Sustainable Weed Management for the Wild Blueberry Industry

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1.0 Overall Summary: Weeds are one of the most important pests limiting wild blueberry yields in Atlantic Canada. A variety of field trials were established in 2012 and 2013 to evaluate potential herbicides and herbicide tank mixes for use by the lowbush blueberry industry. All products evaluated except aminopyralid were safe on lowbush blueberry when applied pre-emergence. Oxyfluorfen caused some damage in one of the trials when applied later than recommended. Glufosinate, pyroxsulam, and hexazionone were all safe even when applied relatively late as long as they were applied prior to emergence. Hexazinone remains the most effective herbicide with a broader spectrum of activity than any of the new herbicides evaluated. Glufosinate is a promising burn-down product for grass and broadleaf weeds that emerge prior to blueberry emergence that should be registered for use. Pyroxsulam effectively controls or suppresses a number of problematic weed species including red sorrel and also should be registered for use. Florasulam, flumioxazin, and oxyfluorfin all have the potential to be effective weed management tools for the wild blueberry industry to address specific weed issues especially when combined with hexazinone. All of the products evaluated tended to be more effective when tank mixed with hexazinone than when applied alone. We conclude that we have identified multiple herbicide products that could be effective tools for the blueberry industry that would slow the advent of herbicide resistance.

2.0 Objectives: The overall objective of this research is to develop sustainable, long-term weed management options for wild blueberry. Specific objectives include:

1. Large-scale evaluations of multiple new herbicide chemistries that the VMRP at the Dalhousie Agricultural Campus (formerly Nova Scotia Agricultural College) has determined are safe for use on wild blueberries. The focus of this objective will be to determine the spectrum of weeds controlled by these products, evaluate their impact on the crop, and collect the data required by the Pest Management Regulatory Agency for registration.
2. Determine the minimal effective dose that adequately controls weeds and maximizes crop yields.
3. Determine the application window in relation to crop emergence that the products can be applied without crop damage.
4. Evaluation of potential herbicide tank mixes that contain herbicides from different groups to maximize the number of weed species controlled and slow or prevent the onset of herbicide resistance.

3.0 Site Description: All experiments were conducted on commercial wild blueberry fields in central Nova Scotia.

4.0 New Herbicide Product Screening:

4.1 Materials & Methods. A 2x9 factorial experiment was set up in the sprout year of three commercial wild blueberry fields in November of 2011. Nine herbicide treatments (including an untreated control) were tested individually and with a tank mix of the industry standard hexazinone (Velpar ™), (Table 1). The research plots were organized as a Randomized Complete Block Design with four blocks. Plots measured 2m x 20m with a 1m buffer between blocks.

Table 1: Herbicide treatments evaluated for use in lowbush blueberry.

Herbicide Treatment	Active Ingredient (s)	Application Rate (g ai ha^{-1})
Untreated Control	-	-
Velpar	hexazinone	1920
Simplicity	Pyroxsulam	15
Simplicity + Velpar	Pyroxsulam + hexazinone	15 + 1920
Florasulam	Florasulam	10
Florasulam + Velpar	Florasulam + hexazinone	10 + 1920
Chateau	Flumioxazin	214
Chateau + Velpar	Flumioxazin + hexazinone	214 + 1920
Ignite	Glufosinate ammonium	375
Ignite + Velpar	Glufosinate ammonium + hexazinone	375 + 1920
Ignite + Alion	Glufosinate ammonium + indaziflam	375 + 75
Ignite + Alion + Velpar	Glufosinate ammonium + indaziflam + hexazinone	375 + 75 + 1920
Milestone	aminopyralid	91
Milestone + Velpar	aminopyralid + hexazinone	91 + 1920
Goal	oxyfluorfen	480
Goal + Velpar	oxyfluorfen + hexazinone	480 + 1920
Casaron	dichlobenil	3200
Casaron + Velpar	dichlobenil + hexazinone	3200 + 1920

Two sites were established in Collingwood, Nova Scotia (Pigeon Hill and Nina's New) and the third site was established outside of Londonderry, Nova Scotia (Cooper Field). After sites had been mowed with a push mower, fall sprays were applied in November, 2011, spring sprays in May, 2012. All treatments were sprayed before blueberry plants had emerged. Herbicide applications were made using a CO_2 pressurized sprayer equipped with XR8002VS Teejet nozzles on a handheld boom. Water volumes for all products were 200L/ha sprayed at 0.22MPa.

