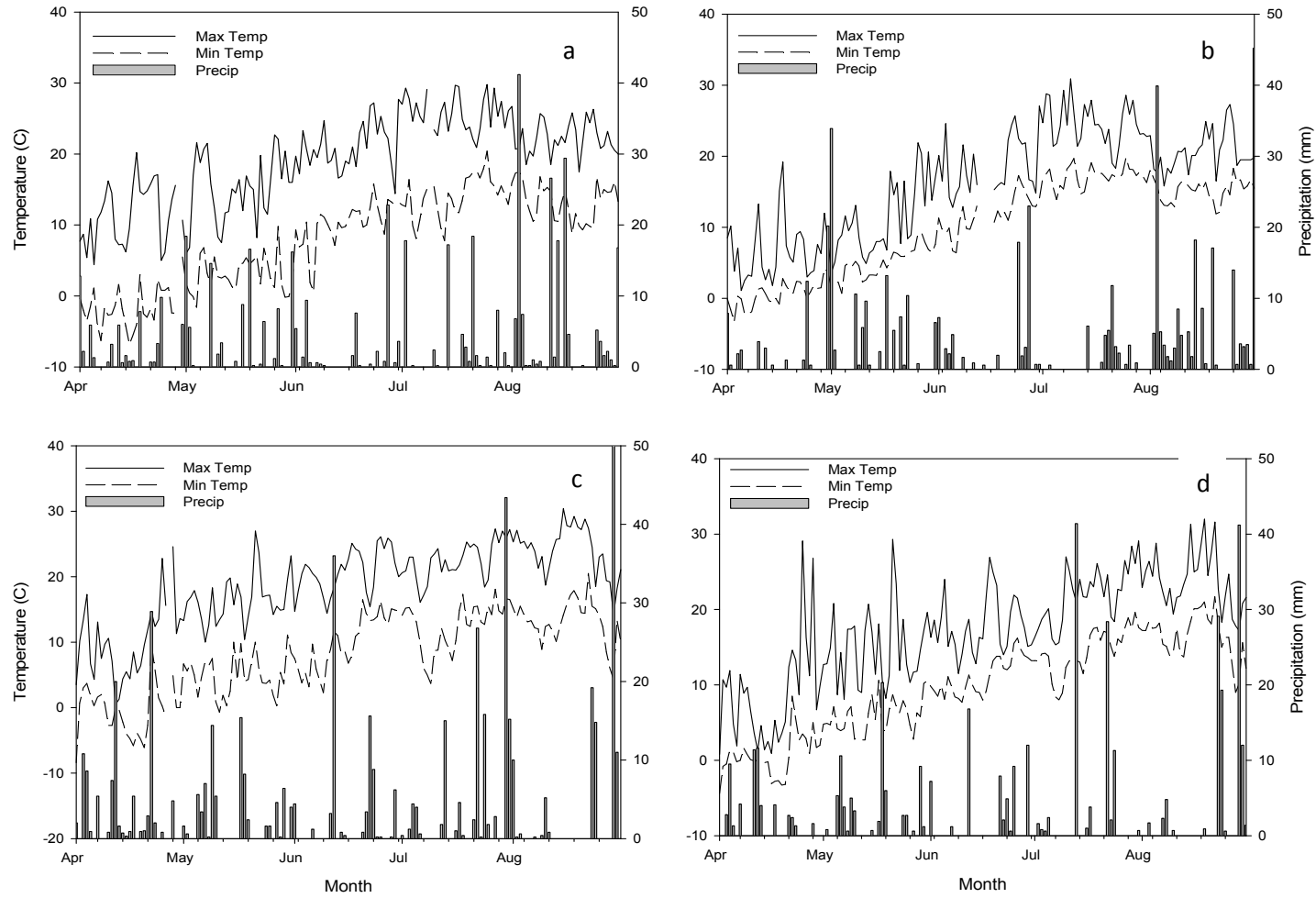
## 2.3 Results and Discussion

### 2.3.1 Meteorological Data

In 2008, precipitation levels were similar at Earltown and Salt Springs between April and August. Both sites received more precipitation in May and August than either site in 2009. In 2009, Collingwood tended to receive more rainfall than Salt Springs throughout the summer. Rainfall at Collingwood was especially high during the month of April (Figure 2.1). Average daily mean temperatures in late April 2008 and 2009 for all sites were below 6° C (the base temperature typically used when modeling hemp dogbane emergence (Webster and Cardina 1999; Webster et al. 2000)) as recorded by the Environment Canada weather stations (Figure 2.1). Temperature started to rise in mid April.

A typical Nova Scotia spring is very damp so it is unlikely that the distribution of spreading dogbane in blueberry fields is moisture limited (Figure 2.1). It is more likely that ramet emergence is temperature driven and as a result growing degree day models were chosen.

Plant development can be expressed in thermal time to facilitate comparisons of plant development across different environments (Lawson et al. 2006, Shirtliffe et al. 2000). An appropriate base temperature is required to obtain a reliable model (Cardina et al. 2007). In the absence of information regarding the actual base temperature for a specific plant species a  $T_{\text{base}}$  of  $0^{\circ}\text{C}$  is used by default in many plant development studies (Bullied et al. 2003; Shirtliffe et al. 2000). However,  $0^{\circ}\text{C}$  probably is too low for the majority of weed species based on current knowledge of biochemical reactions. The base temperature for spreading dogbane is unknown but a base temperature of  $6^{\circ}\text{C}$  was estimated from preliminary studies for hemp dogbane which is also in the Apocynaceae family (Webster and Cardina 1999; Webster et al. 2000). Therefore, the emergence curves were developed using a  $T_{\text{base}}$  of  $6^{\circ}\text{C}$  based on observed emergence timing and research with hemp dogbane.



**Figure 2.1** Air temperature and precipitation data for Earltown, NS in 2008 (a), Salt Springs, NS in 2008 (b), Collingwood, NS in 2009 (c) and Salt Springs, NS in 2009 (d).

Soil temperature fluctuated less than air temperature. This is not surprising given that in blueberry fields, heat holding capacity of soil is high because of covered dense mats of organic matter in soil surface. The soil temperature data recorded by Hobo data loggers in each site showed that the variance of daily soil temperature did not exceed 10° C. The decision was made to base our models on air temperature because: (i) it is difficult for growers to obtain consistent soil temperature data, (ii) air temperature rather than soil temperature has been used to calculate cumulative GDD in many studies (Cardina et al. 2007; Lawson et al. 2006; Satorre et al. 1985), and GDD calculated from air and soil temperatures were highly correlated in blueberry fields ( $r^2=0.9994$ ), (Scott White pers. comm.). Results showed that soil temperatures recorded by Hobo® data loggers at each field site were highly correlated with regional Environment Canada air temperature data ( $r^2=0.90$ ).

### **2.3.2 Spreading Dogbane Ramet Emergence**

Spreading dogbane emergence was first analyzed separately for each site. Emergence at each site was well described by a three parameter non-linear regression model in this study (Table 2.1). Model parameters for each site were compared to determine if it was possible to develop a pooled model for all sites. The differences between each parameter can be compared using an incremental parameter model. If no significant difference is observed between parameters, then the models are not significantly different and a single model can be developed. Only one parameter is different that is enough to suggest that it needs to be modeled separately. Based on results from the NLIN procedure for each parameter, only Earltown in 2008 was significantly

different from the other three sites (Table 2.2). Therefore, Earltown in 2008 was analyzed separately.

**Table 2. 1** Parameter estimates for non-linear models describing spreading dogbane emergence timing at four sites in Nova Scotia in 2008 and 2009.

Site	Model Parameter <sup>a</sup>			
	a	b	x <sub>0</sub>	r <sup>2</sup>
08 Earltown	0.65	40.12	233	0.99
08 Salt Springs	1.11	147.91	214	0.94
09 Salt Springs	1.3	101.3	244	0.93
09 Collingwood	1.0	85.8	152	0.86
Combined model <sup>b</sup>	1.0	107.5	184	0.86

<sup>a</sup> Formula of model is  $y = a / (1 + e^{-((x-x_0)/b)})$ , parameter *a* is the estimated value of maximum emergence, *b* is a curve shaped parameter, *x*<sub>0</sub> is the GDD at 50% emergence; r<sup>2</sup> is coefficient determination.

<sup>b</sup> Combined Salt Springs-08,-09 and Collingwood-09 data together.

At Earltown-08, spreading dogbane ramet emergence only achieved 65% of the maximum observed at that site. The low percentage of cumulative emergence is perhaps one reason the model of Earltown in 2008 was significantly different than those generated at the other sites. The ramets at Earltown may also have had less vigour because they were treated repeatedly with dicamba for several years and there was evidence of an unknown bacterial disease that first was noticed in mid June. The disease tended to kill early emerging ramets resulting in regrowth from the dormant crown buds. Ramet height

was also shorter in Earltown than at the other three sites. All of these variables combined probably explain the observed emergence differences.

