Control of hexazinone tolerant weeds in lowbush blueberries.

by

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ABSTRACT

Field experiments were conducted from 1989 to 1991 to evaluate several sulfonylurea herbicides, glyphosate and clopyralid for the control of bunchberry and other hexazinone tolerant weeds in lowbush blueberry. Broadcast applications of chlorsulfuron, metsulfuron and glyphosate reduced bunchberry densities at all application dates, though crop damage and subsequent yield reductions were unacceptable. Glyphosate was very effective in controlling a large number of plant species when applied as a spot spray treatment. Tribenuron and DPX R9674 were effective in suppressing bunchberry stem densities at all application dates, without major adverse effects on blueberry, and also controlled a large number of hexazinone tolerant weeds when applied as a spot spray treatment. Clopyralid, at rates as low as 100 g a.i. ha^{-1}, was very effective as a broadcast treatment for the control of tufted vetch, although problems with crop tolerance and yield reductions were evident in some instances. Clopyralid did not control a large number of hexazinone tolerant species when applied as a spot spray treatment.

RESUME

Des experiences sur le champ ont ete conduites de 1989 a 1991 afin d'evaluer plusiers herbicides sulfonylurea, glyphosate et clopyralid pour le control de Cornouiller de Canada et d'autres herbes tolerantes a hexazinone dans les bluets. Des applications abondantes de chlorsulfuron, metsulfuron et de glyphosate ont diminue la densite des Cornouiller de Canada a toutes les dates d'applications, meme si les damages a la recoltee et la quantite recolte etaient inacceptable. Glyphosate etait tres effectif pour le control d'une grand nombre d'especes de plantes lorsqu'il etait applique comme un traitement vaporisateur local. Tribenuron et DPX R9674 etaient effectifs pour supprimer les densites de tigis Cornouiller de Canada a toutes les dates d'applications sans effets lethaux majeurs sur les bluetes et aussi effectifs pour controler le grand nombre d'herbes tolerants a hexazinone lorsqu'applique comme un traitement vaporisateur local. Clopyralid, a un taux aussi bas que 100 g a.i. ha^{-1}, etait tres effectif comme traitement abonda sour le controls de Vesce jargeau, meme si certains problems aves la tolerance et la quantite de la recolte etaient evidents a quelques occasion. Clopyralid n'a pas controle un grand nombre d'especes tolerantes a hexazinone lorqu'il etait applique comme un traitement vaporisateur local.

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S.M.H.

I. INTRODUCTION

A. Weed problems in Nova Scotia lowbush blueberry fields.

The lowbush blueberry (*Vaccinium angustifolium* Ait.) is produced in Maine and the Canadian Maritime provinces on fields developed from native stands. Weeds are one of the major limiting factors in the commercial production of lowbush blueberries (Jensen 1989; McCully 1988). Weeds compete with the crop for space, light, water and soil nutrients. This competition not only prevents the spread of the crop plants, but also results in a reduction in crop yield. As well, the quality of the blueberry pack may be decreased with the presence of foreign berries such as bunchberry (*Cornus canadensis* L.) (Hall and Sibley 1976) and barrenberry (*Aronia arbutifolia* (L.)Ell.) (Yarborough and Ismail 1979a). Weeds also serve as an alternate host for diseases which affect blueberry, and can provide shelter for various insect pests (McCully *et al.* 1991). As well, weeds may hinder harvest and reduce the quality of the fruit. Furthermore, use of fertilizers and effectiveness of mechanical harvesters depend on adequate weed control.

In a survey of lowbush blueberry fields in Nova Scotia, McCully *et al.* (1991) identified 119 different weed species. Weeds identified included herbaceous and woody broadleaf weeds as well as many grasses, rushes and sedges. Most of the weeds observed were part of Nova

Scotia's native flora (McCully *et al.* 1991). Most of the weed problems in lowbush blueberry fields are perennial plants, however annuals and biennials are also troublesome (Anon. 1991).

Land preparation for blueberry production affects weed populations in blueberry fields (Hall 1955). A common practice is to allow the spread of blueberry into cleared woodland as a way to increase acreage (Hall 1955). Weeds such as bunchberry, which grow slowly in the shade of the understory, fluorish and compete with the blueberry plants once the forest canopy has been removed (Hall and Sibley 1976).

Many of the major weeds in lowbush blueberry fields are species of the native flora that are well adapted to the 2-year crop management cycle. The most important management practice is pruning, which involves mowing with a flail mower or burning the field every 2 years (Sibley 1983). Pruning induces the growth of new blueberry sprouts, many of which will develop flower buds. The old, highly-branched bushes, with few flower buds, are replaced by single stems which are more productive. Pruning also serves to keep the fields in an early successional stage (Yarborough *et al.* 1986). Blueberry is only one of many plant species that occupies land in the early stages of the succession process of cleared land changing to forest in Eastern North America (Hancher *et al.* 1985). It is through the management of these plant stands that a lowbush blueberry "monoculture" can be obtained. Thus, good weed control is essential in maximizing crop yields. The practice of pruning controls some weeds (Black 1963), while others are invigorated by this practice (Yarborough *et al.* 1986). Pruning by burning releases axillary buds of such weeds as bunchberry (Hall and Sibley 1976) and causes some woody species, such as aspen (*Populus tremuloides* Michx.) to sucker, thus resulting in an increased weed problem (Shirley 1931). It has also been reported that pruning by burning every second year may result in weeds such as lambkill (*Kalmia angustifolia* L.) becoming dominant species in lowbush blueberry fields (Hall and Aalders 1968). McCully (1988) provided a complete review of the effects of pruning on weed populations.

B. Chemical control of weeds in lowbush blueberry.

The most common and effective way to control weeds in commercial lowbush blueberry fields is through the use of herbicides. McCully (1988) stated that the application of herbicides influences weed populations more than any other managerial practice. Chemical control is however, one of the most expensive methods (McCully 1988), though labor is greatly reduced. Currently there are five herbicides recommended for weed control in lowbush blueberries (Anon. 1991). These are asulam (methyl [(4-aminophenyl) sulfonyl] carbamate), dicamba (3,6-dichloro-2-methoxybenzoic acid), terbacil (5-chloro-3-(1,1-dimethyl ethyl) -6- methyl- 2,4 (1*H*,3*H*)- pyrimidinedione) , atrazine (6-chloro -*N*-ethyl-*N*′-(1-methylethyl)-1,3,5-triazine-2,4-diamine), and hexazinone (3-cyclohexyl-6- (dimethylamino) -1-methyl-1,3,5- triazine- 2,4(1*H*,3*H*) -dione. Glyphosate (*N*-(phosphonomethyl)glycine), although not presently registered for use in lowbush blueberry, can be used in land clearing and field preparation. This herbicide is a nonselective, broadspectrum, postemergence herbicide (Baird *et al.* 1974; Sprankle *et al.* 1975) that has been shown to be effective in controlling many perennial weed species (Gottrup *et al.* 1976; Ismail and Yarborough 1981; Wyrrill and Burnside 1976; Yarborough and Ismail 1979b).

Asulam is recommended for the control of bracken fern (*Pteridium aquilinum* (L.) Kuhn) and sensitive fern (*Onoclea sensibilis* L.), though it gives poor control of hay-scented fern (*Dennstaedtia punctilobula* (Michx.)Moore). Asulam is most effective when applied in the prune year at, or just before, the fronds are fully unfurled (Jensen 1986b). Dicamba is effective against woody species such as maple (*Acer spp.* L.), alders, willows (*Salix spp.* L.) and honeysuckle (*Lonicera spp.* L.). Dicamba should be applied in a selective manner in which contact with actively growing blueberry plants is avoided. Selective application of herbicides late in the fall can take advantage of differences in the growth habits of certain weeds. For example, lambkill which is nondeciduous, can be treated selectively with 2,4-D ((2,4-dichlorophenoxy)acetic acid)/dicamba after blueberry leaves have senesced and abscised (Ismail and Yarborough 1981). Many other species such as alders, sweet fern (*Comptonia peregrina* (L.)Coult.) and blackberry (*Rubus spp.* L.) retain their leaves in a viable condition longer than the harvested blueberries and can be treated in October with dicamba (Jensen and North 1987). In these cases, little of the absorbed herbicide is translocated to the blueberry rhizomes, because the blueberry stems are dormant at application, and the pruning operation removes the treated stems in the spring before the plants become active. Other methods of selective herbicide application include hand wiper applications (Yarborough 1985; Yarborough and Hoelper 1985b; Yarborough and Smagula 1986), spot sprays (Yarborough 1990), basal bark or stump treatments, weed wiper (Yarborough 1988) or brush application and the use of weed rollers (Smagula *et al.* 1986a).

Terbacil is a soil-applied, residual herbicide that is applied after pruning and before blueberry emergence. In the past, the use of terbacil has provided control of many grasses, sedges and some flowering herbaceous weeds in lowbush blueberries, resulting in temporary increases in blueberry yields (Ismail 1974). Because of control of grasses and sedges, many herbaceous and woody weeds have increased in density and distribution when terbacil has been used (Yarborough and Ismail 1985). Atrazine, like terbacil, is recommended as a broadcast application for the control of most grasses, sedges and many herbaceous weeds. This herbicide is residual in the soil and will prevent many weeds from establishing from seed. However it will not control woody weeds. Atrazine is best applied in the spring after pruning but before blueberry emergence (Jensen 1986b).

Hexazinone is the most commonly used herbicide for weed control in lowbush blueberry fields and is the only selective soil-applied herbicide that will control woody weeds in lowbush blueberry fields (Jensen 1986a; Yarborough and Ismail 1985). Before the registration of hexazinone, control of woody species was limited to cutting and mowing and the use of selective applications of phenoxy type herbicides (Jensen

1989) which would often result in crop injury. Hexazinone will also control many common grasses and herbaceous broadleaf weeds (Jensen *et al.* 1983). The effectiveness of hexazinone to control such a range of weed species, and thus result in subsequent yield increases, has led to its widespread use by lowbush blueberry producers (Yarborough *et al.* 1986). When applied after pruning but before blueberry emergence, hexazinone will not harm the blueberry plants.

Hexazinone, however, does not control all woody and herbaceous weeds found in lowbush blueberry fields, and its widespread use has resulted in increases in the number of tolerant weeds found in blueberry fields (Jensen 1986b). Hexazinone tolerant weeds include: hay-scented fern, common St. John's wort (*Hypericum perforatum* L.), dogbane (*Apocynum androsaemifolium* L.), witherod (*Viburnum cassinoides* L.), tufted vetch (*Vicia cracca* L.), common wild rose (*Rosa virginiana* Mill.), alders, bracken fern, common juniper (*Juniperus communis* L.), Northern honeysuckle (*Lonicera villosa* (Michx.)R.&S.), common woodrush (*Luzula multiflora* (Retz.)Lejeune), bugleweed (*Lycopus uniflorus* Michx.), sweet fern, lion's paw (*Prenanthes trifoliolata* (Cass.)Fern.) and bunchberry (Anon. 1991; Sampson *et al.* 1990). These weeds are becoming more of a problem in lowbush blueberry fields. Other recommended herbicides have certain disadvantages with their use including limited spectrum of weed control, limited crop tolerance associated with certain application timings and the amount of labor required with certain application methods.

Some weeds found in lowbush blueberry fields, particularly bunchberry, are not controlled by any of the current weed control practices available to producers. McCully (1988) provides a complete review of herbicides tested by other researchers for bunchberry control in lowbush blueberry. None of the treatments provided good crop tolerance and excellent control of the weed. Inconsistent results were obtained from various herbicide treatments evaluated for effectiveness in controlling bunchberry in lowbush blueberry fields (McCully 1988). Differences in location, altitude, soil, environment, climate, blueberry clones, bunchberry clones and application timing could be responsible for these variable results. At the beginning of the present study, selective herbicides that would control bunchberry without harming blueberry stands had not been successful.

One group of herbicides that shows some potential is the sulfonylurea herbicides. Results showing good crop tolerance with poor bunchberry control or good control of bunchberry with poor crop tolerance have been reported with use of various sulfonylurea herbicides including chlorsulfuron (2-chloro-*N*-[[(4-methoxy- 6-methyl-1,3,5-triazin -2-yl)amino]carbonyl]benzenesulfonamide), metsulfuron (2-[[[[(4- methoxy -6-methyl -1,3,5-triazin-2-yl) amino] carbonyl] amino] sulfonyl] benzoic acid) and sulfometuron (2-[[[[(4,6-dimethyl-2-pyrimidinyl)amino] carbonyl]amino]sulfonyl]benzoic acid) (McCully and Sampson 1987; Sampson 1989b; Sampson and Howatt 1988; Thompson and Silver 1989). These results suggest that a herbicide from this family may be found that provides selective bunchberry control and control of other hexazinone tolerant weeds in lowbush blueberry.

C. OBJECTIVES

A survey of the literature revealed that a number of weeds in lowbush blueberry fields, including bunchberry, are tolerant to hexazinone and therefore are escaping control. Further testing of rates, formulations and timings of application of promising alternative herbicides, is required if control of bunchberry and other hexazinone tolerant weeds is to be achieved before they become even more serious problems to commercial lowbush blueberry producers.

The objectives of this project were: 1) to determine the selective activity of various sulfonylurea herbicides and glyphosate for the control of bunchberry in lowbush blueberry, 2) to confirm lowbush blueberry tolerance to clopyralid, and 3) to determine the potential for using these herbicides as spot spray treatments for hexazinone tolerant weeds.

II. BUNCHBERRY CONTROL IN LOWBUSH BLUEBERRY WITH PREEMERGENCE APPLICATIONS OF SELECTED SULFONYLUREA HERBICIDES.

A. Introduction

Bunchberry (*Cornus canadensis* L.) competes with lowbush blueberry (*Vaccinium angustifolium* Ait.) plants and reduces the quality of the blueberry pack with the presence of its orange-red berries. Bunchberry is the most common and most serious weed in Nova Scotia blueberry fields (McCully *et al*. 1991). A survey of lowbush blueberry fields in Nova Scotia revealed that some fields had as much as 20% coverage by this species (Hall and Sibley, 1976). Lowbush blueberry production involves a 2-yr cycle in which the fields are pruned and herbicides applied the first year and the fields harvested the second year. Like many weeds present in blueberry fields, bunchberry survives and is promoted by the 2-yr crop cycle.

Many competing weeds have been supressed with the use of selective herbicides, particularly hexazinone (3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1*H*,3*H*)-dione), when applied as a preemergence soil application after pruning but before the blueberry shoots emerge (Yarborough and Ismail 1985; Jensen *et al*. 1981). Not all species are controlled, however, and in the absence of hexazinone-sensitive weeds, the tolerant ones, such as bunchberry, are able to spread into areas previously occupied by the other weeds (McCully 1988). The sulfonylurea herbicides are a relatively new group of herbicides which control many broadleaf weeds (Beyer *et al.* 1987; Blair and Martin 1988; Palm *et al.* 1980). Previous studies have indicated that preemergence applications of several sulfonylurea herbicides may be effective in controlling bunchberry in lowbush blueberry (Sampson 1989; McCully *et al.* 1988; Poliquin and Turcotte 1988; McCully and Sampson 1987). The objective of this study was to determine if selective control of bunchberry could be obtained with preemergence applications of glyphosate (*N*-(phosphonomethyl)glycine) and several sulfonylurea herbicides, known to have activity against broadleaf perennial weeds, that were available for testing when the study was initiated in 1989.