Weed and blueberry damage ratings were conducted at 14, 35 56 and 365 days after spraying (DAS), (Table 2) on a 0 to 10 scale where 0 is no damage and 10 is complete shoot death. Blueberry stem densities were measured once in the vegetative year by counting the number of blueberry stems within a randomly placed four 25cm x 25 cm quadrats in each plot. Percent ground cover was measured twice in the growing season using the transect method with four replications of a 50cm X 50cm quadrat with 25 transects/quadrat. Density of predominant weed species was also estimated twice in the vegetative year by counting the number of shoots within a given area. Different sized quadrats were used depending upon the size of the plant (i.e. golden rod counts were conducted using a 1m X 1m sized quadrat whereas red sorrel was counted using a 25cm X 25cm quadrat). In all instances, four reps were measured per plot. Biomass collection was completed late in the summer growing season. Four quadrats of 25cm X 25cm size were randomly placed in the plots and all plant matter was clipped and collected within that quadrat. Plant matter was then sorted into blueberry, grass, broadleaf and rush categories and air dried at 60°C for several days. Dried plant matter was removed from bags and weighed and the average of the four quadrats was found.

Table 2: Data collection dates in 2012 and 2013 at all three sites.

Year	Data	Nina's New	Pigeon Hill	Cooper
2012	Blueberry Stem Density	08/21	06/15	06/15
	Weed Density	05/15	05/16	05/29
		06/05	08/27	08/28
		08/29	-	-
	Damage Ratings	05/23	05/24	05/16
		06/13	06/15	06/06
		07/03	07/11	06/26
	Percent Ground Cover	06/28	07/05	06/19
		08/21	08/27	08/28
	Weed and Crop Biomass	07/12-13	07/17-18	07/23-24
2013	Floral Bud Counts and Blueberry Stem Heights	-[1]	-[2]	04/30
	Damage Ratings	-	07/05	06/13
		-	09/13	-
	Blueberry Stem Density	-	-	06/05
	Blueberry Flower Counts	-	06/24	06/13
	Blueberry Stem heights	-	06/24	-
	Weed Density	-	-	07/09
		-	-	07/29
	Ground Cover	-	-	07/09
	Blueberry Yield	-	-	08/12-16

[1]This site was flail mowed by the owner in early spring and as a result data could not be collected in 2013.
[2]This site was bush hogged in 2013 by the owner and as a result only limited data could be collected in 2013.

4.2 Results. Aminopyrald was the only herbicide that caused significant crop damage (Table 3). Care should be taken when applying dichlobenil in combination with hexazinone as low level damage was observed 35 days after spraying (DAS). The remainder of the products were safe for use when applied at the proper time. Indazaflam combined with ignite suppressed goldenrods (60%) with and without hezazinone as did florasulam (50%), (data not shown). Applications of pyroxsulam controlled 80 to 90% of the red sorrel (Table 3). Florasulam and oxyfluorfen combined with hexazinone also suppressed red sorrel. Bluegrass was adequately controlled with hexazinone and glufosinate. Differences in damage ratings generally disappeared in the second year.

Table 3. Blueberry and weed percent damage following application of various preemergence herbicides at Collingwood, Nova Scotia.

Herbicide	Velpar	Blueberry	Red Sorrel	Bluegrass
Untreated	No	0 d[1]	0 e	0 e
	Yes	0 d	0 e	100 a
Pyroxsulam	No	0 d	80 ab	30 cd
	Yes	0 d	90 a	100 a
Florasulam	No	0 d	30 cde	0 e
	Yes	10 cd	70 ab	9 a
Flumioxazin	No	0 d	0 e	0 e
	Yes	0 d	40 bcde	90 ab
Glufosinate	No	0 d	0 e	80 ab
	Yes	10 cd	-	80 ab
Glufosinate+Indazaflam	No	0 d	20 de	60 bc
	Yes	10 cd	40 bcde	100 a
Aminopyralid	No	20 bc	40 bcd	20 de
	Yes	80 a	-	100 a
Oxyfluorfen	No	0 d	10 de	0 e
	Yes	0 d	60 abc	90 ab
Dichlobenil	No	0 d	20 de	20 de
	Yes	30 b	30 cde	90 a

[1] Means within columns followed by different letters are significantly different at $p<0.05$.