**Table 2. 2** Confidence interval of each parameter comparison at four sites in Nova Scotia in 2008 and 2009.

Comparison	95% Confidence Interval		
	Phil1 <sup>a</sup>	Phil2	Phil3
08 Earltown vs. 08 Salt Springs	0.08~0.81* <sup>b</sup>	-136.6~88.07	42.83~168.9*
08 Earltown vs. 09 Salt Springs	-0.03~1.37	-108.8~133.1	7.24~116.3*
08 Earltown vs. 09 Collingwood	-0.02~0.63	-154.8~-13.93*	-11.87~100.1
08 Salt Springs vs. 09 Salt Springs	-0.8~1.24	-180.1~252.9	-151.7~63.51
08 Salt Springs vs. 09 Collingwood	-0.82~0.54	-261.3~141.0	-180.7~57.29
09 Salt Springs vs. 09 Collingwood	-1.62~0.9	-318.0~124.9	-127.9~92.65

<sup>a</sup> Parameter phil1 measures the difference between parameter  $a$  in each comparison, parameter phil2 measures the difference between parameter  $b$ , and parameter phil3 measures the difference between parameter  $x_0$

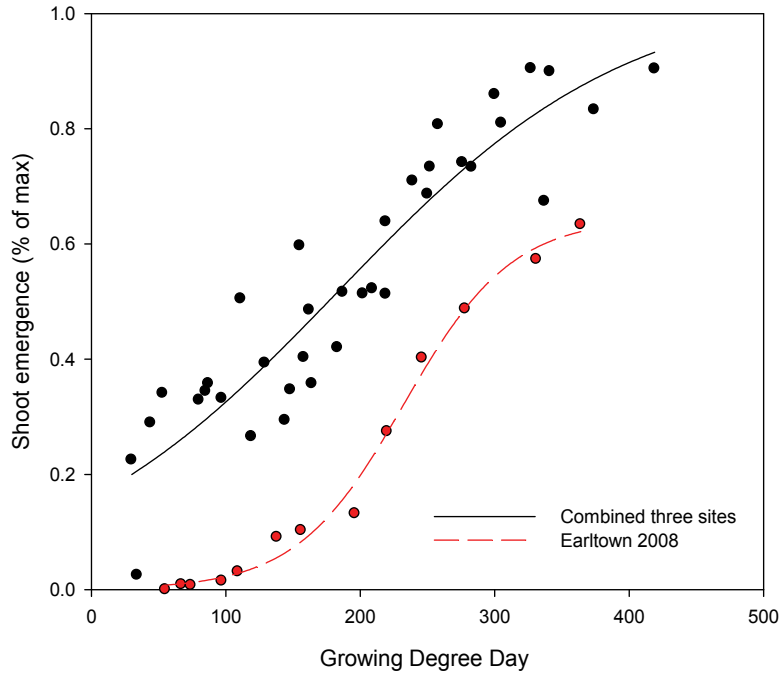
<sup>b</sup> “\*” represents a significant difference between two parameters in each comparison.

A single emergence model was developed for Salt Springs, 2008 and 2009 and Collingwood 2009 (Figure 2.2). The model suggests that 20% ramet emergence would occur at 0 GDD, which may be contributed by the missing initial count in the early summer. The initiate emergence was observed at April 29 (GDD 34) in Collingwood 2009, but approximately 19% and 36% of the maximum number of recorded ramets emerged at first count at May 16 (30 GDD) in Salt Springs 2008 and May 13 (85 GDD) in Salt Springs 2009, respectively. This indicated that spreading dogbane emergence likely began in late April and early May but cannot be accurately predicted with this



model due to late quadrat establishment. Fifty percent ramet emergence ( $x_0$ ) occurred between 152 and 244 GDD with a mean  $x_0$  of 184 GDD for the combined model. Emergence continued for approximately 7 weeks at all three sites and increased steadily until maximum ramet emergence was reached at around 420 GDD. For Earltown-08, initial emergence occurred at 67 GDD, fifty percent ramet emergence at 233 GDD and maximum ramet emergence (65%) was achieved at around 409 GDD. The late initiate emergence was likely due to the less vigour of the plant in Earltown-08.

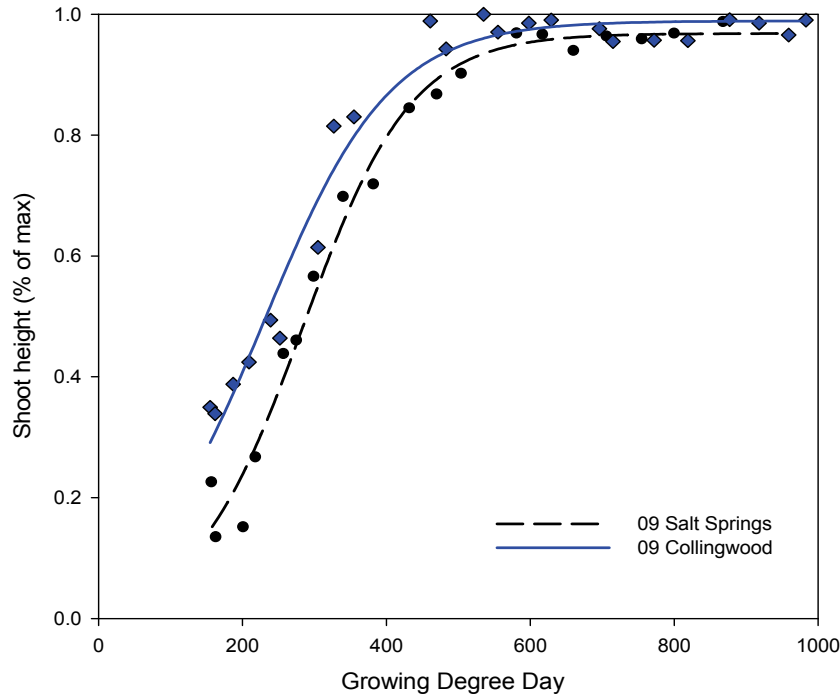
More than 50% of the total ramet emergence occurred between 184 and 420 GDD at both models. These corresponded to Julian days between June 9 and June 30, 2008, and May 31 to June 26, 2009. This is the same emergence period as hemp dogbane (Webster and Cardina 1999).



**Figure 2. 2** Emergence model for spreading dogbane using a non-linear regression analysis combining data from Salt Springs 2008, Salt Springs 2009, and Collingwood 2009, and emergence model for data collected from Earltown 2008 only. For both models,  $T_{base} = 6^{\circ} C$ .

### 2.3.3 Spreading Dogbane Height

A model similar to that for emergence was developed for the dogbane height data collected at Collingwood and Salt Springs in 2009. Height was first analyzed separately by sites so that adequate models were obtained. Spreading dogbane height was almost perfectly described by the sigmoid 3 parameters model (Figure 2.3, Table 2.3).



**Figure 2. 3** Spreading dogbane shoot height as a function with Growing Degree Day at Salt Springs and Collingwood, NS 2009.

The results suggested that all parameters for height model were not significantly different between each site except curve shaped parameter  $b$  (Table 2.3). The missing height data in the early spring due to late quadrat establishment may contribute to this curve shape difference. Therefore, height data of Salt Springs and Collingwood site in 2009 was not pooled. However, the coefficients of determination ( $r^2$ ) for each site model were as high as 0.99 and 0.97, respectively. Both models showed that spreading dogbane grew quickly once established and achieved maximum height at 558 GDD, which corresponds to July 7 to 10, 2009 at both sites. Maximum emergence occurred approximately 2 to 3 weeks earlier, however, the extended emergence time with emergence continuing even after given ramets have reached peak height.

**Table 2. 3** Parameter estimates for non-linear models describing spreading dogbane shoot height pattern at Salt Springs and Collingwood, NS sites in 2009.

Site	Model Parameter <sup>a</sup>			
	a	b	x <sub>0</sub>	r <sup>2</sup>
09 Salt Springs	0.97 a <sup>b</sup>	75.3 a	284.62 a	0.99
09 Collingwood	0.99 a	86.83 b	230.98a	0.97
Combined <sup>c</sup>	0.98	83.68	259.6	0.95

<sup>a</sup> Formula of model is  $y = a / (1 + e^{-(x-x_0)/b})$ , parameter  $a$  is the estimated percentage of maximum emergence,  $b$  is a curve shaped parameter,  $x_0$  is the GDD at 50% maximum height;  $r^2$  is coefficient determination.