B. Materials and Methods

A trial was established on Pigeon Hill, Cumberland Co. in May, 1989 to investigate the effects of five sulfonylurea herbicides applied preemergently for bunchberry control in lowbush blueberry. This field was pruned by mowing. The field had a clay soil with 20% organic matter and pH of 5.0. Herbicide treatments were: 10, 15, 20, and 30 g ha^{-1} chlorsulfuron (2-chloro-*N*-[[(4-methoxy- 6-methyl -1,3,5- triazin- 2-yl) amino]carbonyl]benzenesulfonamide); 15, 20, 30, 40, 50, and 60 g ha^{-1} metsulfuron (2-[[[[(4- methoxy -6- methyl -1,3,5- triazin -2- yl) amino] carbonyl]amino]sulfonyl]benzoic acid); 30, 40, and 50 g ha^{-1} thifensulfuron (3-[[[[(4- methoxy -6- methyl- 1,3,5-triazin-2-yl)amino] carbonyl]amino]sulfonyl]-2-thiophenecarboyylic acid); 60, 80, and 100 g ha^{-1} chlorimuron (2-[[[[(4- chloro -6- methoxy -2- pyrimidinyl) amino] carbonyl]amino]sulfonyl]benzoic acid); 30, 40, 50 and 60 g ha^{-1} DPX R9674[1]; and 2.5 kg ha^{-1} hexazinone. All treatments except chlorsulfuron and hexazinone included 0.5 L ha^{-1} of Enhance™ surfactant. Herbicide treatments were applied on 23 May 1989 in the early evening at an air temperature of approximately 12 C. Blueberry stems had not yet begun to develop. Bunchberry had emerged and leaves were just beginning to unfurl. Bunchberry stem counts and blueberry phytotoxicity ratings were taken on 22 June, 19 July, and 17 August 1989; and postharvest bunchberry counts were taken on 14 August 1990. Blueberry stem counts were taken on 15 November 1989 and 14 August 1990. Crop yield was recorded on 14 August 1990.

This trial was repeated in May 1990 on Glasgow Mountain, Cumberland Co. on a field that had been pruned by burning. The soil texture was sandy loam with 17% organic matter and soil pH of 6.4. Several herbicide treatments from the previous trial omitted due to excessive crop injury problems or lack of bunchberry control in the 1990 trial. Herbicide treatments included in this experiment were: 15 g ha^{-1} chlorsulfuron + 1.25 kg ha^{-1} hexazinone; 20 and 30 g ha^{-1} chlorsulfuron; 15, 20, and 30 g ha^{-1} metsulfuron; 30, 40, and 50 g ha^{-1} thifensulfuron; 30 and 40 g ha^{-1} DPX R9674; and 2.5 kg ha^{-1} hexazinone. All treatments

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1. DPX R9674 is a formulation of three parts thifensulfuron to one part tribenuron (methyl-2-[3-(4-methoxy-6-methyl-1,3,5-triazin-2-yl)-3-methylureidosulphonly]benzoate).

except those containing chlorsulfuron and/or hexazinone were applied with 0.5 L ha^{-1} of Enhance™ surfactant. Treatments were applied on 27 May 1990 in late evening at an air temperature of approximately 10 C. Blueberry stems had not yet begun to emerge, though bunchberry leaves were beginning to unfurl. Bunchberry densities and crop phytotoxicity ratings were taken on 05 July, 31 July, and 21 August. Crop phytotoxicity ratings were also taken on 24 June 1991. Blueberry bud counts were taken on 05 November 1990. Plot yields were not available for this trial as the trial was accidentally destroyed by the cooperating producer.

A field trial was established in 1990 on Glasgow Mountain, Cumberland Co. to investigate the effects of surfactants on crop damage caused by several sulfonylurea herbicides. Previous field trials using sulfonylurea herbicides applied preemergently with a surfactant resulted in crop injury ratings that were much higher than in trials not using surfactants (Sampson 1989a). Since surfactants might be expected to have no effect on preemergence herbicide activity, this trial was established to confirm the observations of Sampson (1989). This field had been pruned by fall burning. Soil texture was a sandy loam with 8% organic matter content and pH of 4.7. Herbicide treatments in this experiment were: 30 g ha^{-1} chlorsulfuron; 15 g ha^{-1} metsulfuron; 30 g ha^{-1} tribenuron; 30 g ha^{-1} DPX R9674; and 2.5 kg ha^{-1} hexazinone. All herbicides were applied with and without 0.5 L ha^{-1} Enhance™ or 0.2% v/v Agral 90™. All treatments were applied 25 May 1990 in the early evening at an air temperature of 7 C. Blueberry stems had not yet begun to emerge. Blueberry damage ratings were recorded on 05 July, 31 July, and 21 August 1990 and on 24 June 1991. Bunchberry control was not evaluated due to the absence of the weed in most plots. Plot yields were not available for this trial as it was accidentally destroyed by the cooperating producer.

All trials were set up in a randomized complete block design with four replicates. Plot size was 2 x 6m with a 2-m buffer between blocks. All experiments included a nontreated check and a standard hexazinone treatment of 2.5 kg/ha as a control. Herbicides were applied with a hand-held CO_2-pressurized sprayer operated at 200 kPa delivering 250 L ha^{-1}. All rates are given in active ingredient (ai)[2] ha^{-1}.

Blueberry phytotoxicity ratings were taken at approximately monthly intervals after herbicide application, that is 30, 60, and 90 days after treatment (dat), throughout the summer months of the sprout year and again in the spring of the harvest year. A linear scale of 0-100 was used, where 0 = no visible crop damage and 100 = complete kill. Bunchberry stem counts were recorded monthly following herbicide application in two randomly placed 50 by 50cm permanent quadrats per plot. Pre-spray bunchberry stem densities were not possible for preemergence applications as trials were set up in spring. Blueberry stem counts were taken at harvest by counting all blueberry stems in two randomly placed 25 by 25cm quadrats within each plot. In order to

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2. Abbreviations: ai, active ingredient; dat, days after treatment.

determine blueberry bud counts, twenty-five random blueberry stems were removed from each plot and the average number of fruit buds per stem was determined. Blueberry yields were taken by randomly placing a 1-m^2 quadrat within each plot and harvesting the mature fruit with a hand held harvesting rake. The weight of the marketable yield (free from immature berries and debris) was recorded.

Crop damage rating data was ranked and a Friedman Two-Way Analysis of Variance was executed on the rankings. Bunchberry and blueberry stem counts were transformed using an arcsine transformation and an analysis of variance was performed on the transformed data. Analysis of variance was performed on the average number of blueberry buds per stem. Analysis of variance was conducted on logarithmically transformed blueberry yield data. Means were separated by Tukey's Studentized Range Test at the 5% level of probability when analysis of variance indicated significance.

C. Results and Discussion

Metsulfuron caused the greatest levels of crop injury of all the sulfonylurea herbicides tested in the preemergence application screening trials (Table 1). All metsulfuron treatments in the Pigeon Hill trial resulted in little or no blueberry stem emergence after application and this damage was evident throughout the growing season (Table 2). No blueberry growth had occurred in the metsulfuron treated plots by October of the application year. For this reason only the three lowest

Table 1. Crop injury ratings after preemergence applications of sulfonylurea herbicides.

Herbicide[2]	Rate ($g\ ha^{-1}$)	Injury Rating (0-100)[1] Pigeon Hill (1989) 30 dat	Pigeon Hill (1989) 90 dat	Glasgow Mtn. (1990) 30 dat	Glasgow Mtn. (1990) 90 dat	Glasgow Mtn. June'91
chlorsulfuron	10	41 fgh[3]	5 e	--[4]	--	--
chlorsulfuron	15	51 gh	14 cde	--	--	--
chlorsulfuron	20	61 c-h	19 a-e	87 a	55 ab	40 abc
chlorsulfuron	30	59 d-h	35 a-e	89 a	66 ab	44 ab
metsulfuron	15	83 a-e	81 abc	92 a	60 ab	39 abc
metsulfuron	20	87 abc	94 ab	81 a	55 ab	26 a-d
metsulfuron	30	85 a-d	74 a-d	95 a	84 a	78 a
metsulfuron	40	83 a-f	90 abc	--	--	--
metsulfuron	50	98 a	98 a	--	--	--
metsulfuron	60	97 ab	97 ab	--	--	--
thifensulfuron	30	58 c-h	4 e	2 bc	0 c	0 d
thifensulfuron	40	64 c-h	6 de	17 bc	0 c	4 cd
thifensulfuron	50	70 a-g	12 cde	22 bc	12 c	9 bcd
DPX R9674	30	63 c-h	4 e	5 bc	0 c	5 bcd
DPX R9674	40	68 b-h	14 cde	0 c	2 c	5 cd
DPX R9674	50	69 a-g	12 b-e	--	--	--
DPX R9674	60	78 a-g	19 a-e	--	--	--
chlorimuron	60	59 e-h	1 e	--	--	--
chlorimuron	80	62 b-h	5 e	--	--	--
chlorimuron	100	48 d-h	1 e	--	--	--
chlorsulfuron+ hexazinone	15 1250	--	--	71 ab	32 bc	48 abc
hexazinone	2500	0 h	0 e	7 bc	2 c	0 d
nontreated	--	0 h	0 e	2 bc	0 c	0 d

[1] Ratings, where 0 = no visible effect and 100 = complete kill.

[2] All herbicides except chlorsulfuron and hexazinone were applied with 0.5 L ha^{-1} Enhance™.

[3] Means followed by the same letter are not significantly different ($p \leq 0.05$) according to Tukey's Studentized Range Test.

[4] Treatments were omitted from Glasgow Mountain trial due to extensive crop damage and/or lack of bunchberry control in Pigeon Hill.

Table 2. Bud counts, stem counts and yield of blueberries after preemergence applications of sulfonylurea herbicides.

Herbicide[1]	Rate ($g\ ha^{-1}$)	Pigeon Hill (1989) stem density (# m^{-2})	Pigeon Hill (1989) yield ($g\ m^{-2}$)	Glasgow Mtn. (1990) bud count (# / 25 stems)
chlorsulfuron	10	364 ns[2]	555 a	--[3]
chlorsulfuron	15	306 ns	259 abc	--
chlorsulfuron	20	382 ns	406 ab	87 ab
chlorsulfuron	30	326 ns	244 abc	34 ab
metsulfuron	15	344 ns	25 bcd	98 ab
metsulfuron	20	442 ns	0 d	41 ab
metsulfuron	30	238 ns	141 cd	0 b
metsulfuron	40	348 ns	97 d	--
metsulfuron	50	318 ns	0 d	--
metsulfuron	60	308 ns	0 d	--
thifensulfuron	30	440 ns	504 a	137 ab
thifensulfuron	40	322 ns	627 a	160 a
thifensulfuron	50	350 ns	264 abc	148 ab
DPX R9674	30	356 ns	504 a	183 a
DPX R9674	40	356 ns	460 a	134 ab
DPX R9674	50	384 ns	482 a	--
DPX R9674	60	306 ns	423 ab	--
chlorimuron	60	360 ns	497 a	--
chlorimuron	80	344 ns	391 ab	--
chlorimuron	100	412 ns	284 abc	--
chlorsulfuron+	15			
hexazinone	1250	---	---	174 ab
hexazinone	2500	368 ns	518 a	157 a
nontreated	--	366 ns	276 ab	149 ab

[1] All herbicides except chlorsulfuron and/or hexazinone were applied with 0.5 L ha^{-1} Enhance™.

[2] Means followed by the same letter are not significantly different ($p \leq 0.05$) according to Tukey's Studentized Range Test.

[3] Treatments were omitted from Glasgow Mountain trial due to extensive crop damage and/or lack of bunchberry control in Pigeon Hill.

rates (15, 20 and 30 g ha^{-1}) were included in the 1990 trial in Glasgow Mountain. Although the blueberries recovered in metsulfuron treated plots in the year following application, yields at Pigeon Hill were greatly reduced by all rates of the herbicide (Table 2). Blueberry plants in the metsulfuron treated plots were stunted and had smaller leaves than those in the nontreated and hexazinone treated plots. Blueberry bud counts were also reduced by applications of metsulfuron (Table 2) as the recovering blueberry plants were only in the vegetative stage in what should have been the harvest year. Metsulfuron has both foliar and soil activity (Nordh 1986) and is quite persistent in the soil (Smith 1986; Walker and Welch 1989). Thus the extensive crop damage in the harvest year could also be partly due to prolonged residual effects of the herbicide in the soil. Yields from metsulfuron treated plots were significantly lower than the nontreated plots for all rates of the herbicide (Table 2). Furthermore, plant height was less than that of the nontreated plots and this leads to increased harvesting difficulty. Similar results have been obtained by Sampson (1989b) using preemergence applications of metsulfuron.

Although all levels of metsulfuron reduced bunchberry densities (Table 3), plots where metsulfuron was applied contained high densities of grass weeds indicating that the herbicide was was allowing grass weeds to become established. Metsulfuron is registered as a selective herbicide in cereal crops to control a wide range of broadleaf weed

Table 3. Bunchberry density after preemergence applications of sulfonylurea herbicides.

Herbicide[1]	Rate ($g\ ha^{-1}$)	Bunchberry density ($\# m^{-2}$) Pigeon Hill (1989) 30 dat	Pigeon Hill (1989) 90 dat	Glasgow Mtn. (1990) 30 dat	Glasgow Mtn. (1990) 90 dat
chlorsulfuron	10	22 ns[2]	32 ns	--[3]	--
chlorsulfuron	15	6 ns	6 ns	--	--
chlorsulfuron	20	90 ns	22 ns	0 ns	0 ns
chlorsulfuron	30	52 ns	34 ns	0 ns	0 ns
metsulfuron	15	90 ns	10 ns	0 ns	4 ns
metsulfuron	20	142 ns	50 ns	0 ns	0 ns
metsulfuron	30	14 ns	0 ns	0 ns	0 ns
metsulfuron	40	152 ns	4 ns	--	--
metsulfuron	50	0 ns	0 ns	--	--
metsulfuron	60	124 ns	0 ns	--	--
thifensulfuron	30	106 ns	144 ns	52 ns	48 ns
thifensulfuron	40	84 ns	70 ns	60 ns	64 ns
thifensulfuron	50	62 ns	74 ns	22 ns	30 ns
DPX R9674	30	2 ns	0 ns	50 ns	122 ns
DPX R9674	40	194 ns	80 ns	48 ns	62 ns
DPX R9674	50	106 ns	130 ns	--	--
DPX R9674	60	350 ns	132 ns	--	--
chlorimuron	60	70 ns	48 ns	--	--
chlorimuron	80	68 ns	76 ns	--	--
chlorimuron	100	24 ns	26 ns	--	--
chlorsulfuron+	15				
hexazinone	1250	--	--	50 ns	34 ns
hexazinone	2500	206 ns	128 ns	186 ns	142 ns
nontreated	--	42 ns	48 ns	180 ns	120 ns

[1] All herbicides except chlorsulfuron and/or hexazinone were applied with 0.5 L ha^{-1} Enhance™.

[2] Means followed by the same letter are not significantly different ($p \leq 0.05$) according to Tukey's Studentized Range Test.

[3] Treatments were omitted from Glasgow Mountain trial due to extensive crop damage and/or lack of bunchberry control in Pigeon Hill.

species (Nordh 1986). This would explain the high densities of escaping grass weeds within the metsulfuron treated plots. Large numbers of sheep sorrel (*Rumex acetosella* L.) were also present in metsulfuron treated plots, indicating that in the absence of crop plant competition, weeds were able to re-establish quickly from seed after the residual effects of the herbicide had dissipated.

Metsulfuron had the same effect in the 1990 trial in Glasgow Mountain as in the Pigeon Hill trial. All rates of this herbicide resulted in crop injury ratings which were greater than those of related sulfonylurea herbicides (Table 1). All rates of metsulfuron in the Glasgow Mountain trial controlled bunchberry topgrowth (Table 3). Only plots treated with 15 g ha^{-1} metsulfuron had bunchberry present 90 days after application, although the density was only 4 plants m^{-2}. Plot yields were not available for treatments in this trial so herbicide effects on subsequent crop yield could not be determined. However, the extent of crop injury in the metsulfuron treated plots suggested that the treatments would have resulted in reduced crop yields, as well as increased harvest difficulty due to the reduced height of the crop.