Ground cover measurments gave similar results. Hexazinone applications significantly reduced bluegrass ground cover (Table 4). There were no consistent trends in broadleaf ground cover at Collingwood. This is not surprising as the weed populations were very patchy and some of the more problematic species tend to occur beneath the blueberry canopy and are not as readily observed when measuring ground cover. At Pigeon Hill, hexazinone applications tended to reduce broadleaf cover more so than any other herbicide tested. Hexazinone was the only herbicide that increased blueberry yields at Collingwood with 1457 kg/ha where hexazinone was applied and 1059 kg/ha where hexazinone was not applied. Unfortunately, the remaining two sites where the experiment occurred were mowed before berries could be harvested.

Table 4. Grass and broadleaf ground cover at Collingwood and Pigeon Hill Nova Scotia following application of various preemergence herbicides.

Herbicide	Velpar	Collingwood Grass	Collingwood Broadleaf	Pigeon Hill Broadleaf
		---%	---	---
Untreated	No	28 bc	10 abcde	55 a
	Yes	4 f	16 abcde	7 cd
Pyroxsulam	No	24 bcd	4 e	49 a
	Yes	10 ef	18 abcd	5 d
Florasulam	No	44 a	6 de	38 ab
	Yes	5 f	8 de	3 d
Flumioxazin	No	22 bcde	22 ab	55 a
	Yes	5 f	15 abcde	1 d
Glufosinate	No	10 ef	20 abc	39 ab
	Yes	16 cdef	7 de	14 cd
Glufosinate+Indazaflam	No	8 f	14 abcde	-
	Yes	3 f	22 a	-
Aminopyralid	No	32 ab	8 cde	24 bc
	Yes	9 ef	5 de	2 d
Oxyfluorfen	No	29 bc	10 bcde	53 a
	Yes	6 f	14 abcde	14 cd
Dichlobenil	No	12 def	22 a	40 ab
	Yes	6 f	10 bcde	1 d

[1] Means within columns followed by different letters are significantly different at $p<0.05$.

5.0 Dose Response Screening Trial

5.1 Materials & Methods: A RCBD experiment was set up in the sprout year of two commercial wild blueberry fields in the spring of 2012 (Pigeon Hill and Nina's New). Each site was mowed previous to spraying using a push mower. Treatments were sprayed early in the spring before blueberries had emerged. Three pre-emergent herbicides at three doses were applied at each site (Table 9).

Table 5. Herbicide treatments applied in the Dose Response Screening Experiment.

Herbicide Treatment	Active Ingredient	Application Rate (g ai ha^{-1})
Untreated Control	None	None
Simplicity 0.75X	pyroxsulam	11
Simplicity 1X	pyroxsulam	15
Simplicity 1.25X	pyroxsulam	19
Florasulam 0.75X	florasulam	8
Florasulam 1X	florasulam	10
Florasulam 1.25X	florasulam	12
Ignite 1X	glufosinate ammonium	375
Ignite 1.5X	glufosinate ammonium	562
Ignite 2X	glufosinate ammonium	750

Herbicides were applied with a CO_2 pressurized sprayer equipped with XR8002VS Teejet nozzles on a hand held boom. Water volumes were 200L/ha sprayed at 0.22MPa for all products. Weed and crop damage ratings were taken 14, 35 and 56 days after spraying (DAS) using a 0 to 10 scale where 0 is no damage and 10 is complete death. Blueberry stem densities were measured once in the vegetative year by counting the number of blueberry stems within two randomly placed 25 cm x 25 cm quadrats. Percent ground cover was measured twice in the growing season using the transect method with four replications of a 50cm X 50cm quadrat with 25 transects/quadrat. Density of predominant weed species was also estimated twice in the vegetative year by counting the number of shoots within a given area. Different sized quadrats were used depending upon the size of the plant (i.e. golden rod counts were conducted using a 1m X 1m sized quadrat whereas red sorrel was counted using a 25cm X 25cm quadrat). In all instances, four reps were measured per plot. Biomass collection was completed late in the summer growing season. Four quadrats of 25cm X 25cm size were randomly placed in the plots and all plant matter was clipped and collected within that quadrat. Plant matter was then sorted into blueberry, grass, broadleaf and rush categories and air dried at 60°C for several days. Dried plant matter was removed from bags and weighed and the average of the four quadrats was found. Floral bud counts and blueberry stem height were measured in the late fall by clipping up to 20 stems per plot and counting the floral buds and measuring the stem length.