<sup>b</sup> Parameter estimates followed by the same letter within the same column are not significantly different at  $\alpha = 0.05$ .

<sup>c</sup> Combined Salt Springs-09 and Collingwood-09 data together.

### 2.3.4 Spreading Dogbane Flowers

The dogbane flowering models were also analyzed separately by sites and models for each site were well described by a peak, Weibull non-linear regression models.

Parameters of each single model were compared in the same way as emergence pattern (Table 2.4). The data were pooled to build a flowering model across all fields.

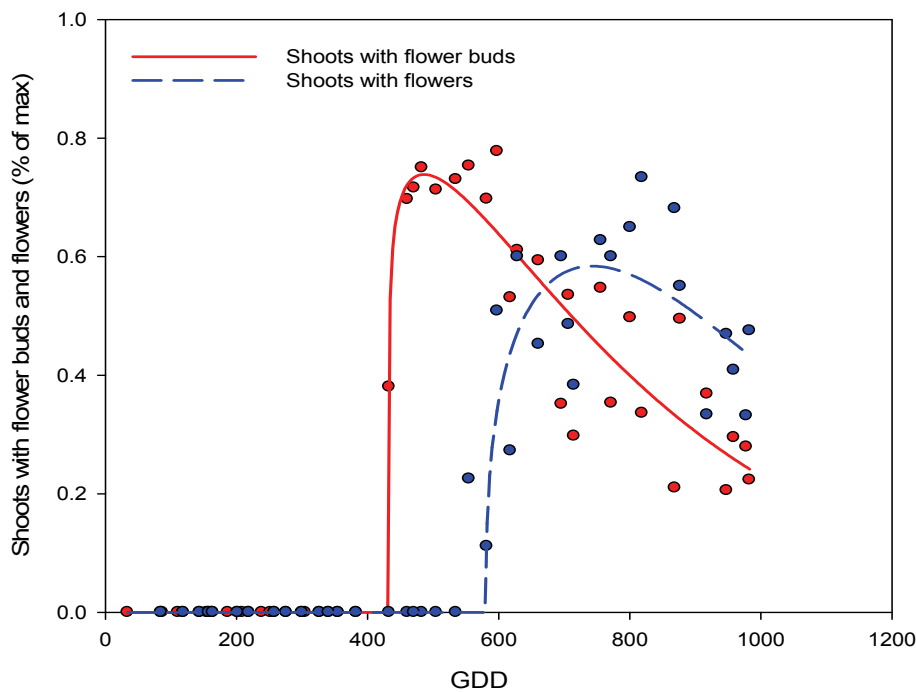
**Table 2. 4** Parameter estimates for non-linear models describing spreading dogbane flowering pattern at Salt Springs and Collingwood, NS sites in 2009.

Model	Site	Model Parameter <sup>a</sup>				
		a	b	c	x <sub>0</sub>	r <sup>2</sup>
Shoots with flower buds	09 Salt Springs	0.72	360.16	1.19	507.38	0.97
	09 Collingwood	0.66	444.74	1.46	555.63	0.89
	Combined <sup>b</sup>	0.74	379.77	1.12	486.08	0.95
Shoots with flowers	09 Salt Springs	0.68	380.09	2.7	811.09	0.99
	09 Collingwood	0.58	522.11	1.25	699.44	0.94
	Combined	0.58	447.54	1.34	742.65	0.91
Flower buds	09 Salt Springs	0.42	256.72	1.57	561.45	0.96
	09 Collingwood	0.59	239.22	1.17	503.62	0.94
	Combined	0.50	248.92	1.38	529.28	0.92
Flowers	09 Salt Springs	0.38	129.28	1.59	762.05	0.99
	09 Collingwood	0.27	198.40	1.24	681.46	0.97
	Combined	0.30	161.22	1.66	751.06	0.89

<sup>a</sup> Formula of model is  $y = a \left(\frac{(c-1)}{c}\right)^{\frac{(1-c)}{c}} \left[\frac{(x-x_0)}{b} + \left(\frac{(c-1)}{c}\right)^{\frac{1}{c}}\right]^{c-1} e^{-\left[\frac{(x-x_0)}{b} + \left(\frac{(c-1)}{c}\right)^{\frac{1}{c}}\right]^c} + (c-1)/c$ , parameter *a* is the estimated percentage of maximum shoots with flower buds/flowers, or percentage of maximum flowers/buds per plant, *b* is location parameter, *c* is a curve shaped parameter, *x*<sub>0</sub> is the GDD at midpoint; *r*<sup>2</sup> is coefficient determination.

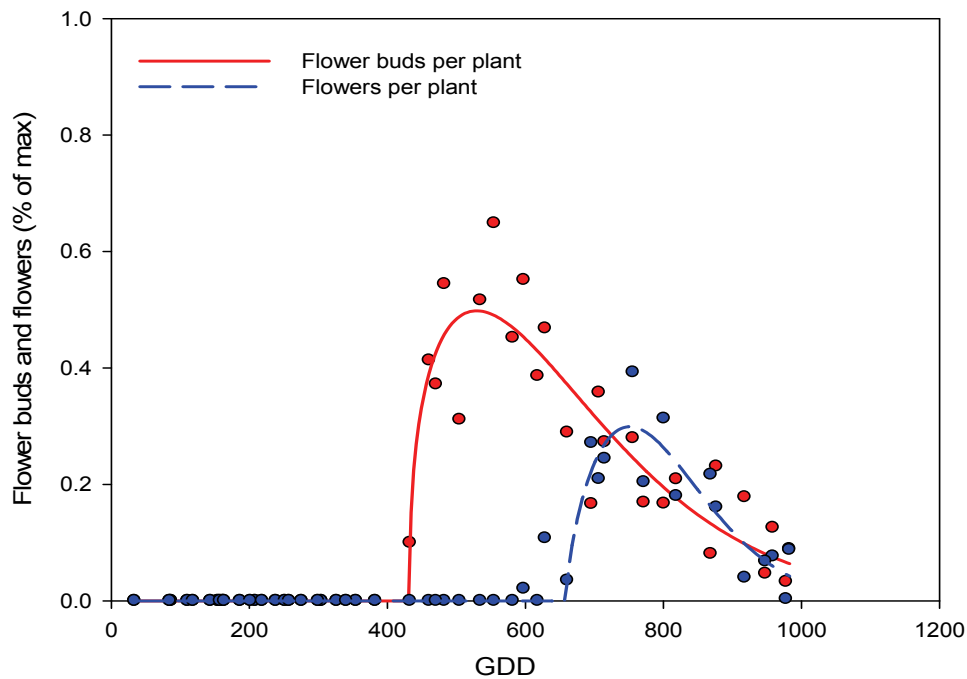
<sup>b</sup> Combined Salt Springs-09 and Collingwood-09 data together.

Percentage of maximum shoots with flower buds and flowers provide information about when most of spreading dogbane in the field start to form flower buds and flowers. No flower buds were predicted before 385 GDD, but the percentage of shoots with flower buds thereafter increased sharply until 486 GDD when more than 75% of shoots in the field had flower buds. Shoots with flower buds declined after 486 GDD, which corresponded to June 30 to July 2, 2009. Bloom of spreading dogbane was predicted by model to occur after 535 GDD. Spreading dogbane shoots with flower peaked (around 60%) at 741 GDD. It took approximately 3-4 weeks for spreading dogbane to achieve maximum shoots with flowers in the field after initial bloom, corresponding to 535-741 GDD (Figure 2.4).



**Figure 2. 4** Spreading dogbane shoots with flower buds and flowers versus Growing Degree Day at Salt Springs and Collingwood, NS 2009.

The model for percentage of flower buds and flowers per plant was used to predict how long flower bud and flower stage last and how long it would take to achieve the maximum flower buds and flowers. Models indicated that the timing to form flower buds was similar to the results from the models of shoots with flower buds, which was around 420 GDD. Then the peak flower buds per plant was achieved around 550 GDD. However, the model predicted individual spreading dogbane plants to initiate bloom at around 660 GDD, around 100 GDD more than the shoot with flowers model predicted, and the maximum flowers per plant was peaked around 750 GDD. This may indicate that timing for opening flower of spreading dogbane is not uniform and it may take more GDD for some individual plants to bloom (Figure 2.5). The models also showed that the percentage of maximum flower buds or flowers were as low as around 50% and 30%, respectively. The dogbane beetle was found in both sites in the middle summer, beetle feeding reduced number of flower buds and flowers and thus skewed the data.



**Figure 2. 5** Spreading dogbane flower buds and flowers as predicted by Growing Degree Day at Salt Springs and Collingwood, NS 2009.