Chlorsulfuron, like metsulfuron, caused a high degree of crop injury in both trials (Table 1). When applied preemergently to blueberry, chlorsulfuron resulted in slight reductions of stem numbers by the harvest year (Table 2). Chlorsulfuron is registered for control of broadleaf weeds in cereal crops and for non-crop land weed control (Palm *et al* 1980; Hageman and Behrens 1981; O'Sullivan 1982). This herbicide is known to control perennial and woody species so lack of selectivity to blueberry might be expected. Similar results were reported by Sampson (1989) and Sampson and Howatt (1988) with preemergent applications of chlorsulfuron. In the Pigeon Hill trial, clonal differences in response to chlorsulfuron was noted. It was observed that the chlorsulfuron completely killed one clone in a plot while leaving an adjacent clone unaffected or only slightly damaged. Differences in clonal response to preemergent applications of hexazinone has been previously reported by Jensen *et al.* (1981) and Yarborough *et al.* (1986). In the Pigeon Hill trial, yields from chlorsulfuron treated plots were not significantly different from those of the nontreated or hexazinone treated plots (Table 2) despite observable injury in the treatment year. At harvest the blueberry plants were stunted and had reduced leaves with injury symptoms similar to those observed in the metsulfuron treated plots. The stunting resulted in increased harvesting difficulty. This stunting was possibly due to the damage inflicted at the time of application as well as the residual activity of the herbicide throughout the season. Chlorsulfuron soil residues have been reported to cause damage to sensitive rotational crops (Ivany 1987; Peterson and Arnold 1986; Walker and Welch 1989). Chlorsulfuron provided good suppression of bunchberry at all rates tested (Table 3). In the Glasgow Mountain trial, the chlorsulfuron + hexazinone treatment resulted in crop damage ratings that were similar to chlorsulfuron applied alone (Table 1), although blueberry bud counts were much higher for the tank mix treatment (Table 2). Bunchberry densities were also reduced by this treatment (Table 3). Crop yield was not available in the Glasgow Mountain trial as the trial was accidentally destroyed by the cooperating producer.

DPX R9674 caused some crop damage when applied preemergently (Table 1), although the crop outgrew much of the damage in the season after application. Sampson (1989) reported that DPX R9674 caused relatively high levels of crop damage that led to reduced crop yield. In the Pigeon Hill trial, yields for DPX R9674 treated plots were higher than yields for the nontreated control. These yield increases were not significant, however (Table 2). Rates of 30 and 40 g ha^{-1} DPX R9674 were included in the Glasgow Mountain trial as they had provided control of bunchberry (Table 3) with low levels of crop damage in the 1989 Pigeon Hill trial. These rates caused no damage to blueberry in the 1990 Glasgow Mountain trial (Table 1).

Chlorimuron caused quite extensive crop injury ratings at 30 dat in the Pigeon Hill trial, although the blueberry plants outgrew the effects of this herbicide by 90 dat (Table 1). The extensive crop damage soon after application had no effect on subsequent crop yield. (Table 2). This herbicide did provide some supression of bunchberry stem numbers in the treated plots (Table 3). Yarborough and Bhowmik (1989a) evaluated chlorimuron as a postemergent application for the control of bunchberry in lowbush blueberry. They found that in one trial, the herbicide reduced bunchberry stem density and increased blueberry stems, while in another trial it had no effect on bunchberry density and reduced crop yield.

Thifensulfuron reduced bunchberry stem densities (Table 3) and caused very little damage to the crop plants (Table 1). In the Pigeon Hill trial, crop injury ratings ranged from 4 to 12 for the three rates tested. Similar results were obtained by Sampson (1989). Crop yields from thifensulfuron treated plots were as high or higher than those from the nontreated control (Table 2). Thifensulfuron has limited soil persistence when compared to chlorsulfuron or metsulfuron (Beyer *et al.* 1987). When applied to the unfurling bunchberry foliage prior to crop emergence, the potential for crop damage was reduced since much of the residual herbicide may be lost from the soil by the time the blueberry shoots emerge.

The effect of hexazinone on bunchberry stem density should be noted. In the Pigeon Hill trial, where initial bunchberry density was low within the plots, it was observed that the density increased in response to weed control with hexazinone (Table 3). This can be seen in a comparison of 48 bunchberry stems m^{-2} in the nontreated plots as compared to 128 m^{-2} in the hexazinone treated plots at 90 dat. This effect was not observed in the Glasgow Mountain trial, where initial bunchberry stem densities were higher (Table 3).

In the Glasgow Mountain surfactant trial, crop injury ratings were similar to the other trials for all herbicides used (Table 4). Chlorsulfuron and metsulfuron both resulted in crop injury ratings that

Table 4. Effect of surfactants on preemergence applications of sulfonylurea herbicides.

Herbicide	Rate (g ha^{-1})	Injury Rating (0-100)[1] 30 dat	90 dat
chlorsulfuron	30	62 a[2]	27 a
chlorsulfuron + E[3]	30	72 a	32 a
chlorsulfuron + A	30	72 a	45 a
metsulfuron	15	52 a	37 a
metsulfuron + E	15	71 a	40 a
metsulfuron + A	15	57 a	35 ab
tribenuron	30	5 b	0 c
tribenuron + E	30	12 b	0 c
tribenuron + A	30	2 b	0 c
DPX R9674	30	0 b	0 c
DPX R9674 + E	30	0 b	0 c
DPX R9674 + A	30	5 b	0 c
hexazinone	2500	2 b	1 bc
nontreated	--	0 b	0 c

[1] Ratings, where 0 = no visible effect and 100 = complete kill.

[2] Means followed by the same letter are not significantly different ($p \leq 0.05$) according to Tukey's Studentized Range Test.

[3] E = Enhance™ at 0.5 L ha^{-1}.
A = Agral 90™ at 0.2% v/v.

were unacceptable at 30 dat. Although the crop recovered from the damage to some extent over the summer, injury ratings at 90 dat were still quite high. Crop injury ratings were significantly higher for the chlorsulfuron and metsulfuron treatments than for any other treatment used in the trial. Tribenuron and DPX R9674 did not cause unacceptable crop injury. In this trial, surfactants did not affect the crop injury rating of the herbicides tested. This was as expected since surfactants should have no influence on preemergence activity of herbicides. Bunchberry densities were not sufficient in this trial to warrant stem counts. Plot yields were not available for this trial so verification of the herbicide damage on subsequent crop yield was not possible.

D. Conclusions

Although preemergenge applications of metsulfuron and chlorsulfuron reduced bunchberry densities, the margin of crop tolerance is too narrow and the subsequent yield reductions were too great for these herbicides to be used by commercial growers. Where damage was moderate, symptoms included stunting of stems and leaves. Where injury was severe, no growth occurred from the blueberry rhizomes. Thifensulfuron, DPX R9674, and tribenuron caused lower levels of crop damage and thifensulfuron and DPX R9674 provided some bunchberry control in this study. More work is needed to determine whether preemergence applications of these herbicides can effectively control bunchberry and other hexazinone tolerant weeds. Analyses of herbicide action at different stages of plant development and assessments of sequential applications of herbicides, may reveal a more effective use pattern for the sulfonylurea herbicides. Also, tank mixes with other herbicides not tested here may prove to be effective. Results obtained in this study suggest that within the sulfonylurea family of herbicides, a chemical that provides bunchberry control with an acceptable level of crop tolerance may exist. Even though several of these herbicides are not effective in preemergent broadcast applications for bunchberry control, the spectrum of weed control shown by the sulfonylurea herbicides suggest that they may be effectively used as spot spray applications to control some other hexazinone tolerant species.

III. EFFECT OF STAGE OF GROWTH AND SPLIT APPLICATIONS ON SULFONYLUREA EFFICACY FOR BUNCHBERRY CONTROL IN LOWBUSH BLUEBERRY.

A. Introduction

Lowbush blueberry (*Vaccinium angustifolium* Ait.) production involves a 2-yr cycle in which the fields are pruned and herbicides applied the first year and the fields harvested the second year. Like many weeds present in blueberry fields, bunchberry (*Cornus canadensis* L.) survives and is promoted by the 2-yr cycle that favors the blueberry crop itself. Bunchberry is the most common and most serious weed in Nova Scotia blueberry fields (McCully *et al.* 1991). A survey of lowbush blueberry fields in Nova Scotia revealed that some fields had as much as 20% coverage by this species (Hall and Sibley, 1976). Bunchberry readily competes with lowbush blueberry plants and reduces the quality of the blueberry pack with the presence of its orange-red berries.

The use of selective herbicides, particularly hexazinone (3-cyclo hexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1*H*,3*H*)-dione, have enabled commercial blueberry producers to control many of the problem weeds in lowbush blueberry fields (Hoelper and Yarborough 1985; Jensen *et al.* 1981; Yarborough and Bhowmik 1989b). Not all species are controlled with hexazinone, however, and in the absence of hexazinone-sensitive weeds, the tolerant ones, such as bunchberry, are able to thrive (McCully 1988). The sulfonylurea herbicides are a relatively new group of herbicides which control many broadleaf weeds

(Beyer *et al.* 1987; Blair and Martin 1988; Palm *et al.* 1980). Previous studies with sulfonylureas failed to demonstrate that the herbicides tested had sufficient selectivity to warrant registration in blueberries, but they did suggest that within the family of herbicides, more selective materials may exist (Sampson 1989b; McCully *et al.* 1988; Poliquin and Turcotte 1988; McCully and Sampson 1987). Studies conducted by other researchers have indicated that variable response of blueberry and bunchberry to the sulfonylurea herbicides can be expected with different application dates (McCully 1988). Postemergence sulfonylureas would be better than preemergence because they could be spot sprayed. Less herbicide would be needed, and injury could be restricted if tolerance was marginal. Therefore, in 1990, new compounds were evaluated. There was some indication that tribenuron was selective prior to this study (Jensen, unpubl. data). The objective of this study was to determine the effect of stage of growth at application on the efficacy of sulfonylurea herbicides and glyphosate (*N*-(phosphonomethyl) glycine) for bunchberry control in lowbush blueberry.

B. Materials and Methods

Two field experiments were established in 1990 to investigate the effects of sulfonylurea herbicides applied at different growth stages on bunchberry control and blueberry damage. One trial was set up in Earltown, Colchester Co. to evaluate several sulfonylurea herbicides and glyphosate applied at four growth stages throughout the summer. Soil texture at this location was a sandy loam with an organic matter content 24.1% and pH of 4.3. This trial was set up in a split-block design with blocks split according to time of application. Herbicides used in this trial were: 30 g ha^{-1} tribenuron (methyl-2-[3- (4-methoxy -6-methyl-1,3,5-triazin-2-yl)-3-methylureidosulphonyl] benzoate); 30 g ha^{-1} DPX R9674 [one part tribenuron to three parts thifensulfuron (3-[[[[(4-methoxy-6- methyl- 1,3,5- triazin-2-yl) amino] carbonyl]amino] sulfonyl]-2-thiophenecarboxylic acid]; 30 g ha^{-1} chlorsulfuron (2-chloro-*N*- [[(4-methoxy-6-methyl- 1,3,5-triazin-2-yl) amino]carbonyl] benzenesulfonamide); 15 g ha^{-1} metsulfuron (2-[[[[(4-methoxy -6-methyl -1,3,5-triazin-2-yl) amino]carbonyl]amino]sulfonyl]benzoic acid; and 450 g ha^{-1} glyphosate. Herbicides were applied on 05 June (late evening, 10 C); 05 July (late evening, 9 C); 07 August (late morning, 30 C); and 12 September (early morning, 8 C). Bunchberry stem counts and blueberry injury ratings were taken monthly after application. Crop yield was recorded on 14 August 1991 as were weed counts and blueberry stem counts.

The second timing trial was established in Highland Village, Colchester Co. on a sandy loam soil with an organic matter content of 3.2% and pH of 5.0. Two sulfonylurea herbicides were used in this trial: 40 g ha^{-1} tribenuron and 40 g ha^{-1} DPX R9674. This trial was set up in a split-block design with the blocks split according to herbicide. Treatments were applied on 04 July (early morning, 14 C); 07 August (late morning, 24 C); and 12 September (early morning, 6 C). Bunchberry stem count and blueberry injury ratings were taken as in the other trial. Crop yield, bunchberry stem counts and blueberry stem counts were recorded on 14 August 1991.

A trial was established in 1990 in Earltown, Colchester Co to investigate the effects of split-applications of sulfonylurea herbicides as compared to a single application of the herbicide for bunchberry control. Soil texture was a sandy loam with an organic matter content of 16.2% and pH of 4.4. Two herbicides, tribenuron and DPX R9674 were used in split and single rate applications. Rates of both were 15 + 15, 30 + 30, and 60 g ha^{-1}. The trial was set up in a split-block design with blocks split according to herbicide. All spray solutions contained 0.2% v/v Agral 90. The high rate of both herbicides (i.e. 60 g ha^{-1}) and the first application of the split treatments were applied on 28 June 1990 (early morning, 10 C). The second application of the split treatments was applied on 06 August (late morning, 29 C). Prespray bunchberry stem counts were recorded on 18 June 1990. Weed stem counts were also recorded on 01 August 1990, 26 September 1990 and 14 August 1991. Blueberry stem counts, bud counts, damage ratings and yields were not taken due to the lack of crop plants in the plots.

Plot size was 2 x 6m with a 2-m buffer between blocks. All experiments included a nontreated check. Herbicides were applied with a hand-held CO_2-pressurized sprayer operated at 200 kPa delivering 250 L ha^{-1}. All rates are given in active ingredient (ai) ha^{-1}.

Blueberry phytotoxicity ratings were taken using a linear scale of 0-100, where 0 = no visible crop damage and 100 = complete kill was used. Bunchberry stem counts were recorded in two randomly placed 50 by 50cm permanent quadrats per plot. Blueberry stem counts were taken at harvest by counting all blueberry stems in two randomly placed 25 by 25cm quadrats within each plot. In order to determine blueberry bud counts, twenty-five random blueberry stems were removed from each plot and the average number of fruit buds per stem was determined. Blueberry yields were taken by randomly placing a one m^2 quadrat within each plot and harvesting the mature fruit with a hand held harvesting rake. The weight of the marketable yield (free from immature berries and debris) was recorded.

Crop damage rating data was ranked and a Friedman Two-Way Analysis of Variance was executed on the rankings. Bunchberry and blueberry stem counts were transformed using the arcsine calculation and an analysis of variance was performed on the transformed data. Analysis of variance was performed on the average number of blueberry buds per stem. Analysis of variance was conducted on logarithmically transformed blueberry yield data. If a significant interaction occurred, orthogonal contrasts were conducted to compare both main plot treatment over sub-plots and sub-plot effect within a main plot. Otherwise, means were separated by Tukey's Studentized Range Test at the 5% level of probability when analysis of variance indicated significance.

C. Results and Discussion

Timing Trials. There was an interaction between herbicide and application date with regard to crop injury at 30 dat in the Earltown timing of application trial (Table 5). Early applications (05 June) of metsulfuron and chlorsulfuron resulted in the greatest crop damage ratings. McCully (1988) also found that early applications of chlorsulfuron caused considerable damage to the crop. Crop injury due to these two sulfonylureas decreased as application date was delayed (Table 5). McCully (1988) reported similar results and suggested that lowbush blueberry was also very sensitive to the timing of application of sulfometuron (2-[[[[(4,6-dimethyl-2-pyrimidinyl)amino]carbonyl]amino] sulfonyl]benzoic acid). Application date caused a similar trend in crop damage from tribenuron and DPX R9674 as it did with the other two sulfonylureas, though ratings were much lower for tribenuron and and DPX R9674 at all application dates. These two herbicides are not as residual in the soil, nor do they tend to be as phytotoxic when applied to the foliage, as metsulfuron and chlorsulfuron. Applications of tribenuron and DPX R9674 made in early August had no effect on blueberry at 30 dat (Table 5). No 30 dat data is available for the 12 September treatments due to crop senescence. Damage symptoms for the sulfonylurea herbicides included curling and chlorosis of the leaves. Leaves were often reduced in size and eventually turned red and fell off the stem. An opposite trend in crop damage was observed with applications of glyphosate in this trial. This herbicide caused increasing crop

Table 5. Effect of timing of application on crop damage, blueberry stem counts, and yield in Earltown in 1990.