5.2 Results. None of the herbicides applied had a significant impact on grass ground cover at Nina's New (Table 6). In fact, grass cover tended to increase where herbicides were applied. This is a common occurrence in lowbush blueberry fields as grasses often colonize unoccupied areas following broadleaf weed control. Pyroxsulam significantly reduced broadleaf weed control at the two lower rates. Although not significant, florasulam also tended to reduce overall broadleaf weed control. Glufosinate tended to reduce broadleaf weed control at the higher rates. There was no difference in ground cover at Pigeon Hill predominately because the species that occurred at this site were not controlled by the three products evaluated in this trial. There were no significant differences between treatments by season end.

Table 6. Grass and broadleaf ground cover at Nina's New field in Collingwood, Nova Scotia following application of three herbicides at three rates.

Herbicide	Rate	Grass	Broadleaf
	g ai ha^{-1}	---------------------%---------------------	
Untreated	0	9 c[1]	30 a
Pyroxsulam	11	56 a	1 b
	15	46 ab	6 b
	19	36 abc	18 ab
Florasulam	8	46 ab	14 ab
	10	28 bc	12 ab
	12	26 bc	9 ab
Glufosinate	375	40 abc	9 ab
	562	22 bc	3 b
	750	22 bc	2 b

[1] Means within columns followed by different letters are significantly different at $p<0.05$.

6.0 Application Timing of Preemergence Products

6.1 Materials and Methods. A RCBD experiment was set up in the sprout year of two commercial wild blueberry fields in the spring of 2013 (Earltown and Collingwood). Each site was flail mowed previous to set up of the experiment. Glufosinate, pyroxsulam, oxyfluorfen, and hexazinone were sprayed at 375, 15, 480, and 1920 g ai ha^{-1} prior to blueberry emergence (Pre), at bud break, and at 10% ramet emergence. Herbicides were applied with a CO_2 pressurized sprayer equipped with XR8002VS Teejet nozzles on a hand held boom. Water volumes were 200L/ha sprayed at 0.22MPa for all products. Weed and crop damage ratings were taken 14, 35 and 56 days after spraying (DAS) using a 0 to 100 scale where 0 is no damage and 100 is complete death.

6.2 Results. All herbicides applied at Earltown significantly damaged the grasses except hexazinone (Table 7). Similar trends were observed at Collingwood with the exception that hexazinone provided significant levels of control. In most cases grass control was enhanced with later applications. As expected, glufosinate caused no crop damage if applied prior to emergence. Late applications caused significant levels of damage. Pyroxsulam was also safe if applied prior to emergence. Oxyfluorfen caused low levels of damage even if applied preemergence. Hexazinone damage was noted at all application dates. We are uncertain why this occurred but suspect it is because the blueberry emerged rapidly in the spring and as a result the plants were more advanced than the desired growth stage for application. For example, rather than 10% emergence it was closer to 15% and at bud break some of the shoots had begun to emerge. Overall, we feel that all products applied at a range of dates were at least as safe as hexazinone and could be registered for use in lowbush blueberry.

Table 7. Impact of application timing of alternative herbicide products on blueberry damage ratings 14 days after spraying at Earltown and Collingwood, Nova Scotia.

		Earltown		Collingwood	
Herbicide	Timing	Grass	Blueberry	Grass	Blueberry
Untreated	-	0 g[1]	0 e	0 g	0 c
Glufosinate	Pre	30 def	0 e	0 g	0 c
	Bud break	30 def	0 e	40 c	10 c
	10% emerg.	70 ab	50 b	90 a	20 bc
Untreated	-	0 g	0 e	0 g	0 c
Pyroxsulam	Pre	30 def	0 e	10 fg	0 c
	Bud break	60 abc	10 de	20 def	0 c
	10% emerg.	42 cde	20 de	20 def	10 c
Untreated	-	0 g	0 e	0 g	0 c
Oxyfluorfen	Pre	50 bcd	10 de	10 efg	10 c
	Bud break	50 cde	40 bc	20 de	20 c
	10% emerg.	80 a	80 a	30 cd	80 a
Untreated	-	0 g	0 e	0 g	0 c
Hexazinone	Pre	0 g	10 de	80 a	50 ab
	Bud break	0 g	0 e	90 a	30 bc
	10% emerg.	0 g	30 cd	60 b	10 c

[1] Means within columns followed by different letters are significantly different at $p<0.05$.