### 2.3.5 Basic Phenology

A phenology table was developed for spreading dogbane based on the models (Table 2.5). Spreading dogbane emergence tended to begin in late April to early May and continued for 7-8 weeks to maximum emergence. Maximum height of dogbane plants occurred 2-3 weeks later. Flower buds were first observed around the end of June, when around 85% of maximum height was achieved. It took around 1 week from first flower bud for peak flower buds emergence and one more week for the first opening flowers to form, which generally occurred in the early July. Seed pods appeared in the end of July.



**Table 2. 5** Approximate timing for emergence, flowering, and seed set of spreading dogbane at Earltown, Salt Springs, NS in 2008 and Salt Springs and Collingwood in 2009.

Site	Initial Emergence	50% Emergence	Peak Emergence	Flower buds	Flowers	Seed Set
08 Earltown	May 20	June 15	July 18	N/A	N/A	N/A
08 Salt Springs	May 5 – 10	June 12	July 1	N/A	N/A	N/A
09 Salt Springs	April 29 – May 10	June 7	June 19	June 23	July 2	July 27
09 Collingwood	April 29	May 24	June 19	June 22	July 8	N/A

Herbicide applications must be timed to maximize efficacy especially given the limited management options available. The stage of development of perennial weeds at the time of treatment can greatly influence their susceptibility to herbicides (Ransom et al. 1983).

In general, weeds are most susceptible to herbicide at early stages during initial flower formation (Silva and Warren 1976). For perennial weeds, they cannot be killed by removal of topgrowth, and regrowth may occur from buds present on the rhizomes or other vegetative structures (Obrigawitch et al. 1990). The most effective control time is at the early vegetative stages when weeds start to form perennial reproductive structures. If herbicide is applied at this time it will be translocated underground with carbohydrates (Ross and Lembi 1999). Maximum total carbohydrates in rhizomes have been found to occur at the early bud stage for many perennial broadleaf weeds (Obrigawitch et al. 1990). Doll (1997) found that glyphosate applied to hemp dogbane at 200-400 GDD, when more than 50% of the total shoot emergence had occurred, did not provide effective control. Glyphosate applied during the early flowering stage, however, provided more

than 92 % control of hemp dogbane and also provided significant regrowth suppression during the following season (Doll 1997). Given the biological and ecological similarities with hemp dogbane, optimal control of spreading dogbane with post-emergence herbicides would likely be obtained at the period between first flower bud formation and first flower opening. Based on models presented here, this will occur between 486 and 535 GDD, which corresponded to calendar dates of June 30 - July 4, 2009 at Salt Springs, and July 2 - July 8, 2009 at Collingwood, respectively.

## **2.4 Conclusions**

Spreading dogbane ramet emergence can be modeled with a sigmoid, three parameters model. Spreading dogbane initiate emergence occurred at low GDD values and peak emergence occurred at approximately 420 GDD. Observed emergence pattern for spreading dogbane indicated that this weed would compete with wild blueberry in the early stage as the timing of initiate emergence was similar as wild blueberry (late April and early May). Spreading dogbane shoot height was also modeled with a sigmoid, three parameters model. The model indicated that spreading dogbane grew quickly once established and peak height was reached at 558 GDD. Since the spreading dogbane can grow 20-100 cm tall and normally grow in patch, the canopy of leaves can inhibit the light for blueberry plant growth when they grow higher than blueberry plants, likely partially explaining their highly competitive in wild blueberry fields. The taller spreading dogbane plant can also hinder blueberry harvest. Therefore, spreading dogbane should be controlled in wild blueberry fields. The flowering data of spreading dogbane was well described by a weibull, four parameter model. The model indicated that most spreading

dogbane formed flower buds at 486 GDD, the first bloom of spreading dogbane was predicted at 535 GDD, and flowers were peaked at 750 GDD.

Due to the early and rapid emergence of spreading dogbane in wild blueberry fields, managing this weed in the spring may be difficult. Hexazinone, a pre-emergence herbicide commonly used in blueberry fields, was found to be resistant by spreading dogbane (Lapointe and Rochefort 2001). To manage spreading dogbane, post-emergence herbicides should be applied when most spreading dogbane in the fields started to form flower buds and flowers. Based on the model build up, this period occurred between 486 to 535 GDD.

## Chapter 3.0 Management of Spreading Dogbane with Herbicides

### Abstract

Spreading dogbane (*Apocynum androsaemifolium* L.) is a serious weed in wild blueberry fields. Field studies were conducted in wild blueberry in 2008 and 2009 to evaluate efficacy of different herbicides and application techniques on spreading dogbane control as well as blueberry tolerance. Result of this research indicated that summer broadcasts of nicosulfuron at 25.1 g ai/ha in 190 L/ha water with 0.5% v/v Merge suppressed (> 60%) spreading dogbane at all sites. At least 90% dogbane damage was achieved with fall broadcast application of dicamba at 3.4 kg ai/ha in 550 L/ha water, and 288 g ai/ha dicamba plus 25.1 g ai/ha nicosulfuron in 190 L/ha water with 0.5% v/v Merge. Spot spray with glyphosate provided much more control than hand pulling. Spot spray with dicamba at 1 kg ai/ha in 550 L/ ha or primosulfuron and dicamba at 165.9 g ai/ha in 200 L/ha water with 0.2% Activate Plus effectively controlled spreading dogbane with minimal blueberry damage at three of four sites. Wiping with glyphosate and triclopyr could be used as an alternative method to control spreading dogbane as well as spot sprays.

### 3.1 Introduction

The lowbush blueberry (*Vaccinium angustifolium* L.), commonly referred to as wild blueberry, is a perennial deciduous shrub native to North America (Vander Kloet 1978). It grows best in wooded or open areas with well-drained acidic soils (Kinsman 1993). It is cultivated commercially in Canada and the United States (Yarborough and Bhowmik 1989). Over the past 50 years, the wild blueberry industry has grown from a small local market economy to a significant international frozen food export commodity (McIssac 1997). Nova Scotia is the second largest producer of wild blueberries in Canada and the wild blueberry industry is a significant part of Nova Scotia's provincial heritage and vegetation economy (Sibley 1987). Based on the 2004 provincial farm report, Nova Scotia makes up 17% of the Canada's total blueberry sales, with 37,230 acres of blueberries, representing 5% of total provincial farm cash receipts in Nova Scotia (Robichaud 2006). In 2009, production of wild blueberries was 14,971 metric tonnes, with a farm value of \$13 million (Statistics Canada 2010).

Spreading dogbane (*Apocynum androsaemifolium* L.) is a perennial herb that reproduces by underground rhizomes and seeds (Sampson et al. 1990). Spreading dogbane is considered a serious weed in wild blueberry fields because it spreads rapidly once established (Sampson et al. 1990). Spreading dogbane is competitive and may decrease blueberry yields and field profitability (Yarborough and Marra 1997). Yarborough and Bhowmik (1989) reported that spreading dogbane was one of the most frequent weeds in blueberry fields in Maine with 57% occurrence in fields surveyed. A survey of blueberry fields conducted in Quebec reported 87.5% spreading dogbane occurrence in the Saguenay–Lac-Saint-Jean region (Lapointe and Rochefort 2001). In a

Nova Scotia weed survey, only 3.6% of 115 sampled blueberry fields had spreading dogbane (McCully et al. 1991), but more recent grower reports suggest spreading dogbane is becoming more common throughout the province.

Competition with weeds is a major yield limiting factor in berry production (Yarborough 2008a; Jensen 2003). Many important weeds in wild blueberry fields are perennial, like spreading dogbane. They spread vegetatively by interconnected underground root systems. Blueberry is a perennial that have similar growth and development with these perennial weeds. Therefore, some production practices that promote blueberry growth and spread, such as pruning, fertilization and irrigation, also promote development of perennial weeds. Further, chemical or cultural management practices that suppress some weed species will actually encourage others. It is therefore necessary to develop an integrated approach, combining both cultural and chemical methods.

Since the introduction of herbicides in the late 1940's, they have been used as the primary method of weed control in wild blueberry fields (Dill et al. 1998; Yarborough 1999; Jensen and Yarborough 2004). The widespread use of the herbicide hexazinone effectively controlled most common weed species and lead to increased blueberry yields (Jensen 1985). Herbicides are typically broadcast sprayed, spot sprayed, or wiped using a range of wick wipers.

Broadcast sprays are recommended for treating areas with a uniform rate of herbicide, or large infestations of some species. For example, hexazinone is normally broadcast applied in the spring of the sprout year. Depending on the product and the time of application, some herbicides can injure or kill blueberry plants. In these cases, it is

important to spot spray and wipe weed to avoid crop injury via broadcast applications. Perennial weeds growing above blueberry plants can be effectively controlled by wiping or applying spot treatments of herbicides. Dicamba, which is a non-selective broadleaf herbicide, can be applied as a spot spray to control perennial weeds with less blueberry damage. Glyphosate, another non-selective herbicide, can be safely used in blueberry fields and selectively applied to the weed foliage by wiping.