Herbicide	Rate (g ha^{-1})	05 June	05 July	07 Aug.	12 Sept.
		Crop Damage (0-100)[1,2]			
metsulfuron	15	97 a A	55 b AB	45 b B	--[3]
chlorsulfuron	30	95 ab A	40 b AB	40 b B	--
tribenuron	30	62 abc A	18 c B	5 c B	--
DPX R9674	30	38 c A	15 c AB	5 c B	--
glyphosate	450	58 bc A	74 a B	89 a C	--
nontreated	--	0 d NS	0 d NS	0 c NS	--
		Blueberry Stem Density (# m^{-2})[2,4]			
metsulfuron	15	224 ns A	240 ns A	44 a B	0 a B
chlorsulfuron	30	268 ns NS	406 ns NS	294 b NS	198 b NS
tribenuron	30	264 ns NS	276 ns NS	366 b NS	372 c NS
DPX R9674	30	308 ns NS	374 ns NS	328 b NS	362 bc NS
glyphosate	450	306 ns A	232 ns A	82 a B	260 bc A
nontreated	--	348 ns NS	348 ns NS	348 b NS	348 bc NS
		Blueberry Yield (g m^{-2})[2]			
metsulfuron	15	210 ns A	53 b AB	1 b B	0 b B
chlorsulfuron	30	218 ns A	258 a A	13 b B	0 b C
tribenuron	30	198 ns BC	806 a A	481 a AB	126 a C
DPX R9674	30	567 ns NS	606 a NS	308 a NS	233 a NS
glyphosate	450	308 ns A	325 a A	13 b B	10 b B
nontreated	--	459 ns NS	459 a NS	459 a NS	459 a NS

Application Date applies to columns 05 June through 12 Sept.

[1] Ratings at 30 dat, where 0 = no visible effect and 100 = complete kill.

[2] Significant interaction ($p \leq 0.05$) occurred between herbicide treatment and date of application according to orthogonal contrasts. Lower case letters are for comparisons between herbicides within a given date of application; upper case letters are for comparison between dates of application within given herbicide treatments.

[3] Crop damage ratings were not available for 30 dat treatments applied on September 12 as crop was beginning to senesce.

[4] Blueberry stem counts taken at harvest (14 August 1991).

injury with later application dates. Glyphosate damage symptoms were characteristic of this herbicide, and included chlorosis of the leaves followed by necrosis. Plants also showed signs of proliferation of smaller leaves and stems. This was also noted by Ismail and Yarborough (1981), Hodges *et al.* (1979) and Yarborough and Hoelper (1985a).

Interaction also occurred between herbicide and date of application with regard to blueberry stem density in Earltown (Table 5). Metsulfuron resulted in the greatest decrease in blueberry stems after all timings of application. The other sulfonylurea herbicides, chlorsulfuron, tribenuron and DPX R9674, did not have a significant effect on blueberry stem counts as compared to the nontreated control. Glyphosate had its greatest effect on stem counts when applied on 07 August (Table 5). Applications of DPX R9674 and tribenuron had no effect on blueberry stem density or bud counts when applied at any of the three tested application dates in the Highland Village trial (Table 6).

Interaction occurred between herbicide and date of application with regard to crop yield in the Earltown trial (Table 5). Metsulfuron resulted in the greatest reductions in crop yield at all application dates. This herbicide is quite persistent in the soil, so it probably was supressing the crop plants for a longer period. Chlorsulfuron was more damaging when applied later in the season as opposed to the early

Table 6. Effect of timing of application of DPX R9674 and tribenuron on blueberry stem and bud count in Highland Village in 1990.

Application Date	Stem Count ($\# \ m^{-2}$)[1] DPX R9674	tribenuron	Bud # per 25 stems[1] DPX R9674	tribenuron
04 July	256	416	107	128
07 August	272	304	138	109
12 September	336	272	106	111
nontreated	288	320	109	147

[1] Application date nor herbicide were significant ($P \leq 0.05$).

Table 7. Effect of timing of application of DPX R9674 and tribenuron on blueberry yield in Highland Village in 1990.

Application Date	Crop Yield ($g \ m^{-2}$)[1] DPX R9674	tribenuron	mean
04 July	594	743	669 AB
07 August	568	519	544 AB
12 September	529	339	434 B
nontreated	745	859	802 A

[1] Herbicide did not have a significant effect ($p \leq 0.05$) on crop yield, however application date did. Means of application dates were separated using Tukey's Studentized Range Test and compared using upper case letters.

treatments. When applied on 07 August and 12 September, chlorsulfuron plot yields were significantly lower than the nontreated control. DPX R9674 and tribenuron had no significant effect on blueberry yield within the plots. These two herbicides were not significantly different with regard to crop yield in the Highland Village trial, however application date did affect yield (Table 7). When applied on 12 September, these herbicides resulted in plot yields that were lower than that of the nontreated plot areas. Glyphosate had greater effects on crop yield when applied later in the season with yields from 07 August and 12 September being significantly lower than the nontreated control (Table 5).

In the Earltown trial, herbicide and application date both had a significant effect on bunchberry stem density, although no interaction occurred between these two parameters (Table 8). Initial bunchberry densities were very low in the plots in the Earltown trial, as indicated by the counts of zero in all of the nontreated plots. Herbicide applications made on 05 June and 12 September resulted in the greatest bunchberry suppression as compared to the other two timings. Chlorsulfuron, metsulfuron and tribenuron provided the highest level of weed suppression in this study. Timing of application had no effect on bunchberry suppression with tribenuron and DPX R9674 in the Highland Village trial (Table 9). Herbicide blocks had a significantly different level of bunchberry, where the DPX R9674 block had a nontreated mean of 22 and the tribenuron block, one of 6 (Table 9). Glyphosate was least effective for controlling bunchberry at all timings of application in

Table 8. Effect of timing of application on bunchberry stem density in Earltown in 1990.

		Bunchberry Stem Density (# m^{-2})[1]				
	Rate	Application Date				
Herbicide	(g ha^{-1})	05 June	05 July	07 Aug.	12 Sept.	mean
metsulfuron	15	0	24	26	0	12 AB
chlorsulfuron	30	0	12	0	0	3 A
tribenuron	30	0	24	48	0	18 AB
DPX R9674	30	6	32	54	0	21 AB
glyphosate	450	0	74	82	24	45 B
nontreated	--	0	0	0	0	0 A
mean		1 A	28 B	35 B	4 A	

[1] No interaction occurred between herbicide and application date. Means of both parameters are compared separately . Means followed by the same letter are not significantly different ($p \leq 0.05$) according to Tukey's Studentized Range Test.

Table 9. Effect of timing of application of DPX R9674 and tribenuron on bunchberry stem density in Highland Village in 1990.

	Bunchberry Density (# m^{-2})[1] at 30 dat	
Application Date	DPX R9674	tribenuron
04 July	18	4
07 August	18	10
12 September	21	9
nontreated	22	6
mean	20 A	7 B

[1] Timing of application did not have a significant effect ($p \leq 0.05$) on bunchberry stem density, however herbicide did. Means of herbicides are compared by Tukey's Studentized Range Test using upper case letters.

the Earltown trial (Table 8). It should be noted, however, that rates of glyphosate used in this trial were much below those normally recommended for perennial weed control. Yarborough and Hoelper (1985a) also reported unsatisfactory bunchberry control with broadcast applications of glyphosate. Yarborough (1990), however, observed reduced bunchberry stem densities with broadcast applications of this herbicide and reported that timing of application had no effect on bunchberry supression.

Observations made at harvest revealed that with all applications of metsulfuron and chlorsulfuron, blueberry plants had stunted stems and small leaves. As well, the reduction in blueberry and bunchberry stem densities within the plots allowed other weeds, such as sedges, sheep sorrel (*Rumex acetosella* L.) and annual grasses, which arose from seed after the herbicides have disappeared to thrive and become the major plant species in these plots. Blueberry plants were stunted and weeds arising from seed, such as sheep sorrel and some annual grasses, were the prevalent species. Applications of tribenuron and DPX R9674 did not result in problems with other weeds, as was observed in plots treated with the other two sulfonylureas. This was probably due to the fact that tribenuron and DPX R9674 did not damage the crop plants to the extent that they were unable to outcompete the other species. Glyphosate caused effects which were similar, at all timings, to those observed with chlorsulfuron and metsulfuron.

Split application trial. Split applications of DPX R9674 and tribenuron had a significant effect on bunchberry stem density in the fall of the application year, although the weed had outgrown the effects of the sulfonylureas by harvest (Table 10). The 30g ha^{-1} + 30g ha^{-1} split treatment caused the greatest reduction in bunchberry density within the plots. There was little difference in bunchberry suppression between the split application of 15g ha^{-1} + 15 g ha^{-1} and the single application of 60g ha^{-1}, although both reduced bunchberry growth. Tribenuron resulted in lower bunchberry stem densities than DPX R9674 at both assessment dates (Table 10). All treatments of both herbicides caused some crop injury though damage was not unacceptable. Split applications of 30g ha^{-1} + 30g ha^{-1} tribenuron caused the greatest crop damage. The single application of 60g ha^{-1} DPX R9674 was the most damaging treatment of these sulfonylureas.

Table 10. Effect of split applications of DPX R9674 and tribenuron on bunchberry stem density in Earltown in 1990.

Rate (g/ha)[1]	Assessment Date	Bunchberry stem density (# m^{-2}) DPX R9674	tribenuron	mean
0 + 0	26 September 1990	412	142	277 B[2]
15 + 15	26 September 1990	258	86	172 AB
30 + 30	26 September 1990	190	40	115 A
60 + 0	26 September 1990	276	62	169 AB
mean		284 A	83 B	
0 + 0	14 August 1991	658	374	
15 + 15	14 August 1991	488	280	
30 + 30	14 August 1991	582	160	
60 + 0	14 August 1991	796	180	
mean		631 A[3]	249 B	

[1] First application made on 28 June; second on 06 August.

[2] No interaction ($p \leq 0.05$) occurred between herbicide treatment and date of application. Means of both parameters are compared separately by Tukey's Studentized Range Test using upper case letters.

[3] Only herbicide had a significant effect ($p \leq 0.05$). Means of herbicide treatments are compared by Tukey's Studentized Range Test using upper case letters.

D. Conclusions

Results from these trials suggest that chlorsulfuron, metsulfuron and glyphosate may be effective in controlling bunchberry, at all timings studied, although crop tolerance is unsatisfactory. These herbicides damaged the crop plants to the extent that other weeds were able to compete and thrive in the plots due to reduced competition. Other weeds included species such as several grasses which would be tolerant to the sulfonylureas, as well as escaping species such as sheep sorrel that arose from seed and was able to take advantage of the reduced competition from the crop in these plots. Both tribenuron and DPX R9674 appeared to be effective in suppressing bunchberry stem densities without extensive injury to the blueberry plants. Since the crop plants were not seriously injured by these two herbicides, they did not seem to lose their ability to compete with the other weed species, as other weeds did not appear within the plots.

More work is required in the study of rates of tribenuron and DPX R9674, although tribenuron appears to be most effective. Applications made either early or late in the growing season seem to have the greatest effect on bunchberry densities, although more research is needed to verify this observation. Various split application combinations using tribenuron should be examined to find the treatment that provides the greatest bunchberry supression with the least crop damage. Tribenuron shows the greatest potential for use by commercial blueberry producers for the control of bunchberry, although other new sulfonylurea herbicides should not be overlooked.

IV. LOWBUSH BLUEBERRY TOLERANCE TO CLOPYRALID.

A. Introduction

Weed control is one of the most limiting factors in the production of lowbush blueberries (*Vaccinium angustifolium* Ait.) (Jensen 1989; McCully 1988). Many competing weeds have been supressed with the use of preemergently applied selective herbicides, particularly hexazinone (3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4 (1*H*,3*H*) -dione) (Yarborough and Bhowmik 1989b; Jensen *et al*. 1981). However, not all species are controlled, and with the removal of hexazinone sensitive weeds, the tolerant ones are permitted to spread into areas previously occupied by sensitive weeds (McCully 1988). Many weeds, including sheep-sorrel (*Rumex acetosella* L.), goldenrod (*Solidago spp*. L.) and St. John's wort (*Hypericum perforatum* L.), often escape control with hexazinone, while other species such as alder (*Alnus spp*. L.), bracken fern (*Pteridium aquilinum* (L.)Kuhn), bunchberry (*Cornus canadensis* L.) and tufted vetch (*Vicia cracca* L.), are tolerant to applications of hexazinone (McCully *et al*. 1991; Sampson *et al*. 1990). Tufted vetch is a common weed in many blueberry fields throughout the Maritime Provinces. It interferes with harvesting and competes with the blueberry plants for resources (Sampson *et al*. 1990).

Clopyralid (3,6-dichloro-2-pyridinecarboxylic acid) is registered for selective control of weeds of the Polygonaceae, Leguminosae and Asteraceae families while members of the Brassicaceae family are quite resistant (Hall and Vanden Born 1988). Clopyralid has been reported to cause little or no damage to blueberry (McCully *et al.* 1988; Sampson and Howatt 1988; Thompson and Silver 1985), and previous studies have suggested that clopyralid may be used to control some hexazinone tolerant weeds in lowbush blueberry (McCully 1988). Clopyralid provides good control of weeds such as vetch and strongly supresses sheep-sorrel in strawberries (Doohan *et al.* 1989; McCully *et al.* 1990a; McCully *et al.* 1990b). The objectives of this study were to verify lowbush blueberry tolerance to clopyralid and to obtain data on control of tufted vetch in lowbush blueberry with broadcast applications of clopyralid.

B. Materials and Methods

Five trials were established in 1990 and 1991 to evaluate the effects of clopyralid on blueberry crop damage. Site characteristics and application information for the five trials are summarized in Table 11. In one trial vetch control was also evaluated. Herbicide rates in the experiments were: 100, 200, 300, 400 and 800 g ha^{-1} clopyralid.

All trials were set up in a randomized complete block design with four replicates. Plot size was 2 by 4m with a 2m buffer between blocks and a 0.5m buffer between plots. All experiments included a nontreated check. Herbicides were applied with a hand-held CO_2-pressurized sprayer

Table 11. Site characteristics for crop tolerance to clopyralid study locations.

Location, application date (time)	Air Temp. (°C)	Soil Type	Soil pH	Soil organic matter (%)
Lakelands, Cumberland Co. 30 July (late evening)	20	sandy loam	5.6	21.6
Earltown, Colchester Co. 13 July (early morning)	15	sandy loam	4.3	24.1
Glasgow Mtn., Cumberland Co. 30 July (late evening)	20	sandy loam	6.4	16.8
Pigeon Hill, Cumberland Co. 16 July (early morning)	19	sandy loam	N/A	N/A
Pigeon Hill, Cumberland Co. 16 July (early morning)	19	sandy loam	N/A	N/A

operated at 200 kPa and delivering 200 L ha^{-1}. Crop damage ratings and weed ratings were taken approximately 30 days after treatment (dat) and again in the spring of the harvest year using a linear scale of 0-100, where 0 = no visible damage and 100 = complete kill. Blueberry bud counts were taken in the fall of the year of application and blueberry stem counts and marketable yield (free from debris and immature berries) from 2 m^2 within each plot were recorded at maturity.

Crop damage rating data was ranked and a Friedman Two-Way Analysis of Variance was executed on the rankings. Blueberry stem densities were transformed using the arcsine transformation and an analysis of variance was performed on the transformed data. Analysis of variance was performed on the average number of blueberry buds per stem. Analysis of variance was conducted on logarithmically transformed blueberry yield data. Means were separated by Tukey's Studentized Range Test at the 5% level of probability when analysis of variance indicated significance.

C. Results and Discussion

Clopyralid caused little or no observable crop phytotoxicity at all rates applied in Glasgow Mountain and Lakelands in 1990 (Table 12). In Glasgow Mountain, clopyralid at 800 g ha^{-1}, caused very slight damage to the crop plants. Clopyralid did, however, cause damage to the crop at all rates in the Earltown trial. Ratings ranged from 4 to 25 at 30 dat, with crop damage increasing with increasing rates of clopyralid.

Table 12. Lowbush blueberry tolerance to clopyralid in 1990.

		Injury Rating (0-100)[1]					
	Rate	Glasgow Mtn.		Earltown		Lakelands	
Herbicide	(g ha^{-1})	30 dat	date2[2]	30 dat	date2	30 dat	date2
clopyralid	100	0 b[3]	0 a	4 c	5 cd	0	0
clopyralid	200	0 b	0 a	10 bcd	22 bcd	0	0
clopyralid	300	0 b	0 a	17 abc	40 abcd	0	0
clopyralid	400	0 b	0 a	19 ab	50 ab	0	0
clopyralid	800	7 a	0 a	25 a	87 a	-	-
nontreated	---	0 b	0 a	0 c	0 d	0	0

[1] Ratings where 0 = no visible effect and 100 = complete kill.