7.0 Grass Herbicide Sequence Trial

6.1 Materials & Methods. A 2x2x2 factorial experiment was set up in the sprout year of two commercial wild blueberry fields in the spring of 2012 (Portapique and Nina's New in Collingwood, Nova Scotia). Each site was mowed previous to spraying. The factors evaluated were the presence versus absence of a pre-emergence burndown (Ignite at 375 g ai ha^{-1}), presence versus absence of a pre-emergence herbicide (Sinbar at 2000 g ai ha^{-1}), and the presence versus absence of a post emergence herbicide (Venture at 250 g ai ha^{-1}). Varying combinations of the herbicides were applied (Table 7). Sinbar™ and Ignite™ were sprayed pre-emergence and Venture™ was sprayed post emergence.

Table 8. Summary of treatments for grass herbicide sequence trial.

Herbicide Treatment	Active Ingredient (s)	Application Rate (g a.i. ha^{-1})
Untreated	None	NA
Ignite	glufosinate	375
Sinbar	terbacil	2000
Venture	fluazifop-p	250
Ignite+Sinbar	glufosinate+terbacil	375 + 2000
Ignite + Venture	glufosinate+fluazifop-p	375 + 250
Sinbar + Venture	terbacil + fluazifop-p	2000 + 250
Ignite + Sinbar + Venture	Glufosinate+terbacil+fluazifop-p	375 + 2000 + 250

Herbicide applications were made using a CO_2 pressurized sprayer equipped with XR8002VS Teejet nozzles on a hand held boom. Water volumes used were 200L/ha sprayed at a pressure of 0.22MPa.

Crop and weed damage ratings were conducted 14, 35 and 56 days after spraying (DAS) as per PMRA guidelines. Blueberries and the most prominent grasses at each site were rated for damage on a 0 to 10 scale where 0 represents no damage and 10 complete kill. Blueberry stem densities were counted once in the growing season within two randomly placed 25 x 25 cm quadrat within each plot. Percent ground cover was measured twice in the growing season using the transect method using two replications of a 50cm X 50cm quadrat with 25 transect points per plot. Weed density of the most prominent weeds at each site were measured twice in the growing season by counting the number of each species in a randomly thrown quadrat. Different sized quadrats were used depending upon the size of the plant (i.e. golden rod counts were conducted using a 1m X 1m sized quadrat whereas red sorrel was counted using a 25cm X 25cm quadrat). In all instances, two reps per plot were measured per plot. Floral bud counts and blueberry stem height were measured in the late fall by clipping up to 20 stems per plot, counting the floral buds and measuring the stem height of each stem.

6.2 Results. Glufosinate and terbacil did not effectively control the grasses in the Nina's new field. Fluazifop reduced the number of tufts from 2 m^{-2} to 0.7 m^{-2}. This site was mowed prior to harvest and as a result no harvest data was collected. At Portipique, glufosinate ($p=0.013$), terbacil ($p<0.0001$), and fluazifop-p ($p=0.033$) had a significant impact on tuft counts. Terbacil had the greatest impact on tuft counts and was as effective as any other combination (Table 8).

Table 9. Impact of glufosinate, terbacil, and fluazifop-p applications on poverty oatgrass control at Portipique, Nova Scotia.

Glufosinate	Terbacil	Fluazifop-p	Tuft Count
			# m^{-2}
No	No	No	20 a[1]
Yes	No	No	14 ab
No	No	Yes	13 b
Yes	No	Yes	8 bc
No	Yes	Yes	4 cd
Yes	Yes	No	4 cd
No	Yes	No	2 cd
Yes	Yes	Yes	1 d

[1] Means within columns followed by different letters are significantly different at $p<0.05$.