In addition to herbicides, weeds in blueberry fields may be managed by biannual mowing, hand pulling, or clipping. Pulling effectively provides short term control of small infestations of perennials (McCully et al. 2005; Yarborough 2008b). However, most perennial weeds regenerate from roots or rhizomes after a short period of time. Clipping may be used for species taller than blueberry plants. Clipping of top growth prevents seed production, improves harvest ease, and reduces shading. Both techniques must be repeated multiple times in a season to exhaust root reserves. Repeated passes may damage wild blueberries and increase soil compaction.

### **3.2 Objectives**

Although spreading dogbane is aggressive and can result in a reduction in potential blueberry yield, little is known about its biology and no research has been published examining the most effective means of controlling established population of spreading dogbane.

The overall objective of this study was to identify an effective, best management plan for spreading dogbane in wild blueberry. Specific objectives were to:

1. Evaluate summer broadcast herbicide sprays, fall broadcast herbicide sprays, and spot sprays in the sprout year of wild blueberry production for control of spreading dogbane, and their effects on blueberry growth.

2. Compare the efficacy of hand pulling with that of glyphosate wiping and spots sprays for dogbane control.

### **3.3 Materials and Methods**

Experiments were conducted in 2008 and 2009 in the vegetative year of commercial wild blueberry fields located throughout Nova Scotia in Windham Hill (45°36'50" N , 63°59'45" W), Salt Springs (45°30'44" N , 63°00'40" W), Oxford (45°43'48" N , 63°52'12" W), Parrsboro (45° 24' 21" N, 64° 19' 33" W), Collingwood (45° 36' 35.941" N, 63° 47' 09.797" W), and Southampton(45°34'48" N , 64°14'24" W).

A site in Mt. Stewart, Prince Edward Island (46°21'56" N , 62°52'08" W) was also included.

Soil at Windham Hill and Salt Springs is a Westbrook type soil series that is well drained and composed of reddish brown sandy loam over reddish brown sandy loam to gravelly sandy loam (Webb et al. 1991). Soil at Oxford is of the Hebert type soil series, excessively drained and composed of grayish brown or brown over yellowish red sand to sandy loam. Soil at Parrsboro is of the Hebert type soil series, excessively drained and composed of grayish brown or brown over yellowish red sand to sandy loam (Nowland



and MacDougal 1973). Soil at the Collingwood site is a stony, well drained sandy loam of the Rodney soil series (Nowland and MacDougall 1973). Soil at Southampton is of the Rodney type soil series, well drained and composed of dark brown sandy loam over yellowish red to reddish brown gravelly sandy loam to gravelly loam. Soil at Mt. Stewart, PEI is medium to moderately coarse textured, acid glacio fluvial material on depressional to gently undulating relief and poorly drained.

All herbicides were applied with a CO<sub>2</sub> pressurized hand-held sprayer equipped with Teejet 8002VS nozzles spaced 50cm on a 1.5m boom for broadcast spray and a single nozzle for spot spray, to calibrate to deliver the appropriate water volume at a pressure of 275 KPa. A “hockey-stick” applicator was used for wiping. The herbicide was slowly delivered from an absorbent covered drum to the foliage of weeds. Roller was operated slowly in two directions to improve coverage and control.

All experiments, except the spot spray treatments, were set up as randomized completely block design (RCBD) with four blocks in each field. Individual plot size was 2x6 m with a 1 m wide unsprayed buffer strip between each plot. Replicated untreated plots were included as a control for each experiment.

### **3.3.1 Summer Broadcast**

Efficacy of five broadcast post-emergence (POST) herbicides combinations on spreading dogbane was evaluated at Windham Hill and Salt Springs in 2008, and Oxford and Mt. Stewart in 2009 (Table 3.1). Herbicides were applied at the flower bud to early

flowering growth stage. Herbicides were sprayed on July 2 at Windham Hill, July 4 at Salt Springs, July 8 at Mt. Stewart, and July 9 at Oxford.

### **3.3.2 Fall Broadcast**

The efficacy of six postemergence herbicide combinations on spreading dogbane was evaluated in Parrsboro in 2008 (Table 3.1). Herbicides were applied on September 12, when a large proportion of the blueberry leaves had dropped but most dogbane leaves were still green. Because blueberry foliage senesce at this time so that herbicide cannot be translocated through the plant, and thus reduce the blueberry damage caused by these herbicides.

**Table 3. 1** Herbicide treatments applied POST in the summer and fall broadcast experiments in 2008 and 2009.

Application Time	Trade Name	Active Ingredient	Application Rate --g ai/ha--	Water Volume --L/ha--	Surfactant --% v/v--
Summer	Accent	Nicosulfuron	25.1	190	Activate Plus 0.2
	Accent	Nicosulfuron	25.1	190	Merge 0.5
	Callisto	Mesotrione	100.8	200	Activate Plus 0.2
	Callisto+	Mesotrione	100.8+	400	Activate Plus 0.2
	Ultim	+Nicosulfuron /rimsulfuron	25.5		
	Ultim	Nicosulfuron /rimsulfuron	25.5	400	Activate Plus 0.2
Fall	Weathermax	Glyphosate	723.6	100	None
	Banvel II	Dicamba	3408	550	None
	2,4-D	2,4-D L.V. ester	3420	550	None
	Banvel II+	Dicamba+2,4- D L.V. ester	1104+3420	550	None
	2,4-D				
	Accent+	Nicosulfuron	25.1+ 3408	550	Merge 0.5
	Banvel II	+dicamba			
	Summit	Primisulfuron +dicamba	165.9	200	Activate Plus 0.2

### 3.3.3 Summer Spot Spray

The herbicide efficacy was evaluated on spreading dogbane at Windham Hill and Collingwood, NS, in 2008 and Southampton, NS, and Mt. Stewart, PEI in 2009. The experimental design was a completely randomized design with seven replications. Forty-

nine individual spreading dogbanes were randomly selected and flagged in each field. Seven herbicides were tested (Table 3.2) and all of these chemicals were sprayed at the flower bud formation stage and early flower stage. The date of sprayed herbicide was July 2 at Collingwood, and July 4 at Collingwood 2008, July 8 at P.E.I, and July 9 at Southampton 2009.

**Table 3. 2** Herbicides evaluated for spreading dogbane control in summer spot spray experiments in Nova Scotia and Prince Edward Island, 2008 and 2009.

Trade Name	Active Ingredient	Application Rate --g ai/ha--	Water Volume ---L/ha--	Surfactant --% v/v--
Milestone	Aminopyralid	120	200	Activate Plus 0.2
Overdrive	Diflufozopyr +dicamba	110.8	200	Activate Plus 0.2
Infinity	Pyrasoufotole + bromoxynil	31.1+174.3	100	None
Weathermax	Glyphosate	1600	300	None
Banvel	Dicamba	1000	550	None
Banvel + 2,4-D	Dicamba+2,4-D L.V. ester	1100 +3800	550	None
Summit	Primisulfuron +dicamba	165.9	200	Activate Plus 0.2

### 3.3.4 Summer Spot Spray Versus Wiping and Hand Pulling

An experiment comparing spot spraying versus wiping was done in Southampton and Mt. Stewart in 2009. The treatments were: (1) wiping glyphosate at 154 g ai/L water, (2) wiping triclopyr (Garlon) at 144 g ai/L mineral oil; (3) spot spray glyphosate at 5.4 g ai/L

water, and (4) untreated control. The second experiment compared spot spraying with glyphosate versus hand pulling. Glyphosate was applied at the same rate as the spot spray versus wiping experiment. For hand pulling, all spreading dogbane plants were grabbed close to the ground and pulled out the plot with hand pulling treatment. Both treatments were done at July 3, 2008 in Salt Springs, July 9 in Southampton and July 8 in Mt. Stewart in 2009.

### **3.3.5 Data Collection**

The total number of spreading dogbane shoots in each plot was counted twice in all experiments. The first counts were conducted the day herbicides were sprayed and the second counts were done during final damage rating data collection, near the end of the growing season (late of August). The difference between counts was used to estimate percent above ground control. For the fall experiment, the second count was conducted midsummer of the following fruit year (July 21, 2009).

Herbicide damage was evaluated in most experiments 14 days after spraying (DAS), 21DAS, 35DAS and 56DAS. A 0 to 100 scale was used where 0 meant no visible injury and 100 was a dead plant. Both blueberry and spreading dogbane were rated. Ratings were conducted for the fall broadcast herbicide experiment 21 DAS and 312 DAS.