[2] Date 2 represents ratings taken in the spring of the harvest year.

[3] Means followed by the same letter are not significantly different ($p \leq 0.05$) according to Tukey's Studentized Range Test.

Table 13. Effect of clopyralid on bud and stem counts and crop yield in 1990.

	Rate	Glasgow Mtn.	Earltown		Lakelands		
Herbicide	(g ha^{-1})	bud[1]	stem[2]	yield[3]	bud	stem	yield
clopyralid	100	95 ns[4]	576 ns	305 a	96 ns	634 ns	112 a
clopyralid	200	99 ns	576 ns	139 ab	83 ns	742 ns	54 ab
clopyralid	300	01 ns	560 ns	160 ab	92 ns	776 ns	13 c
clopyralid	400	99 ns	544 ns	77 bc	120 ns	646 ns	18 bc
clopyralid	800	68 ns	544 ns	37 c	--	--	--
nontreated	--	90 ns	496 ns	307 a	122 ns	686 ns	144 a

[1] Number of buds per 25 blueberry stems.

[2] Blueberry stem density per m^2.

[3] Blueberry yield per m^2.

[4] Means followed by the same letter are not significantly different ($p \leq 0.05$) according to Tukey's Studentized Range Test

Injury symptoms included curling and reddening of the leaves. Similar symptoms were observed by McCully (1988) using clopyralid at 200 and 400 g ha^{-1} in the greenhouse, though no symptoms were recorded when the same rates of clopyralid were applied in the field. It should be noted that, in practice, clopyralid would only be used at rates of 100 to 200 g ha^{-1}. Other results revealed no damage to the blueberry crop with applications of clopyralid (McCully *et al.* 1988; Sampson and Howatt 1988; Thompson and Silver 1985). Visible crop damage in the Earltown trial was more extensive in the harvest year than in the year of application, with crop damage increasing with clopyralid rate. Clopyralid caused absolutely no visible crop damage at 30 dat in the two trials established in Pigeon Hill in 1991.

Clopyralid did not show a trend in its effect on bud counts per stem in any of the trials in 1990, although in the Glasgow mountain trial the bud count was quite low with clopyralid at 800 g ha^{-1} as compared to the other treatments (Table 13). The herbicide also had no effect on blueberry stem density (Table 13). Many of the blueberry stems in plots with high crop damage ratings, however, were new stems that arose in the season following application. McCully (1988) also reported new growth on blueberry plants after treatment with clopyralid at 200 and 400 g ha^{-1}. Clopyralid had a detrimental effect on the subsequent yield of the crop (Table 13). In both the Lakelands trial and the Earltown trial, crop yield decreased with increasing rates of clopyralid. In Earltown, clopyralid at 400 and 800 g ha^{-1} resulted in significantly lower yields than in the nontreated plot areas. In the Lakelands trial, significantly lower blueberry yields were obtained from plots treated with 300 and 400 g ha^{-1} clopyralid, than from nontreated plots. Rates of clopyralid used by commercial producers would not normally be this high, however. McCully (1983) did not observe any significant crop damage with applications of clopyralid. Yield data is not available from the Glasgow Mountain trial as the trial was accidentally destroyed by the cooperating producer.

The Lakelands trial and the Glasgow Mountain trial were sprayed on 30 July in late evening, while the Earltown trial was sprayed on 13 July in early morning. Auxin like herbicides are generally absorbed through the cuticle and translocated through the phloem. Therefore, it is usually best to apply these herbicides in the morning of a warm, sunny day to ensure that they are absorbed and translocated with other photosynthetic products (Salisbury and Ross 1985). In mid-July blueberry is more actively growing than in late-July when tip dieback occurs. Thus the time and date of application of clopyralid in the Earltown trial may partly explain the higher crop damage ratings observed in this trial. The blueberry plants may have absorbed and translocated a greater quantity of the herbicide, at each respective rate, in the Earltown trial than in either the Glasgow Mountain trial or the Lakelands trial.

The observed crop damage in the year of application is not the only factor resulting in yield reduction, since no crop damage was observed in the Lakelands trial but subsequent reductions in yield occurred, with higher losses with increasing rates. The reduction in crop yield after applications of clopyralid in the Lakelands trial can probably be attributed to an effect on flowering in the year of application. The auxin-like activity of clopyralid (Hall and Vanden Born 1988) may have had microscopic effects on the flower buds during floral initiation. In the Lakelands trial, there was very little bloom on the blueberry plants treated with clopyralid at 200 g ha^{-1} and higher rates. Upon close inspection of the flowers, it was observed that, in many, the floral tube was fused together, making pollination impossible. This injury is comparable to the effect of growth regulators on wheat, when they are applied at critical times during floral initiation (Tottman 1977). Similar effects have also been observed with applications of clopyralid on strawberries (Clay and Andrews 1984). Despite crop injury observed in these trials, clopyralid at 200 g ha^{-1} caused no measurable effect on berry size, firmness, dry matter percentage, percentage of soluble solids, titratable acidity and citric acid content, when sampled at harvest (K. Jensen, unpubl. data).

Clopyralid proved to be very effective in supressing tufted vetch in the Lakelands trial. All rates of clopyralid completely killed all vetch that was present in the treated plots in 1990. Similar results were reported by McCully *et al.* (1990b) and Doohan *et al.* (1989) using similar rates in Nova Scotia strawberries. Some vetch reappeared in the plots in 1991, though all were seedlings. None were arising from the previous years rootstocks.

D. Conclusions

This study indicated that, under some circumstances, there may be problems with crop tolerance to clopyralid. Although no crop damage was observed in four of the trials, results from the Earltown and Lakelands trials reveal that clopyralid can have a detrimental effect on crop yield. More research in the area of blueberry stage of growth at application, as well as time of day and temperature at application may help explain some of the crop damage. Also, work should be conducted to more accurately determine whether crop damage is significantly affected by location or blueberry clones within a field. Clopyralid was very effective in controlling vetch at very low rates (100 g ha^{-1}) which did not significantly affect crop yield.

V. SPOT SPRAY APPLICATIONS FOR CONTROL OF HEXAZINONE TOLERANT WEEDS IN LOWBUSH BLUEBERRY.

A. Introduction

Weed control has become one of the major problems in lowbush blueberry (*Vaccinium angustifolium* L.) production in Nova Scotia (McCully 1988). In a survey of lowbush blueberry fields in the province, McCully *et al.* (1991) identified ninety-seven different weed species. These included woody and herbaceous species, as well as many grasses, rushes, and sedges. Hall (1955) reported that many native species are adapted to the blueberry management practices and thus constitute serious weed problems. Many competing weeds have been suppressed with the use of selective herbicides, particularly hexazinone (3-cyclohexyl-6- (dimethylamino)-1- methyl- 1,3,5- triazine-2,4 (1*H*,3*H*)-dione) (Jensen 1986a; Yarborough and Ismail 1985), but not all herbaceous or woody broadleaf species are controlled (Anonymous 1991; Jensen *et al.* 1983; Yarborough *et al.* 1986) and the number of hexazinone tolerant weeds is increasing (Jensen and North 1987). In the absence of hexazinone sensitive weeds, the tolerant weeds become more of a threat (McCully 1988).

Several herbicides have been shown to be effective in controlling hexazinone-tolerant weeds. Glyphosate (*N*-(phosphonomethyl)glycine) is a nonselective, broad-spectrum postemergence herbicide that is effective in controlling a wide range of perennial and annual weed species (Ashton and Crafts 1981; Lynn 1979). When applied selectively as a directed spray, glyphosate is safe for use in orchards (Baird *et al.* 1974; Neal and Skroch 1985; Putnam 1976) and vineyards (Rogers *et al.* 1978). Glyphosate has been reported to effectively control several weeds found in lowbush blueberry fields (Yarborough 1985; Yarborough and Smagula 1986) but has also been reported to cause considerable damage to the crop (Yarborough and Ismail 1982). D'Anjou (1990) found, however, that blueberry showed some tolerance to applications of glyphosate.

Recently, the sulfonylurea class of herbicides has proven to be useful for the control of many broadleaf and some grass weeds (Blair and Martin 1988; Beyer *et al.* 1987; Palm *et al.* 1980). The sulfonylureas are characterized by their broad spectrum of weed control at low rates (2-75 g/ha) and good selectivity (Brown 1990). Tribenuron (methyl-2-[3- (4-methoxy-6-methyl-1,3,5-triazin-2-yl) -3-methylureidosulphonyl] benzoate) is an effective cereal herbicide applied early postemergence in the spring (Ferguson *et al.* 1985). Preliminary studies have indicated that tribenuron can give excellent control of wild rose (*Rosa virginiana* Mill.) and yellow loosestrife (*Lysimachia terrestris* (L.)BSP.) in lowbush blueberries, though barrenberry (*Aronia arbutifolia* (L.)Ell.), bayberry (*Myrica pensylvanica* Loisel.), sweet fern (*Comptonia peregrina* (L.)Coult.) and huckleberry (*Gaylussacia bacatta* (Wang.)K.Koch.) are quite resistant (Jensen 1990). DPX R9674, a formulated mixture of one part tribenuron to three parts thifensulfuron (3-[[[(4-methoxy-6-methyl

-1,3,5-triazin-2-yl)amino]carbonyl]amino]sulfonyl]-2-thiophenecarboxylic acid), another sulfonylurea herbicide, may also have potential for the control of several hexazinone tolerant weeds in lowbush blueberries.

Clopyralid (3,6-dichloro-2-pyridinecarboxylic acid) has recently been registered in strawberries (*Fragaria ananassa* Duchesne) and a "Minor Use Registration" is being pursued in lowbush blueberries in Nova Scotia. Clopyralid is known to be effective against weeds belonging to the Polygonaceae, Leguminosae and Asteraceae families (Hall and Vanden Born, 1988). Clopyralid has been reported to control several hexazinone tolerant weeds, such as ox-eye daisy (*Chrysanthemum leucanthemum* L.), knapweed (*Centaurea spp.* L.), Canada thistle (*Cirsium arvense* (L.)Scop.), vetch (*Vicia spp.* L.), goldenrod (*Solidago spp.* L.) and sheep sorrel (*Rumex acetosella* L.) (Doohan *et al.* 1989; McCully *et al.* 1990b). Preliminary studies have indicated that blueberries are tolerant to postemergent applications of clopyralid and that this herbicide may be useful for postemergent control of certain weeds in lowbush blueberries (McCully 1988). The objective of this study was to determine the potential for using glyphosate, clopyralid, tribenuron and DPX R9674 as spot spray treatments for control of hexazinone tolerant weeds in commercial lowbush blueberry fields.

B. Materials and Methods

Spot spray trials were established in 1990 and 1991 to determine the response of a number of woody and herbaceous species to tribenuron, DPX R9674, clopyralid, and glyphosate (Table 14). Treatments used were: 0.15 g ai L^{-1} tribenuron + 0.2% v/v Agral 90; 0.45 g ai L^{-1} DPX R9674 + 0.2% Agral 90; 0.25 g ai L^{-1} clopyralid + 0.2% Agral 90; and 4.0 g ai L^{-1} glyphosate + 0.5% Enhance. Due to poor spectrum of weed control observed in 1990, clopyralid was not evaluated in 1991. Plant species were sprayed with a garden sprayer until wet or run off was observed. The rate of DPX R9674 (i.e. 0.45 g L^{-1}) delivers 0.15 g L^{-1} tribenuron and the rate of glyphosate is approximately equivalent to the label rate of a 1% Roundup™ solution. Two replicate plots were used for each treatment in each year. Plot size was a circular area at least 1m diameter around a permanent stake for low growing species and at least one plant for woody species. Species were sprayed between 27 June and 03 August 1990 and between 09 July and 16 July 1991. Data collected included growth stage at application and injury rating at 30 and 60 days after treatment (dat) as well as one year after application. Injury ratings were taken using a linear scale of 0-100 where 0 = no injury and 100 = total death of aboveground portion, as compared to an nontreated check.

Table 14. Weed species sprayed in spot spray study.

Scientific name	common name	stage at application
Woody species		
Vaccinium angustifolium Ait.	blueberry	tip dieback
Acer rubrum L.	red maple	0.5m tall
Abies balsamea (L.)Mill.	balsam fir	0.5m tall
Rubus hispidus L.	trailing blackberry	full leaf
Rosa virginiana Mill.	common wild rose	flowering
Kalmia angustifolia L.	lambkill	late flower
Betula papyrifera Marsh.	white birch	1.25m tall
Spiraea latifolia (Ait.)Borkh	hardhack	full leaf
Rubus strigosus Michx.	wild raspberry	full leaf
Populus tremuloides Michx.	trembling aspen	0.5-1m tall
Salix spp. L.	willows	0.5-1m tall
Comptonia peregrina (L.)Coult.	sweet fern	0.5m tall
Rhododendron canadense (L.)Torr.	rhodora	full leaf
Viburnum cassinoides L.	witherod	fruit formed
Lonicera villosa (Michx.)R&S	honeysuckle	flowering
Alnus rugosa (DuRoi)Spreng.	speckled alder	0.75m tall
Juniperus communis L.	common juniper	1m tall
Picea glauca (Moench)Voss	white spruce	0.75m tall
Herbaceous species		
Cornus canadensis L.	bunchberry	flowering
Dennstaedtia punctilobula (Michx.)Moore	hay-scented fern	0.5m tall
Epilobium angustifolium L.	fireweed	flowering
Pteridium aquilinum (L.)Kuhn	bracken fern	fully unfurled
Hypericum perforatum L.	common St John's wort	flowering
Luzula multiflora (Retz.)Lejeune	common woodrush	seed forming
Apocynum androsaemifolium L.	spreading dogbane	full flower
Rumex acetosella L.	sheep-sorrel	flowering
Solidago juncea Ait.	early goldenrod	early flower
Lycopus uniflorus Michx.	bugle weed	flowering
Vicia cracca L.	tufted vetch	seed forming
Prenanthes trifoliolata (Cass.) Fern.	lion's paw	flowering
Chrysanthemum leucanthemum L.	ox-eye daisy	flowering
Anaphalis margaritacea (L.) C.B.Clarke	pearly everlasting	flowering
Aralia hispida Vent.	bristly aralia	full leaf

C. Results and Discussion

Woody species. By 30 dat, glyphosate killed topgrowth of all woody species, except wild rose and willow (Table 15). Wild rose was the only species with live foliage after a spot spray application of this herbicide by 60 dat (Table 16). When rated one year after application, wild raspberry showed the most regrowth, although only 20% (Table 17). Although glyphosate provided good control of most woody species, it completely killed topgrowth of lowbush blueberry plants as well.

Sulfonylurea herbicides did not completely kill foliage of all woody species at 30 dat (Table 15). By 60 dat, however, topgrowth of many of the woody species had been severely injured (Table 16). Both tribenuron and DPX R9674 controlled topgrowth of red maple, hardhack, wild raspberry, trembling aspen, willow, witherod and speckled alder. Other species such as balsam fir, wild rose and Canadian rhodora were moderately susceptible to these sulfonylurea herbicides while the remaining woody species were quite tolerant. Spot spray treatments of the two sulfonylurea herbicides resulted in little or no regrowth from wild raspberry, trembling aspen, mountain-fly honeysuckle, speckled alder and common juniper when rated one year after application (Table 17). Considerable damage was still evident on red maple, balsam fir, lambkill, willow and sweet fern, while other woody species showed little or no evidence of herbicide treatment in the previous year. Neither of these herbicides harmed the blueberry plants in this study.

Table 15. Injury Ratings at 30 days after treatment[1].

WEED SPECIES	glyphosate 1990	glyphosate 1991	tribenuron 1990	tribenuron 1991	R9674 1990	R9674 1991	clopyralid 1990
Woody species							
Vaccinium angustifolium	100	100	10	20	10	20	0
Acer rubrum	100	100	75	85	80	95	10
Abies balsamea	100	73	15	20	15	15	0
Rubus hispidus	100	88	20	35	5	68	5
Rosa virginiana	70	90	10	55	20	45	0
Kalmia angustifolia	100	100	10	20	0	35	0
Betula papyrifera	100	100	0	8	5	10	0
Spiraea latifolia	100	--[2]	55	--	0	--	0
Rubus strigosus	100	--	50	--	30	--	15
Populus tremuloides	95	--	55	--	85	--	0
Salix spp.	65	--	50	--	95	--	0
Comptonia peregrina	100	--	0	--	0	--	0
Rhododendron canadense	80	--	60	--	5	--	0
Viburnum cassinoides	100	--	25	--	80	--	0
Lonicera villosa	100	--	15	--	25	--	30
Alnus rugosa	100	--	60	--	60	--	90
Juniperus communis	100	--	0	--	0	--	0
Picea glauca	--	100	--	0	--	0	--
Herbaceous species							
Cornus canadensis	60	65	100	65	100	65	0
Dennstaedtia punctilobula	100	100	0	20	0	20	0
Epilobium angustifolium	100	100	10	30	10	80	20
Pteridium aquilinum	30	85	0	50	0	38	0
Hypericum perforatum	100	100	40	50	25	50	25
Luzula multiflora	100	100	0	50	0	30	20
Apocynum androsaemifolium	100	95	0	30	0	20	30
Rumex acetosella	100	--	100	--	95	--	95
Solidago juncea	100	--	30	--	70	--	25
Lycopus uniflorus	100	--	100	--	100	--	0
Vicia cracca	100	--	100	--	100	--	100
Prenanthes trifoliolata	100	--	100	--	100	--	45
Chrysanthemum leucanthemum	--	100	--	70	--	60	--
Anaphalis margaritacea	--	100	--	25	--	30	--
Aralia hispida	--	95	--	93	--	98	--

[1] Ratings from 0-100, where 0 = no effect and 100 = complete kill.

[2] Species was not evaluated in this year.

Table 16. Injury ratings at 60 days after treatment[1].

WEED SPECIES	glyphosate	tribenuron	R9674	clopyralid
Woody species				
Vaccinium angustifolium	100	0	0	0
Acer rubrum	100	100	100	0
Abies balsamea	100	45	60	0
Rubus hispidus	--[2]	--	--	--
Rosa virginiana	75	75	0	0
Kalmia angustifolia	100	45	20	0
Betula papyrifera	100	0	0	0
Spiraea latifolia	100	100	100	0
Rubus strigosus	100	100	100	25
Populus tremuloides	100	100	95	10
Salix spp.	100	85	100	5
Comptonia peregrina	100	0	25	30
Rhododendron canadense	100	50	20	30
Viburnum cassinoides	100	85	100	0
Lonicera villosa	100	0	20	65
Alnus rugosa	100	100	100	100
Juniperus communis	100	35	10	0
Herbaceous species				
Cornus canadensis	70	100	100	0
Dennstaedtia punctilobula	100	0	30	0
Epilobium angustifolium	--	--	--	--
Pteridium aquilinum	100	0	30	50
Hypericum perforatum	100	40	25	0
Luzula multiflora	--	--	--	--
Apocynum androsaemifolium	--	--	--	--
Rumex acetosella	--	--	--	--
Solidago juncea	100	65	100	0
Lycopus uniflorus	100	100	100	60
Vicia cracca	100	100	100	100
Prenanthes trifoliolata	100	100	100	100

[1] Ratings from 0-100, where 0 = no effect and 100 = complete kill.

[2] Species could not be evaluated due to senescence.

Table 17. Percent regrowth one year after application[1].

WEED SPECIES	glyphosate	tribenuron	R9674	clopyralid
Woody species				
Vaccinium angustifolium	--[2]	--	--	--
Acer rubrum	0	60	20	100
Abies balsamea	0	65	45	100
Rubus hispidus	5	85	80	100
Rosa virginiana	--	--	--	--
Kalmia angustifolia	0	55	55	100
Betula papyrifera	0	100	100	100
Spiraea latifolia	--	--	--	--
Rubus strigosus	20	5	25	100
Populus tremuloides	0	0	0	100
Salix spp.	0	35	50	100
Comptonia peregrina	0	40	50	75
Rhododendron canadense	--	--	--	--
Viburnum cassinoides	0	100	100	100
Lonicera villosa	0	0	0	0
Alnus rugosa	0	0	0	0
Juniperus communis	0	0	10	100
Herbaceous species				
Cornus canadensis	5	0	0	100
Dennstaedtia punctilobula	0	3	0	100
Epilobium angustifolium	0	100	100	100
Pteridium aquilinum	--	--	--	--
Hypericum perforatum	--	--	--	--
Luzula multiflora	--	--	--	--
Apocynum androsaemifolium	10	100	100	100
Rumex acetosella	20	10	10	100
Solidago juncea	0	100	25	100
Lycopus uniflorus	--	--	--	--
Vicia cracca	--	--	--	--
Prenanthes trifoliolata	0	0	0	0

[1] Percent regrowth, where 0 = no regrowth and 100 = no sign of herbicidal damage.

[2] Regrowth ratings not available due to removal of permanent stake by cooperating producers.

Spot spray applications of clopyralid had very little effect, at 30 dat, on any of the woody species treated, except for speckled alder (Table 15). Clopyralid resulted in an injury rating of 90% at 30 dat and topgrowth of this species was completely killed by 60 dat (Table 16). At 60 dat, several other species were slightly damaged by clopyralid, though damage ratings were low. These species included: wild raspberry, trembling aspen, willow, sweet fern, rhodora and mountain-fly honeysuckle (Table 16). Mountain-fly honeysuckle showed the greatest damage at 60 dat, with a rating of 65. When evaluated one year after application, most woody species treated with clopyralid showed no signs of herbicide damage (Table 17). However, regrowth was completely supressed in speckled alder and mountain-fly honeysuckle. Sweet fern plants treated with clopyralid also showed slight reductions in regrowth at one year after application.

Glyphosate was highly effective for controlling all woody species tested. Results from other studies have also indicated that glyphosate is effective for the control of woody species such as birch, willow, maple, poplar, cherry, alder, aspen and *Rubus* species (Smagula *et al.* 1986b; Stamm and Ashley 1981; Vonce and Skroch 1989; Yarborough and Hoelper 1985b; Yarborough and Ismail 1982; Yarborough and Smagula 1986). However, there is a problem with crop damage if the blueberry plants are contacted with the glyphosate solution. Damage to blueberries, including reduced crop stand, stunting and stem and leaf proliferation have been previously reported (Hodges *et al.* 1979; Ismail and Yarborough 1981; Smagula *et al.* 1986b; Yarborough 1990; Yarborough and Hoelper

1985a). The two sulfonylurea herbicides, tribenuron and DPX R9674, provided a limited spectrum of weed control. Several species, such as wild raspberry, trembling aspen, mountain-fly honeysuckle, speckled alder and common juniper, were controlled for up to one year after spot spray application of the sulfonylureas. Other researchers have also found tribenuron to be effective for the control of woody species such as false honeysuckle and wild rose, though species such as bayberry, barrenberry and huckleberry are quite resistant (Jensen 1990). The spectrum of woody plant control was very similar for the two sulfonylurea herbicides in this study. Clopyralid was generally ineffective for the control of woody weeds in lowbush blueberry fields, with the exception of mountain-fly honeysuckle and speckled alder. However, the absence of crop damage in this and other studies (McCully 1988) suggests that it may be useful as a postemergent applied herbicide in some instances.

Herbaceous species. Glyphosate applied as a spot spray treatment in mid-summer, completely killed foliage, at 30 dat, of all herbaceous plants tested, except for bunchberry and bracken fern (Table 15), although these two species were extensively damaged. Similar effects were observed on bunchberry at 60 dat, however topgrowth of bracken fern was totally killed (Table 16). When evaluated one year after application, only three species, bunchberry, spreading dogbane and sheep sorrel showed signs of regrowth (Table 17). Bunchberry and spreading dogbane were arising from rhizomes, thus appeared to be tolerant to applications of glyphosate, while sheep sorrel was arising from seed.

The two sulfonylurea herbicides, tribenuron and DPX R9674, gave a wide range of effectiveness at 30 dat for the control of herbaceous species and results were slightly different between 1990 and 1991 applications (Table 15). Both herbicides killed topgrowth of bunchberry, sheep sorrel, bugleweed, vetch, lion's paw and bristly aralia at 30 dat. All other species were injured by applications of these herbicides, although damage was slight to moderate at best. Results were similar at 60 dat (Table 16). When evaluated one year after application, both sulfonylureas still effectively supressed bunchberry, hay-scented fern, sheep sorrel and lion's paw (Table 17).

Clopyralid controlled topgrowth of sheep sorrel and vetch at 30 dat (Table 15). By 60 dat, lion's paw was also effectively controlled by spot spray applications of this herbicide (Table 16). Bugleweed and bracken fern were moderately susceptible to clopyralid at 60 dat. One year after aplication, lion's paw was the only herbaceous species that was still supressed by clopyralid. Other species such as sheep sorrel and vetch may still have been controlled, though regrowth ratings were not available for these species.

These results suggest that, on herbaceous plants, spot spray applications of glyphosate can effectively control all species tested. Yarborough and Hoelper (1985a) reported unsatisfactory control of bunchberry with applications of glyphosate, although Yarborough (1990) found that glyphosate reduced bunchberry densities. Prior to this study, glyphosate has also been reported to control dogbane (Smagula *et al.* 1986b; Yarborough 1988). Control lasted for at least one year for most species tested in this study. Tribenuron and DPX R9674 resulted in good control of bunchberry, sheep sorrel, bugleweed, vetch, lion's paw and bristly aralia and caused some damage to other species evaluated. Jensen (1990) also reported tribenuron to give excellent control of yellow loosestrife in lowbush blueberries. Clopyralid effectively controlled lion's paw, sheep sorrel and vetch but was uneffective against other species tested.

D. Conclusions.

Postemergent applications of glyphosate, although damaging to lowbush blueberries, provided excellent control of hexazinone tolerant woody and herbaceous weeds in commercial lowbush blueberry fields. Since the treatment is so damaging to the crop, commercial growers would have to take extreme care to avoid contact with the crop. The two sulfonylurea herbicides, tribenuron and DPX R9674, were quite effective for the postemergent control of several hexazinone tolerant weeds in lowbush blueberry fields. As these herbicides do not damage the crop plants, they could be used to control these weeds without the risks associated with glyphosate. Clopyralid caused no observable damage to the blueberry plants while providing excellent control of several weeds. The spectrum of weed control with clopyralid is very limited, however.

These results suggest that glyphosate, if applied selectively to the weed plants, is the most effective herbicide for postemergent control of hexazinone tolerant weeds. Although tribenuron, DPX R9674 and clopyralid do not control as many species as glyphosate, they do provide as effective of control of selected species, without the associated risk of damage to the blueberry plants. Thus these herbicides may be preferred for the control of susceptible weeds by commercial growers. More work is needed to determine the complete spectrum of weed control provided with these three herbicides.

VI. GENERAL CONCLUSIONS

Studies to determine the efficacy of broadcast applications of the sulfonylureas and glyphosate, for the control of bunchberry in lowbush blueberry, revealed some promising results. Preemergence applications of chlorsulfuron and metsulfuron failed to demonstrate that these sulfonylureas had satisfactory selectivity to be used by commercial blueberry producers. Also, the level of damage to the crop plants permitted other weed species to become greater problems due to reduced competition. Preemergence and postemergence applications of tribenuron and DPX R9674 provided some suppression of bunchberry with good crop tolerance. The use of postemergence sulfonylureas would be preferred since they could be spot sprayed on the bunchberry, thus resulting in the use of less herbicide as well as restricted crop injury if tolerance to the material was marginal. Tribenuron, applied either early or late postemergence or in a split application, appears to be the most promising herbicide tested for the control of bunchberry. More research should be conducted to determine the most effective rates and timings of application of this herbicide. Also, the results obtained with applications of the sulfonylureas, suggest that within this family of herbicides more selective materials may exist. Therefore, continued screening of new sulfonylureas for bunchberry control should be conducted.

Trials conducted to determine the tolerance of lowbush blueberry to clopyralid revealed that this herbicide may result in crop damage and decreased yield in some instances. Results suggested that blueberry is very susceptible to damage from clopyralid at some stages of growth, most likely at some point early in flower formation. Additional research should be conducted to more accurately determine the exact effects of this herbicide on blueberry, and to determine optimum growth stage for safe application of clopyralid. This study revealed that clopyralid is very effective in controlling tufted vetch at very low rates. Clopyralid, when safely applied, would probably be quite useful to commercial growers for the control of several other susceptible, hexazinone tolerant weeds present in lowbush blueberry fields.

Spot spray treatments of glyphosate revealed that this herbicide provided excellent control of almost all hexazinone tolerant, woody and herbaceous weeds. Contact with the blueberry plants should be avoided if at all possible, as glyphosate is equally damaging to the crop. Tribenuron and DPX R9674 were effective in controlling many hexazinone tolerant species, although the spectrum of weed control was not as broad as that of glyphosate. However, the associated risk of crop damage is very low with these two herbicides. Clopyralid provided excellent control of a few weed species, also with no risk of permantnt crop damage. Results suggest that spot spray applications of all herbicides evaluated would be useful for the control of hexazinone tolerant weeds in commercial lowbush blueberry fields.

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Appendix I.

Crop injury ratings and bunchberry densities not discussed within text.

Appendix 1. Effect of timing of application on crop damage in Earltown in 1990.

Herbicide	Rate(g ha^{-1})	Application Date	Crop damage 60 dat	Crop damage 90 dat
metsulfuron	15	05 June	96 a[1]	90 a
chlorsulfuron	30	05 June	80 ab	64 ab
tribenuron	30	05 June	33 bc	34 bc
glyphosate	450	05 June	25 bc	15 cd
DPX R9674	30	05 June	8 cd	3 d
nontreated	--	05 June	0 d	0 d

[1] Means followed by the same letter are not significantly different ($p \leq 0.05$) according to Tukey's Studentized Range Test.

Appendix 2. Effect of timing of application on crop damage in Earltown in 1990.

Herbicide	Rate(g ha^{-1})	Application Date	Crop damage 60 dat
metsulfuron	15	05 July	57 b[1]
chlorsulfuron	30	05 July	30 c
tribenuron	30	05 July	15 d
glyphosate	450	05 July	74 a
DPX R9674	30	05 July	8 d
nontreated	--	05 July	0 d

[1] Means followed by the same letter are not significantly different ($p \leq 0.05$) according to Tukey's Studentized Range Test.

Appendix 3. Crop injury ratings and bunchberry densities after preemergence applications of sulfonylurea herbicides.

		Pigeon Hill (1989)			Glasgow Mtn. (1990)	
		60 dat	60 dat	14 Aug 1990	60 dat	60 dat
Herbicide[1]	Rate ($g\ ha^{-1}$)	phyto (0-100)[2]	density ($\#\ m^{-2}$)	density ($\#\ m^{-2}$)	phyto (0-100)[2]	density ($\#\ m^{-2}$)
chlorsulfuron	10	35 e-h	24 ns	48 ns	--[4]	--
chlorsulfuron	15	29 e-i	4 ns	10 ns	--	--
chlorsulfuron	20	54 de	18 ns	68 ns	75 a	0 ns
chlorsulfuron	30	60 de	18 ns	86 ns	80 a	0 ns
metsulfuron	15	93 a-d	4 ns	0 ns	70 a	0 ns
metsulfuron	20	99 ab	16 ns	212 ns	68 a	0 ns
metsulfuron	30	93 a-d	0 ns	190 ns	91 a	0 ns
metsulfuron	40	91 a-d	2 ns	70 ns	--	--
metsulfuron	50	99 a	0 ns	0 ns	--	--
metsulfuron	60	98 abc	0 ns	10 ns	--	--
thifensulfuron	30	33 e-h	120 ns	54 ns	0 b	104 ns
thifensulfuron	40	28 e-i	52 ns	68 ns	0 b	84 ns
thifensulfuron	50	50 def	26 ns	158 ns	10 b	38 ns
DPX R9674	30	33 e-i	0 ns	156 ns	0 b	92 ns
DPX R9674	40	40 efg	28 ns	146 ns	0 b	78 ns
DPX R9674	50	55 cde	24 ns	0 ns	--	--
DPX R9674	60	56 b-e	30 ns	306 ns	--	--
chlorimuron	60	15 f-i	42 ns	80 ns	--	--
chlorimuro	80	15 f-i	60 ns	80 ns	--	--
chlorimuron	100	10 ghi	32 ns	18 ns	--	--
chlorsulfuron+ hexazinone	15 1250	--	--	--	35 b	50 ns
hexazinone	2500	4 hi	126 ns	146 ns	0 b	180 ns
nontreated	--	0 i	46 ns	28 ns	0 b	152 ns

1 All herbicides except chlorsulfuron and/or hexazinone were applied with 0.5 L ha^{-1} Enhance™.

2 Ratings where 0 = no visible effect and 100 = complete kill.

3 Means followed by the same letter are not significantly different ($p \leq 0.05$) according to Tukey's Studentized Range Test.