Ten spreading dogbane shoots were harvested from each plot in the summer broadcast experiment at all four sites near the end of August. Shoots were collected at 50 cm intervals along a diagonal transect. Samples were dried at 60° C for 48 hours and then weighed. Blueberry floral buds were counted on fifteen stems located every 40 cm along

a diagonal transect in early September. Floral buds were not counted at Oxford in 2009 due to low blueberry cover.

### **3.3.6 Statistical Analysis**

Damage ratings were analyzed using the PROC MIXED procedure with repeated measures in the SAS system for Windows, version 9.1(SAS Institute1999). Percent control of spreading dogbane, spreading dogbane shoot biomass, and blueberry floral bud numbers were also statistically analyzed using the PROC MIXED procedure in SAS. The damage rating and percentage control data from fall broadcast herbicide treatments experiment was analyzed using the PROC GLM procedure in SAS. Differing data transformations were used at some sites to achieve normality and constant variance. Data were then back-transformed for interpretation and figure creation.

The least significant difference (LSD) means separation test was used to determine inter-treatment differences in spreading dogbane and blueberry injury, percentage control of spreading dogbane, spreading dogbane biomass and blueberry floral bud numbers. Unless otherwise stated, significance values were set at  $\alpha = 0.05$ .

Data was analyzed using a nested design with blocks nested within sites when analyzing data across sites. This design was chosen because treatments were randomized within blocks but not across sites. Sites were analyzed separately because of the known differences between sites and because the blocks nested within sites factor was significant ( $P < 0.0001$ ). Sites differed in field age, management history, and organic matter content.

### 3.4 Results and Discussion

#### 3.4.1 Summer Broadcast

Herbicides had a significant impact on spreading dogbane damage ratings ( $P = 0.0168$ ). Nicosulfuron plus merge, nicosulfuron/rimsulfuron plus mesotrione, and nicosulfuron/rimsulfuron controlled (> 83%) spreading dogbane at Windham Hill and Mt. Stewart. Nicosulfuron plus Activate Plus and mesotrione suppressed (> 60%) spreading dogbane at Windham Hill and Mt. Stewart. None of the products were effective at Salt Springs (Table 3.3).

Nicosulfuron, a sulfonyleurea herbicide, was used to control many annual and perennial grass weeds with additives of an oil emulsifier mixture (OEM), such as Merge or non-ionic surfactants (NIS), such as Activate Plus (Williams and Harvey 1996). Nicosulfuron plus Merge generally cause higher dogbane injury than nicosulfuron plus Activate Plus in this study. At Salt Springs and Mt. Stewart, nicosulfuron plus Merge caused 40% and 25% more dogbane injury than nicosulfuron plus Activate Plus (Table 3.3). Although there was no significant effect of herbicide in Windham Hill and Oxford, nicosulfuron plus Merge gave 12% and 7% higher dogbane injury than the nicosulfuron plus Activate mixture (Table 3.3). These support that nicosulfuron with OEM provided better weed control than nicosulfuron with (NIS) (Nalewaja et al. 1991).

Schuster et al. (2007) reported that mix of mesotrione and nicosulfuron /rimsulfuron resulted in lower control than nicosulfuron / rimsulfuron alone due to antagonism between mesotrione and sulfonyleurea herbicides. This was not observed in our study. In some cases, significantly higher control was achieved with the mix than with nicosulfuron/rimsulfuron alone.

There was a significant site impact on herbicide efficacy ( $P < 0.0001$ ). High efficacy of 73-95% spreading dogbane damage was observed at Windham Hill, but lower control of 13-58% damage was found at Salt Springs. Nicosulfuron/rimsulfuron and nicosulfuron/rimsulfuron with mesotrione were effective at Mt. Stewart, resulting in 85% and 93% injury, respectively (Table 3.3). Unusually high spreading dogbane densities (around 40 plants/m<sup>2</sup>) and growth (plants were approximately twice as high as at other sites) at Mt. Stewart likely partially explains the higher herbicide efficacy at this site. The spreading dogbane biomass data at Mt. Stewart also supported that nicosulfuron plus Merge, nicosulfuron/rimsulfuron and mixed nicosulfuron/rimsulfuron with mesotrione caused significant less dogbane biomass than other treatments (Table 3.4).



**Table 3. 3** Summer broadcast herbicide efficacy on spreading dogbane and wild blueberry at Windham Hill and Salt Springs, Nova Scotia in 2008 and Oxford, Nova Scotia and Mt. Stewart, Prince Edward Island in 2009.

Treatment	Windham Hill		Salt Springs		Oxford		Mt. Stewart	
	Dogbane <sup>a</sup> damage	Blueberry damage	Dogbane damage	Blueberry damage	Dogbane damage	Blueberry damage	Dogbane damage	Blueberry damage
	------%-----							
None	0	0	0	0	0	0	0	0
Nicosulfuron+Activate	73 a <sup>b</sup>	15 b	18 b	13 a	53 a	15 a	60 b	18 a
Nicosulfuron +Merge	85 a	10 b	58 a	13 a	60 a	15 a	85 a	18 a
Mesotrione	78 a	10 b	20 b	8 a	53 a	13 a	63 b	15 a
Nicosulfuron/rimsu	83 a	28 a	20 b	10 a	63 a	13 a	93 a	20 a
lfuron+Mesotrione								
Nicosulfuron/rim sulfuron	95 a	10 b	13 b	13 a	55 a	15 a	85 a	20 a

<sup>a</sup>Dogbane and blueberry damage was taken at 54 days after spraying and damage were done on a 0-100 scale.

<sup>b</sup>Means within columns followed by the same letter are not significantly different (LSD,  $P < 0.05$ ).

**Table 3. 4** Spreading dogbane biomass following different herbicide combinations at Windham Hill and Salt Springs, Nova Scotia in 2008 and Oxford, Nova Scotia and Mt. Stewart, Prince Edward Island in 2009.

Treatment	Windham Hill	Salt Springs	Oxford	Mt. Stewart
	g / plant			
None	1.6 a <sup>a</sup>	2.6 b	4.4 a	8.1 a
Nicosulfuron+Activate	1.4 a	2.4 b	3.4 a	5.9 c
Nicosulfuron +Merge	1.7 a	4.6 ab	3.5 a	6.2 bc
Mesotrione	1.9 a	8.5 a	3.7 a	7.5 ab
Nicosulfuron/rimsulfuron+Mesotrione	1.5 a	4.9 ab	3.4 a	5.2 c
Nicosulfuron/rimsulfuron	1.9 a	2.5 b	4.1 a	5.2 c

<sup>a</sup>Means followed by the same letter are not significantly different (LSD,  $P < 0.05$ ).

None of the herbicides except nicosulfuron/rimsulfuron plus mesotrione in Windham Hill, caused unacceptable blueberry damage after 56 DAS (day after spray) (Table 3.3). The number of blueberry floral buds was not different among treatments (Table 3.5). For some growers, 15-20% blueberry damage may seem high, but this may be an acceptable trade-off if good weed control is obtained. The Mt. Stewart site is a good example. It was the only site with a dense population of spreading dogbane, almost no floral buds were formed which suggests it was highly competitive with blueberry for resources (Table 3.5).

**Table 3. 5** Blueberry floral buds count following different herbicide combinations at Windham Hill and Salt Springs, Nova Scotia in 2008 and Oxford, Nova Scotia and Mt. Stewart, Prince Edward Island in 2009.

Treatment	Windham Hill	Salt Springs	Oxford	Mt. Stewart
	buds / stem			
None	7 a <sup>a</sup>	4 a	-	1 a
Nicosulfuron+Activate	6 a	4 a	-	0 a
Nicosulfuron +Merge	5 a	4 ab	-	0 a
Mesotrione	7 a	2 b	-	0 a
Nicosulfuron/rimsulfuron+Mesotrione	5 a	3 ab	-	1 a
Nicosulfuron/rimsulfuron	5 a	4 ab	-	1 a

<sup>a</sup>Means followed by the same letter are not significantly different (LSD,  $P < 0.05$ ).