4 Treatments were omitted from Glasgow Mountain trial due to extensive crop damage and/or lack of bunchberry control in Pigeon Hill.

Appendix 4. Effect of surfactants on preemergence ıpplications of sulfonylurea herbicides.

Herbicide	Rate (g ha^{-1})	Injury Rating(0-100)[1] 60 dat
chlorsulfuron	30	53 a[2]
chlorsulfuron + E[3]	30	53 a
chlorsulfuron + A	30	64 a
metsulfuron	15	49 a
metsulfuron + E	15	61 a
metsulfuron + A	15	45 a
tribenuron	30	0 b
tribenuron + E	30	5 b
tribenuron + A	30	0 b
DPX R9674	30	0 b
DPX R9674 + E	30	0 b
DPX R9674 + A	30	0 b
hexazinone	2500	3 b
nontreated	--	0 b

1 Ratings, where 0 = no visible effect and 100 = complete kill.

2 Means followed by the same letter are not significantly different ($p \leq 0.05$) according to Tukey's Studentized Range Test.

3 E. Enhance[TM] at 0.5 L ha^{-1}.
A. Agral 90[TM] at 0.2% v/v.

Appendix II.

Analysis of variance (AOV) tables for results presented within the text.

Appendix 5. AOV table for crop injury ratings at 30 dat in Pigeon Hill preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	24	2590.5000000	107.9375000	7.60	0.0001
Error	63	894.5000000	14.1984127		
Corrected Total	87	3485.0000000			

R-Square	C.V.	Root MSE	RPHY1 Mean
0.743329	32.76590	3.7680781	11.500000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
BLOCK	3	0.0000000	0.0000000	0.00	1.0000
TRT	21	2590.5000000	123.3571429	8.69	0.0001

Appendix 6. AOV table for crop injury ratings at 60 dat in Pigeon Hill preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	24	3008.7500000	125.3645833	16.46	0.0001
Error	63	479.7500000	7.6150794		
Corrected Total	87	3488.5000000			

R-Square	C V.	Root MSE	RPHY2 Mean
0.862477	23.99603	2.7595433	11.500000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
BLOCK	3	0.0000000	0.0000000	0.00	1.0000
TRT	21	3008.7500000	143.2738095	18.81	0.0001

Appendix 7. AOV table for crop injury ratings at 90 dat in Pigeon Hill preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	24	2622.0000000	109.2500000	9.40	0.0001
Error	63	732.0000000	11.6190476		
Corrected Total	87	3354.0000000			

R-Square	C.V.	Root MSE	RPHY3 Mean
0.781753	29.64063	3.4086724	11.500000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
BLOCK	3	0.0000000	0.0000000	0.00	1.0000
TRT	21	2622.0000000	124.8571429	10.75	0.0001

Appendix 8. AOV table for bunchberry density at 30 dat in Pigeon Hill preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	24	2.94006245	0.12250260	1.76	0.0386
Error	63	4.38793739	0.06964980		
Corrected Total	87	7.32799984			

R-Square	C.V.	Root MSE	RD1 Mean
0.401209	19.12327	0.2639125	1.3800597

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	1.74237196	0.58079065	8.34	0.0001
TRT	21	1.19769049	0.05703288	0.82	0.6872

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	1.74237196	0.58079065	8.34	0.0001
TRT	21	1.19769049	0.05703288	0.82	0.6872

Appendix 9. AOV table for bunchberry density at 60 dat in Pigeon Hill preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	24	0.93612664	0.03900528	1.47	0.1134
Error	63	1.67229857	0.02654442		
Corrected Total	87	2.60842521			

R-Square	C.V.	Root MSE	RD2 Mean
0.358886	11.05381	0.1629246	1.4739222

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.43684827	0.14561609	5.49	0.0021
TRT	21	0.49927837	0.02377516	0.90	0.5966

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.43684827	0.14561609	5.49	0.0021
TRT	21	0.49927837	0.02377516	0.90	0.5966

Appendix 10. AOV table for bunchberry density at 60 dat in Pigeon Hill preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	24	1.41254656	0.05885611	1.28	0.2184
Error	63	2.90561837	0.04612093		
Corrected Total	87	4.31816493			

R-Square	C.V.	Root MSE	RD3 Mean
0.327117	14.88258	0.2147578	1.4430149

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.71050113	0.23683371	5.14	0.0031
TRT	21	0.70204543	0.03343073	0.72	0.7918

Soource	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.71050113	0.23683371	5.14	0.0031
TRT	21	0.70204543	0.03343073	0.72	0.7918

Appendix 11. AOV table for bunchberry density at harvest in Pigeon Hill preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	24	2.58446830	0.10768618	1.45	0.1201
Error	63	4.66831553	0.07410025		
Corrected Total	87	7.25278383			

R-Square	C.V.	Root MSE	RD4 Mean
0.356342	19.59340	0.2722136	1.3893125

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	1.29313302	0.43104434	5.82	0.0014
TRT	21	1.29133528	0.06149216	0.83	0.6744

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	1.29313302	0.43104434	5.82	0.0014
TRT	21	1.29133528	0.06149216	0.83	0.6744

Appendix 12. AOV table for blueberry yield in Pigeon Hill preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	24	553.80673416	23.07528059	14.18	0.0001
Error	63	102.50678711	1.62709186		
Corrected Total	87	656.31352127			

R-Square	C.V.	Root MSE	TYIE Mean
0.843814	28.92251	1.2755751	4.4103200

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	7.53809601	2.51269867	1.54	0.2118
TRT	21	546.26863815	26.01279229	15.99	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	7.53809601	2.51269867	1.54	0.2118
TRT	21	546.26863815	26.01279229	15.99	0.0001

Appendix 13. AOV table for blueberry stem density at harvest in Pigeon Hill preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	24	273090.90909	11378.78788	1.26	0.2303
Error	63	569146.18182	9034.06638		
Corrected Total	87	842237.09091			

R-Square	C.V.	Root MSE	STE Mean
0.324245	27.01614	95.047706	351.81818

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	96677.81818	32225.93939	3.57	0.0189
TRT	21	176413.09091	8400.62338	0.93	0.5564

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	96677.81818	32225.93939	3.57	0.0189
TRT	21	176413.09091	8400.62338	0.93	0.5564

Appendix 14. AOV table for bunchberry density 30 dat in Earltown timing of application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	45	1.93214254	0.04293650	3.57	0.0002
Error	30	0.36052559	0.01201752		
Corrected Total	75	2.29266813			

R-Square	C.V.	Root MSE	TD1 Mean
0.842748	7.472661	0.1096244	1.4670069

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.50416161	0.16805387	13.98	0.0001
TIME	2	0.32556495	0.16278247	13.55	0.0001
BLOCK*TIME	6	0.60152486	0.10025414	8.34	0.0001
HERB	6	0.07840033	0.01306672	1.09	0.3924
BLOCK*HERB	18	0.33475179	0.01859732	1.55	0.1412
TIME*HERB	10	0.08773901	0.00877390	0.73	0.6907

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.45394279	0.15131426	12.59	0.0001
TIME	2	0.28166265	0.14083132	11.72	0.0002
BLOCK*TIME	6	0.57573838	0.09595640	7.98	0.0001
HERB	6	0.07840033	0.01306672	1.09	0.3924
BLOCK*HERB	18	0.33475179	0.01859732	1.55	0.1412
TIME*HERB	10	0.08773901	0.00877390	0.73	0.6907

Appendix 15. AOV table for crop injury ratings at 30 dat in Earltown timing of application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	45	2136.8958333	47.4865741	21.23	0.0001
Error	30	67.1041667	2.2368056		
Corrected Total	75	2204.0000000			

R-Square	C.V.	Root MSE	RPH1 Mean
0.969553	14.95595	1.4955954	10.000000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.0000000	0.0000000	0.00	1.0000
TIME	3	433.6458333	144.5486111	64.62	0.0001
BLOCK*TIME	9	41.4375000	4.6041667	2.06	0.0670
HERB	5	1356.0416667	271.2083333	121.25	0.0001
BLOCK*HERB	15	38.9583333	2.5972222	1.16	0.3509
TIME*HERB	10	266.8125000	26.6812500	11.93	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.0208333	0.0069444	0.00	0.9998
TIME	3	241.2708333	80.4236111	35.95	0.0001
BLOCK*TIME	9	40.6458333	4.5162037	2.02	0.0722
HERB	5	1356.0416667	271.2083333	121.25	0.0001
BLOCK*HERB	15	38.9583333	2.5972222	1.16	0.3509
TIME*HERB	10	266.8125000	26.6812500	11.93	0.0001

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
herb in time 1	5	622.17708333	124.43541667	55.63	0.0001
herb in time 2	5	397.37500000	79.47500000	35.53	0.0001
herb in time 3	5	603.30208333	120.66041667	53.94	0.0001

Appendix 16. AOV table for crop injury ratings at 60 dat in Earltown timing of application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	40	774.79166667	19.36979167	4.23	0.0020
Error	15	68.70833333	4.58055556		
Corrected Total	55	843.50000000			

R-Square	C.V.	Root MSE	RPH2 Mean
0.918544	28.53631	2.1402232	7.5000000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
TIME	3	177.77083333	59.25694444	12.94	0.0002
BLOCK*TIME	9	16.64583333	1.84953704	0.40	0.9139
HERB	5	497.22916667	99.44583333	21.71	0.0001
BLOCK*HERB	15	26.52083333	1.76805556	0.39	0.9625
TIME*HERB	5	56.62500000	11.32500000	2.47	0.0799

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.13888889	0.04629630	0.01	0.9985
TIME	3	9.18750000	3.06250000	0.67	0.5843
BLOCK*TIME	9	13.72916667	1.52546296	0.33	0.9498
HERB	5	497.22916667	99.44583333	21.71	0.0001
BLOCK*HERB	15	26.52083333	1.76805556	0.39	0.9625
TIME*HERB	5	56.62500000	11.32500000	2.47	0.0799

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
herb in time 1	5	312.55208333	62.51041667	13.65	0.0001
herb in time 2	5	241.30208333	48.26041667	10.54	0.0002

Appendix 17. AOV table for bunchberry densities at harvest in Earltown timing of application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	50	2.21480346	0.04429607	3.23	0.0001
Error	45	0.61763589	0.01372524		
Corrected Total	95	2.83243934			

R-Square	C.V.	Root MSE	TDE4 Mean
0.781942	7.816703	0.1171548	1.4987749

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.42209767	0.14069922	10.25	0.0001
TIME	3	0.33372080	0.11124027	8.10	0.0002
BLOCK*TIME	9	0.59233737	0.06581526	4.80	0.0002
HERB	5	0.28173369	0.05634674	4.11	0.0037
BLOCK*HERB	15	0.38017089	0.02534473	1.85	0.0572
TIME*HERB	15	0.20474304	0.01364954	0.99	0.4770

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.42209767	0.14069922	10.25	0.0001
TIME	3	0.33372080	0.11124027	8.10	0.0002
BLOCK*TIME	9	0.59233737	0.06581526	4.80	0.0002
HERB	5	0.28173369	0.05634674	4.11	0.0037
BLOCK*HERB	15	0.38017089	0.02534473	1.85	0.0572
TIME*HERB	15	0.20474304	0.01364954	0.99	0.4770

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
herb in time 1	5	0.01004026	0.00200805	0.15	0.9801
herb in time 2	5	0.13130199	0.02626040	1.91	0.1109
herb in time 3	5	0.30447758	0.06089552	4.44	0.0023
herb in time 4	5	0.04065691	0.00813138	0.59	0.7057

Appendix 18. AOV table for blueberry stem densities at harvest in Earltown timing of application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	50	1.24254616	0.02485092	3.12	0.0001
Error	45	0.35803805	0.00795640		
Corrected Total	95	1.60058421			

R-Square	C.V.	Root MSE	TSTEM Mean
0.776308	-50.39016	0.0891987	-0.1770160

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.04315140	0.01438380	1.81	0.1593
TIME	3	0.07055179	0.02351726	2.96	0.0424
BLOCK*TIME	9	0.06073943	0.00674883	0.85	0.5767
HERB	5	0.61250616	0.12250123	15.40	0.0001
BLOCK*HERB	15	0.08088382	0.00539225	0.68	0.7918
TIME*HERB	15	0.37471356	0.02498090	3.14	0.0015

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.04315140	0.01438380	1.81	0.1593
TIME	3	0.07055179	0.02351726	2.96	0.0424
BLOCK*TIME	9	0.06073943	0.00674883	0.85	0.5767
HERB	5	0.61250616	0.12250123	15.40	0.0001
BLOCK*HERB	15	0.08088382	0.00539225	0.68	0.7918
TIME*HERB	15	0.37471356	0.02498090	3.14	0.0015

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
herb in time 1	5	0.03879102	0.00775820	0.98	0.4433
herb in time 2	5	0.11488893	0.02297779	2.89	0.0241
herb in time 3	5	0.41504123	0.08300825	10.43	0.0001
herb in time 4	5	0.41849853	0.08369971	10.52	0.0001

Appendix 19. Aov table for blueberry yield in Earltown timing of application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	50	575.52865775	11.51057316	8.98	0.0001
Error	45	57.67215340	1.28160341		
Corrected Total	95	633.20081115			

R-Square	C.V.	Root MSE	TYIE Mean
0.908920	26.72674	1.1320792	4.2357546

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	9.16816650	3.05605550	2.38	0.0817
TIME	3	146.09486192	48.69828731	38.00	0.0001
BLOCK*TIME	9	2.80115811	0.31123979	0.24	0.9859
HERB	5	282.39248373	56.47849675	44.07	0.0001
BLOCK*HERB	15	23.84803651	1.58986910	1.24	0.2790
TIME*HERB	15	111.22395098	7.41493007	5.79	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	9.16816650	3.05605550	2.38	0.0817
TIME	3	146.09486192	48.69828731	38.00	0.0001
BLOCK*TIME	9	2.80115811	0.31123979	0.24	0.9859
HERB	5	282.39248373	56.47849675	44.07	0.0001
BLOCK*HERB	15	23.84803651	1.58986910	1.24	0.2790
TIME*HERB	15	111.22395098	7.41493007	5.79	0.0001

Contrast	DF	Contrast SS	Mean Square	F Value	Pr > F
herb in time 1	5	8.71270813	1.74254163	1.36	0.2574
herb in time 2	5	41.64673980	8.32934796	6.50	0.0001
herb in time 3	5	156.20275494	31.24055099	24.38	0.0001
herb in time 4	5	187.05423184	37.41084637	29.19	0.0001

Appendix 20. AOV table for crop injury ratings at 30 dat in Glasgow Mountain surfactant trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	691.50000000	43.21875000	13.02	0.0001
Error	39	129.50000000	3.32051282		
Corrected Total	55	821.00000000			

R-Square	C.V.	Root MSE	RPHY1 Mean
0.842266	24.29637	1.8222274	7.5000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
TRT	13	691.50000000	53.19230769	16.02	0.0001