### 3.4.2 Fall Broadcast

All fall herbicide treatments in this study provided excellent (>95%) spreading dogbane control when evaluated 21 DAS. The following summer (312 DAS) all fall herbicide applications retained at least 80% control except primisulfuron with dicamba and 2,4-D alone (Table 3.6). Glyphosate caused the highest blueberry damage (75%), while fall application of dicamba, dicamba plus 2,4-D, dicamba plus nicosulfuron and primisulfuron plus dicamba caused the lowest injury to blueberry plants (23-38%). In the following fruit year, more severe blueberry damage was observed. Applications of glyphosate and dicamba plus 2,4-D resulted in 90 and 93% blueberry damage, respectively. Dead blueberry stems were observed in both plots

and the overall cover of blueberry plants was decreased. The lowest blueberry damage occurred in plots with dicamba, 2,4-D, dicamba plus nicosulfuron and primisulfuron + dicamba, which was 55, 65, 70 and 23%, respectively. Although the blueberry damage was high in some cases, blueberry growers are likely to accept this level of damage due to the need to control this weed species. Collectively considering the herbicide efficacy and blueberry damage tolerance, fall application of dicamba and dicamba plus nicosulfuron are the best options for controlling spreading dogbane. These options inflicted significantly lower damage to blueberry plants than all other treatments except 2,4-D, which did not provide adequate control. These results corroborate reports that applications of nicosulfuron plus dicamba can control hemp dogbane, a species very similar to spreading dogbane (Glenn and Anderson 1993; Glenn et al. 1997; Ransom and Kells 1998).

### **3.4.3 Summer Spot Spray**

The efficacy of spot spray applications varied among products and between sites (Table 3.7). All herbicides spot sprayed in this study injured spreading dogbane severely (90-100%) except pyrasulfotole plus bromoxynil at Collingwood and dicamba at Farmington. A spot spray of dicamba caused the least blueberry damage at three of four sites (19-23%), with the exception of the Collingwood trial (53% dicamba damage) (Table 3.7). Compared to the 55% blueberry damage caused by a fall broadcast of dicamba, spot sprays of dicamba appear to be safer. Primisulfuron plus dicamba spot sprays caused the second least amount of damage to blueberry plants (27-50%). Considering the effects of chemicals on both the target weed and the

crop plant, spot spray with dicamba or primisulfuron plus dicamba are the best options to control spreading dogbane while minimizing blueberry damage.

**Table 3. 6** Efficacy of fall broadcasts of herbicides on spreading dogbane and wild blueberry, Parrsboro, Nova Scotia, in 2008.

Treatment	Dogbane injury	Dogbane control	Blueberry Injury	
	21 DAS	312 DAS	21 DAS	312 DAS
	-----%-----			
None	68 b <sup>a</sup>	-79 c <sup>b</sup>	13 e	0 d
Glyphosate	100 a	90 a	75 a	90 a
Dicamba	95 a	89 a	30 cd	55 b
2,4-D L.V. ester	100 a	-51 c	55 b	65 b
Dicamba+2,4D,L.V. ester	100 a	80 a	38 c	93 a
Nicosulfuron+dicamba	100 a	90 a	33 cd	70 b
Primisulfuron & dicamba	100 a	25 b	23 de	23 c

<sup>a</sup>Means within columns followed by the same letter are not significantly different (LSD  $P < 0.05$ ).

<sup>b</sup>Minus mean the spreading dogbane density increased.

**Table 3. 7** Efficacy of herbicides spot spray on spreading dogbane and wild blueberry damage at Farmington and Collingwood, Nova Scotia in 2008, and Southampton, Nova Scotia and Mt. Stewart Prince Edward Island in 2009.

Treatment	Farmington		Collingwood		Southampton		Mt. Stewart	
	Dogbane damage <sup>a</sup>	Blueberry damage	Dogbane damage	Blueberry damage	Dogbane damage	Blueberry damage	Dogbane damage	Blueberry damage
	-----%-----							
Aminopyralid	100 a <sup>b</sup>	51 bc	100 a	67 b	99 a	87 a	100 a	41 bc
Difluozopyr& dicamba	100 a	37 d	100 a	50 cd	100 a	45 cd	100 a	27 cd
Pyrasoufotole& bromoxynil	90 a	61 b	76 b	59 bc	100 a	46 cd	87 b	23 d
Glyphosate	96 a	81 a	100 a	100 a	100 a	100 a	100 a	93 a
Dicamba	57 b	20 e	100 a	53 bc	80 b	23 e	99 ab	19 d
Dicamba+2,4-D L.V. ester	100 a	50 c	100 a	65 b	89 ab	73 b	100 a	49 b
Primisulfuron& dicamba	94 a	31 d	100 a	39 d	87 ab	31 de	90 ab	24 d

<sup>a</sup>Dogbane and blueberry damage was taken at 54 days after spraying (DAS) and damage were done on a 0-100 scale.

<sup>b</sup>Means within columns followed by the same letter are not significantly different (LSD  $P < 0.05$ ).

### 3.4.4 Summer Spot Spray Vs. Wiping and Hand Pulling

All treatments provided good control (> 90%) of spreading dogbane at both sites in the spot spray vs. wiping experiment. There was no significant difference between each treatment at locations (Table 3.8). Severe blueberry damage (63-78%) was observed at PEI, which likely due to the high spreading dogbane density.

**Table 3. 8** Effects of wiping and spot sprays on spreading dogbane and blueberry at Southampton, Nova Scotia and Mt. Stewart, Prince Edward Island 2009.

Treatment	Southampton		Mt. Stewart	
	Dogbane control	Blueberry damage	Dogbane control	Blueberry damage
	%			
None	36 a <sup>a</sup>	0 a	40 a	0 a
Wiping glyphosate	89 b	28 b	97 b	63 b
Wiping triclopyr	98 b	38 b	100 b	70 b
Spot spray glyphosate	93 b	21 b	96 b	78 b

<sup>a</sup>Means within columns followed by the same letter are not significantly different (LSD  $P < 0.05$ ).

In the spot spray vs. hand pulling experiment, results from all sites suggest that spot sprays with glyphosate provide better control of spreading dogbane than hand pulling (Table 3.9). Hand pulling suppressed dogbane at Salt Springs, 2008 and Southampton 2009, but it did not work at Mt. Stewart, again, a result that was likely due to the high density of dogbane at this site. Data collection in the following spring at Salt Springs also indicated that spot sprays with glyphosate effectively inhibit spreading dogbane shoot development year after application.

**Table 3. 9** Effect of spot sprays and hand pulling on spreading dogbane at Salt Springs, Nova Scotia in 2008, Southampton, Nova Scotia and Mt. Stewart, Prince Edward Island in 2009.

Site	Year	Treatment	Dogbane control	
			60 DAS <sup>a</sup>	361DAS
			%	
Salt Springs	2008	Spot spray	99 a <sup>b</sup>	85
		Hand pulling	72 b	35
Southampton	2009	Spot spray	79 a	-
		Hand pulling	72 a	-
PEI	2009	Spot spray	87 a	-
		Hand pulling	28 b	-

<sup>a</sup>Days after spraying

<sup>b</sup>Means within columns in each site followed by the same letter are not significantly different (LSD  $P < 0.05$ ).

### 3.5 Conclusions

Spreading dogbane is an herbaceous perennial becoming more and more frequently found in wild blueberry fields. Drought-tolerant and capable of both sexual and vegetative reproduction make it a serious problem. Result of this research indicates that hand pulling alone is ineffective for controlling an established population of spreading dogbane. Hand pulling can starve the root system of carbohydrates and reduce the population significantly. However, large food reserves build up in the roots can support spreading dogbane to survive without aboveground growth. The root system fragments easily and segments can easily produce new individuals. Therefore, hand pulling is only effective when spreading dogbane are new seedlings, prior to the formation of the perennial buds.



If the spreading dogbane population is small, spot spray or wiping is a good option for control. The result of this study indicates that spot sprays of glyphosate at 5.4 g ai/L provides much more effective control for spreading dogbane, but it is a non-selective herbicide that is toxic to blueberry plants. Therefore, care should be taken to minimize effects in non-target area, due to spray drift. Other than that, spot spray with dicamba at 1 kg ai/ha in 550 L/ ha or primosulfuron plus dicamba at 165.9 g ai/ha in 200 L/ha water with 0.2% Activate Plus are recommended for controlling spreading dogbane with minimum blueberry damage. Wiping with glyphosate at 154 g ai/L water or wiping triclopyr at 144 g ai/L mineral oil can also be used as an alternate method to control small population of spreading dogbane in blueberry fields. Both spot spray and wiping should be applied at early flowering stage.

If the population is large, then broadcast spray should be considered. Summer broadcast of nicosulfuron at 25.1 g ai/ha with a water volume 190 L/ha plus 0.5% v/v Merge consistent suppress spreading dogbane in all sites, while 25.5 g ai/ha nicosulfuron/rimsulfuron mixed with 100.8 g ai/ha mesotrione in 400 L/ha water with 0.2% v/v Activate Plus, and nicosulfuron/rimsulfuron at 25.5 g ai/ha in 400 L/ha water alone or with 0.2% v/v Activate Plus provide inconsistent dogbane control in blueberry fields with the light blueberry injury. Herbicides should be applied at early flowering stage. Results suggest that efficacy of these herbicides for spreading dogbane control corresponds with plant growth and density. Control (> 85%) is achieved when high growing activity and plant density occurred.

If summer broadcast can not control spreading dogbane effectively, then fall broadcast spray should be adopted. Fall broadcast application of dicamba at 3.4 kg ai/ha

in 550 L/ha water, and 288 g ai/ha dicamba plus 25.1 g ai/ha nicosulfuron in 190 L/ha water with 0.5% v/v Merge provide good spreading dogbane control based on the results of this study. However, due to their high blueberry damage, they should be used very carefully when dogbane issue need to be solved in the fields.

In summary, if spreading dogbane is detective early in the blueberry fields (prior to the formation of perennial buds, normally three to four weeks old), hand pulling the seedling with as much of root system as possible can effectively remove spreading dogbane. If small spreading dogbane population is detective when they established perennial growth, then spot spray glyphosate, dicamba and primosulfuron plus dicamba are three options for spreading dogbane control. Extreme care is needed to spot spray glyphosate due to its high toxicity to non-target plants. Wiping with glyphosate or triclopyr can also be used as an alternate method to control small population of spreading dogbane in blueberry fields. But if there is a large spreading dogbane infestation, summer broadcast spray nicosulfuron plus Merge in vegetative year of blueberry production cycle should be first considered. If the result is not ideal, then fall broadcast spray dicamba or dicamba plus nicosulfuron at fruit year following harvest should be tried.

## **Chapter 4.0 Conclusion**

### **4.1 Overview**

The main focus of this study was to develop a best management plan for spreading dogbane in wild blueberry fields. Of particular interest was how spreading dogbane develops, with an attempt to evaluate efficacy of different herbicides and application techniques for control of spreading dogbane. The specific objectives were to: (1) broaden our understanding of the phenology and biology of spreading dogbane; (2) model spreading dogbane ramet emergence, flowering, and height in commercial wild blueberry fields; (3) evaluate efficacy of summer broadcast, fall broadcast and summer spot sprays of herbicides in sprout field on spreading dogbane and their phytotoxic effects on blueberry; and (4) compare efficacy of hand pulling with glyphosate wiping and spots sprays for dogbane control.

### **4.2 Overall Conclusions**

Spreading dogbane is a perennial herb that is becoming more and more common on wild blueberry fields. It reproduces by underground rhizomes and seeds. Ramets (vegetative shoots) emergence and height were well described by a three parameter sigmoid regression model in this study. Ramets emergence tended to begin in late April to early May with low GDD values and usually reached peak emergence around 420 GDD, which correspond to mid-late June. Maximum height was achieved at 558 GDD, which is around 2-3 weeks after peak emergence. Spreading dogbane flowering models were well described by peak, weibull non-linear regression models. The model showed

that most spreading dogbane formed flower buds at 486 GDD, the first bloom of spreading dogbane was occurred at 535 GDD, and flowers were peaked at 750 GDD.

These models represent the first attempt at modeling the growth and development of spreading dogbane in early successional environments. By quantifying the development of spreading dogbane with thermal units, it allows more precise prediction of phenology, which is the study of dynamics of development that focus on the inherent schedule of biotic events. These thermal models provide precise estimates of when particular biotic events occurred at varied environments. Therefore, weed control tactics can be conducted accurately at different conditions. In term of timing of applying herbicides, the most effective time to control a perennial weed is when carbohydrates move down into roots as the plant prepares for winter. This usually coincides with at the early flowering stage. But because of the different weather condition, the biotic events may vary at different sites. By creating a thermal model, a precise timing can be applied uniformly across the sites. In this study, the best time to manage spreading dogbane with POST herbicides was determined to be between 486 and 535 GDD, when dogbane started to form flower buds and flowers.

Screening experiments examined the potential of alternative herbicides, application methods and hand-pulling to suppress spreading dogbane. The summer broadcast experiments, where POST herbicides were applied to sprout fields in the summer, had variable results. Nicosulfuron plus Merge suppressed spreading dogbane well at all four sites. At the Windham Hill and Mt. Stewart sites, effective control was even achieved (> 85%). Nicosulfuron/rimsulfuron mixed with mesotrione plus Activate Plus, and nicosulfuron/rimsulfuron plus Activate Plus also provided good dogbane control in

blueberry fields with some blueberry injury. However, results were inconsistent between sites, which were likely due to the different soil structure, plant growing activity and plant density. Therefore, a summer broadcast of nicosulfuron plus Merge is a potential candidate for spreading dogbane suppression and control with large dogbane infestation.

All products applied in fall broadcast experiments were effective against spreading dogbane except primisulfuron with dicamba and 2,4-D alone. However, most herbicides used in this study were non-selective and server injury was occurred once contacted wild blueberry plants. Extreme care is needed when applied these herbicides, late application may reduce the herbicide efficacy, while early application may cause high blueberry damage. Therefore, it is important to require a precise prediction on the optimal timing of fall broadcast spray. In this study, fall applied glyphosate and dicamba plus 2,4-D caused a significant blueberry damage (at least 90%). It is possible that imprecise application time lead to the high damage for blueberry, but further experiments should be conducted to confirm. The reliable control shown by dicamba and dicamba plus nicosulfuron, combined with minimum effects on the blueberry plants, made them effective as options for spreading dogbane control. Due to the relative high blueberry damage, fall broadcast is only recommended when summer broadcast can not effectively control spreading dogbane.

To control small population of spreading dogbane and also to avoid causing high blueberry damage, summer spot sprays were evaluated in this study. All products used in this experiment provided good control for spreading dogbane. Considering herbicide efficacy and blueberry tolerance, spot spray of dicamba caused the least blueberry damage at three of four sites. It is safer to apply dicamba in spot spray than fall broadcast.

In addition to dicamba, spot sprays of primisulfuron and dicamba could be a candidate for spreading dogbane control with minima blueberry injury.

Glyphosate is registered as a POST herbicide in wild blueberry fields, and is widely used to control a broad range of weeds. Results showed that spreading dogbane was very sensitive to glyphosate. However, due to the severe crop injury following contact with glyphosate, it should be applied carefully and selectively. Wiping or spot sprays of glyphosate reduced the blueberry damage, especially for those blueberry fields with less dogbane infestation. Compared to hand pulling, glyphosate spot sprays showed more permanent dogbane control. Wiping with triclopyr could also be used as an alternate method to control spreading dogbane, with less blueberry damage.

In summary, if spreading dogbane is detected early in the blueberry fields (prior to the formation of perennial buds, normally three to four weeks old), hand pulling the seedling with as much of root system as possible can effectively remove spreading dogbane. If small spreading dogbane population is detected when they established perennial growth, then spot spray glyphosate, dicamba and primosulfuron plus dicamba are three options for spreading dogbane control. Extreme care is needed to spot spray glyphosate due to its high toxicity to non-target plants. Wiping with glyphosate or triclopyr can also be used as an alternate method to control small population of spreading dogbane in blueberry fields. But if there is a large spreading dogbane infestation, summer broadcast spray nicosulfuron plus Merge in vegetative year of blueberry production cycle should be first considered. If the result is not ideal, then fall broadcast spray dicamba or dicamba plus nicosulfuron at fruit year following harvest should be tried. In term of

timing of spraying herbicides, the best time to apply POST emergence herbicide is between 486-535 GDD.

### **4.3 Future Direction**

Spreading dogbane is a perennial weed that reproduces by seeds and shoots. Previous work indicates that *Apocynum cannabinum* (hemp dogbane) seeds are not long-lived (Burnside et al. 1981) and population growth by seeding is not common in fields with minimal disturbance (Webster and Cardina 1999), but they are protected by attached pappus and are moved and established into uncolonized areas. Therefore, further studies should be conducted on spreading dogbane seed germination in wild blueberry fields. Additional research should be conducted to determine how temperature and moisture affect spreading dogbane seed germination, and if there are exact factors that may aid or prohibit seedling survival. The ramet emergence, shoot height and flowering model presented in this paper can be used as a management decision tool for spreading dogbane control. These models should be improved through collection of early season remet emergence, determination of optimal base temperature for spreading dogbane, and collection one more data set for model's validation. Base on this model, timing of management, such as pre-emergence and post-emergence herbicides application time can be predicted. Further research could be conducted to predict the precise timing for fall broadcast spray. To extend the use of this model, it should also be applied in other areas out of Nova Scotia.

Additional studies are needed to assist in documenting more effective products for spreading dogbane control. This study showed that spreading dogbane was sensitive to

most herbicides applied in this project but caused severe blueberry damage. Further research could be conducted to evaluate different rates of herbicides on blueberry tolerance, particularly on fall broadcast spray. Due to the spreading dogbane damage caused by insects, which was found in this study, biological control also can be developed as a potential option for spreading dogbane control.



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