Appendix 21. AOV table for crop injury ratings at 60 dat in Glasgow Mountain surfactant trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	627.37500000	39.21093750	12.68	0.0001
Error	39	120.62500000	3.09294872		
Corrected Total	55	748.00000000			

R-Square	C.V.	Root MSE	RPHY2 Mean
0.838737	23.44904	1.7586781	7.5000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
TRT	13	627.37500000	48.25961538	15.60	0.0001

Appendix 22. AOV table for crop injury ratings at 90 dat in Glasgow Mountain surfactant trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	16	580.00000000	36.25000000	10.21	0.0001
Error	39	138.50000000	3.55128205		
Corrected Total	55	718.50000000			

R-Square	C.V.	Root MSE	RPHY3 Mean
0.807237	25.12646	1.8844846	7.5000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
TRT	13	580.00000000	44.61538462	12.56	0.0001

Appendix 23. AOV table for crop injury ratings at 30 dat in Glasgow Mountain preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	537.25000000	35.81666667	9.75	0.0001
Error	36	132.25000000	3.67361111		
Corrected Total	51	669.50000000			

R-Square	C.V.	Root MSE	RPHY1 Mean
0.802465	27.38095	1.9166667	7.0000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
TRT	12	537.25000000	44.77083333	12.19	0.0001

Appendix 24. AOV table for crop injury ratings at 60 dat in Glasgow Mountain preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	551.00000000	36.73333333	22.04	0.0001
Error	36	60.00000000	1.66666667		
Corrected Total	51	611.00000000			

R-Square	C.V.	Root MSE	RPHY2 Mean
0.901800	18.44278	1.2909944	7.0000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
TRT	12	551.00000000	45.91666667	27.55	0.0001

Appendix 25. AOV table for crop injury ratings at 90 dat in Glasgow Mountain preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	533.12500000	35.54166667	12.81	0.0001
Error	36	99.87500000	2.77430556		
Corrected Total	51	633.00000000			

R-Square	C.V.	Root MSE	RPHY3 Mean
0.842220	23.79464	1.6656247	7.0000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
TRT	12	533.12500000	44.42708333	16.01	0.0001

Appendix 26. AOV table for crop injury ratings at 13 months after treatment in Glasgow Mountain preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	485.50000000	32.36666667	6.77	0.0001
Error	36	172.00000000	4.77777778		
Corrected Total	51	657.50000000			

R-Square	C.V.	Root MSE	RPHY4 Mean
0.738403	31.22590	2.1858128	7.0000000

Source	DF	Anova SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
TRT	12	485.50000000	40.45833333	8.47	0.0001

Appendix 27. AOV table for bunchberry density at 30 dat in Glasgow Mountain preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	1.28414052	0.08560937	2.97	0.0038
Error	36	1.03900404	0.02886122		
Corrected Total	51	2.32314455			

R-Square	C.V.	Root MSE	RD1 Mean
0.552760	11.87044	0.1698859	1.4311681

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.24263449	0.08087816	2.80	0.0536
TRT	12	1.04150602	0.08679217	3.01	0.0052

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.24263449	0.08087816	2.80	0.0536
TRT	12	1.04150602	0.08679217	3.01	0.0052

Appendix 28. AOV table for bunchberry density at 60 dat in Glasgow Mountain preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	1.37109946	0.09140663	2.52	0.0116
Error	36	1.30539628	0.03626101		
Corrected Total	51	2.67649574			

	R-Square	C.V.	Root MSE	RD2 Mean
	0.512274	13.49302	0.1904232	1.4112719

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.27700098	0.09233366	2.55	0.0712
TRT	12	1.09409848	0.09117487	2.51	0.0162

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.27700098	0.09233366	2.55	0.0712
TRT	12	1.09409848	0.09117487	2.51	0.0162

Appendix 29. AOV table for bunchberry density at 30 dat in Glasgow Mountain preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	1.10257705	0.07350514	2.68	0.0077
Error	36	0.98578645	0.02738296		
Corrected Total	51	2.08836350			

	R-Square	C.V.	Root MSE	RD3 Mean
	0.527962	11.61347	0.1654780	1.4248800

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.18993985	0.06331328	2.31	0.0925
TRT	12	0.91263720	0.07605310	2.78	0.0088

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.18993985	0.06331328	2.31	0.0925
TRT	12	0.91263720	0.07605310	2.78	0.0088

Appendix 30. AOV table for blueberry bud counts on 05 November in Glasgow Mountain preemergence sulfonylurea trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	15	2.06927888	0.13795193	2.82	0.0055
Error	36	1.76284552	0.04896793		
Corrected Total	51	3.83212440			

R-Square	C.V.	Root MSE	TBUD Mean
0.539982	18.99167	0.2212870	1.1651791

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.07532190	0.02510730	0.51	0.6761
TRT	12	1.99395698	0.16616308	3.39	0.0022

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.07532190	0.02510730	0.51	0.6761
TRT	12	1.99395698	0.16616308	3.39	0.0022

Appendix 31. AOV table for crop injury ratings at 30 dat in Earltown split application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	153.96875000	6.99857955	17.84	0.0001
Error	9	3.53125000	0.39236111		
Corrected Total	31	157.50000000			

R-Square	C.V.	Root MSE	RPHY1 Mean
0.977579	13.91972	0.6263873	4.5000000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
HERB	1	1.53125000	1.53125000	3.90	0.0796
BLOCK*HERB	3	2.34375000	0.78125000	1.99	0.1859
RATE	3	135.00000000	45.00000000	114.69	0.0001
BLOCK*RATE	9	7.00000000	0.77777778	1.98	0.1613
HERB*RATE	3	8.09375000	2.69791667	6.88	0.0105

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
HERB	1	1.53125000	1.53125000	3.90	0.0796
BLOCK*HERB	3	2.34375000	0.78125000	1.99	0.1859
RATE	3	135.00000000	45.00000000	114.69	0.0001
BLOCK*RATE	9	7.00000000	0.77777778	1.98	0.1613
HERB*RATE	3	8.09375000	2.69791667	6.88	0.0105

Appendix 32. AOV table for bunchberry density at 30 dat in Earltown split application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	3.94245029	0.17920229	9.23	0.0008
Error	9	0.17475631	0.01941737		
Corrected Total	31	4.11720660			

R-Square	C.V.	Root MSE	TD1 Mean
0.957555	18.17683	0.1393462	0.7666147

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.67741639	0.22580546	11.63	0.0019
HERB	1	1.28805380	1.28805380	66.34	0.0001
BLOCK*HERB	3	1.21607272	0.40535757	20.88	0.0002
RATE	3	0.14619068	0.04873023	2.51	0.1246
BLOCK*RATE	9	0.48884735	0.05431637	2.80	0.0707
HERB*RATE	3	0.12586936	0.04195645	2.16	0.1626

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.67741639	0.22580546	11.63	0.0019
HERB	1	1.28805380	1.28805380	66.34	0.0001
BLOCK*HERB	3	1.21607272	0.40535757	20.88	0.0002
RATE	3	0.14619068	0.04873023	2.51	0.1246
BLOCK*RATE	9	0.48884735	0.05431637	2.80	0.0707
HERB*RATE	3	0.12586936	0.04195645	2.16	0.1626

Appendix 33. AOV table for bunchberry density at 60 dat in Earltown split application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	3.45883524	0.15721978	6.44	0.0033
Error	9	0.21968675	0.02440964		
Corrected Total	31	3.67852199			

R-Square	C.V.	Root MSE	TD2 Mean
0.940279	19.66051	0.1562358	0.7946685

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.39137549	0.13045850	5.34	0.0218
HERB	1	1.37174880	1.37174880	56.20	0.0001
BLOCK*HERB	3	1.04569661	0.34856554	14.28	0.0009
RATE	3	0.06522507	0.02174169	0.89	0.4823
BLOCK*RATE	9	0.53758242	0.05973138	2.45	0.0993
HERB*RATE	3	0.04720686	0.01573562	0.64	0.6056

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.39137549	0.13045850	5.34	0.0218
HERB	1	1.37174880	1.37174880	56.20	0.0001
BLOCK*HERB	3	1.04569661	0.34856554	14.28	0.0009
RATE	3	0.06522507	0.02174169	0.89	0.4823
BLOCK*RATE	9	0.53758242	0.05973138	2.45	0.0993
HERB*RATE	3	0.04720686	0.01573562	0.64	0.6056

Appendix 34. AOV table for bunchberry density at 90 dat in Earltown split application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	2.18245629	0.09920256	4.78	0.0099
Error	9	0.18693283	0.02077031		
Corrected Total	31	2.36938913			

R-Square	C.V.	Root MSE	TD3 Mean
0.921105	12.36737	0.1441191	1.1653172

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.20695059	0.06898353	3.32	0.0706
HERB	1	0.67773983	0.67773983	32.63	0.0003
BLOCK*HERB	3	0.63491636	0.21163879	10.19	0.0030
RATE	3	0.31183392	0.10394464	5.00	0.0260
BLOCK*RATE	9	0.32610802	0.03623422	1.74	0.2099
HERB*RATE	3	0.02490757	0.00830252	0.40	0.7566

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.20695059	0.06898353	3.32	0.0706
HERB	1	0.67773983	0.67773983	32.63	0.0003
BLOCK*HERB	3	0.63491636	0.21163879	10.19	0.0030
RATE	3	0.31183392	0.10394464	5.00	0.0260
BLOCK*RATE	9	0.32610802	0.03623422	1.74	0.2099
HERB*RATE	3	0.02490757	0.00830252	0.40	0.7566

Appendix 35. AOV table for bunchberry density at harvest in Earltown split application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	3.46397606	0.15745346	4.87	0.0093
Error	9	0.29111737	0.03234637		
Corrected Total	31	3.75509343			

R-Square	C.V.	Root MSE	TD4 Mean
0.922474	20.44780	0.1798510	0.8795617

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.01823403	0.00607801	0.19	0.9020
HERB	1	1.38355666	1.38355666	42.77	0.0001
BLOCK*HERB	3	1.29248108	0.43082703	13.32	0.0012
RATE	3	0.10389393	0.03463131	1.07	0.4091
BLOCK*RATE	9	0.47895057	0.05321673	1.65	0.2349
HERB*RATE	3	0.18685978	0.06228659	1.93	0.1960

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.01823403	0.00607801	0.19	0.9020
HERB	1	1.38355666	1.38355666	42.77	0.0001
BLOCK*HERB	3	1.29248108	0.43082703	13.32	0.0012
RATE	3	0.10389393	0.03463131	1.07	0.4091
BLOCK*RATE	9	0.47895057	0.05321673	1.65	0.2349
HERB*RATE	3	0.18685978	0.06228659	1.93	0.1960

Appendix 36. AOV table for blueberry injury ratings at 30 dat in Earltown split application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	62.95788043	2.99799431	3.84	0.3850
Error	1	0.78125000	0.78125000		
Corrected Total	22	63.73913043			

R-Square	C.V.	Root MSE	RPHY2 Mean
0.987743	25.41165	0.8838835	3.4782609

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	5.73913043	1.91304348	2.45	0.4318
HERB	1	11.18478261	11.18478261	14.32	0.1645
BLOCK*HERB	2	6.39855072	3.19927536	4.10	0.3299
RATE	3	23.99759070	7.99919690	10.24	0.2249
BLOCK*RATE	9	14.52324263	1.61369363	2.07	0.4959
HERB*RATE	3	1.11458333	0.37152778	0.48	0.7571

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	10.05208333	3.35069444	4.29	0.3378
HERB	1	1.18947072	1.18947072	1.52	0.4336
BLOCK*HERB	2	3.30208333	1.65104167	2.11	0.4374
RATE	3	8.21875000	2.73958333	3.51	0.3696
BLOCK*RATE	9	13.28125000	1.47569444	1.89	0.5146
HERB*RATE	3	1.11458333	0.37152778	0.48	0.7571

Appendix 37. AOV table for bunchberry density in Highland Village timing of application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	2.20666511	0.10030296	5.69	0.0053
Error	9	0.15860650	0.01762294		
Corrected Total	31	2.36527162			

	R-Square	C.V.	Root MSE	TD3 Mean
	0.932944	11.86410	0.1327514	1.1189340

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.94768998	0.31589666	17.93	0.0004
TIME	3	0.04535899	0.01511966	0.86	0.4971
BLOCK*TIME	9	0.11178227	0.01242025	0.70	0 6947
HERB	1	0.92542164	0.92542164	52.51	0.0001
BLOCK*HERB	3	0.14900982	0.04966994	2.82	0.0996
HERB*TIME	3	0.02740243	0.00913414	0.52	0.6801

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.94768998	0.31589666	17.93	0.0004
TIME	3	0.04535899	0.01511966	0.86	0.4971
BLOCK*TIME	9	0.11178227	0.01242025	0.70	0.6947
HERB	1	0.92542164	0.92542164	52.51	0.0001
BLOCK*HERB	3	0.14900982	0.04966994	2.82	0.0996
HERB*TIME	3	0.02740243	0.00913414	0.52	0.6801

Appendix 38. AOV table for blueberry bud counts in Highland Village timing of application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	0.12044925	0.00547497	1.34	0.3343
Error	9	0.03668196	0.00407577		
Corrected Total	31	0.15713121			

R-Square	C.V.	Root MSE	TBUD Mean
0.766552	5.901922	0.0638418	1.0817117

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.01369718	0.00456573	1.12	0.3911
TIME	3	0.00597346	0.00199115	0.49	0.6987
BLOCK*TIME	9	0.05411320	0.00601258	1.48	0.2859
HERB	1	0.00356050	0.00356050	0.87	0.3744
BLOCK*HERB	3	0.02599571	0.00866524	2.13	0.1670
HERB*TIME	3	0.01710919	0.00570306	1.40	0.3052

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.01369718	0.00456573	1.12	0.3911
TIME	3	0.00597346	0.00199115	0.49	0.6987
BLOCK*TIME	9	0.05411320	0.00601258	1.48	0.2859
HERB	1	0.00356050	0.00356050	0.87	0.3744
BLOCK*HERB	3	0.02599571	0.00866524	2.13	0.1670
HERB*TIME	3	0.01710919	0.00570306	1.40	0.3052

Appendix 39. AOV table for blueberry stem density density in Highland Village timing of application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	0.18108204	0.00823100	2.28	0.1011
Error	9	0.03252819	0.00361424		
Corrected Total	31	0.21361024			

R-Square	C.V.	Root MSE	TSTEM Mean
0.847722	6.371055	0.0601186	0.9436204

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.03640148	0.01213383	3.36	0.0689
TIME	3	0.01019133	0.00339711	0.94	0.4610
BLOCK*TIME	9	0.06388684	0.00709854	1.96	0.1645
HERB	1	0.01398858	0.01398858	3.87	0.0807
BLOCK*HERB	3	0.01331059	0.00443686	1.23	0.3552
HERB*TIME	3	0.04330322	0.01443441	3.99	0.0462

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.03640148	0.01213383	3.36	0.0689
TIME	3	0.01019133	0.00339711	0.94	0.4610
BLOCK*TIME	9	0.06388684	0.00709854	1.96	0.1645
HERB	1	0.01398858	0.01398858	3.87	0.0807
BLOCK*HERB	3	0.01331059	0.00443686	1.23	0.3552
HERB*TIME	3	0.04330322	0.01443441	3.99	0.0462

Appendix 40. AOV table for blueberry yield in Highland Village timing of application trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	22	4.60977165	0.20953507	1.48	0.2773
Error	9	1.27313583	0.14145954		
Corrected Total	31	5.88290748			

R-Square	C.V.	Root MSE	TYIE Mean
0.783587	5.937277	0.3761111	6.3347402

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.37004782	0.12334927	0.87	0.4907
TIME	3	2.11864865	0.70621622	4.99	0.0262
BLOCK*TIME	9	0.92763617	0.10307069	0.73	0.6776
HERB	1	0.01601260	0.01601260	0.11	0.7442
BLOCK*HERB	3	0.65424483	0.21808161	1.54	0.2699
HERB*TIME	3	0.52318159	0.17439386	1.23	0.3535

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.37004782	0.12334927	0.87	0.4907
TIME	3	2.11864865	0.70621622	4.99	0.0262
BLOCK*TIME	9	0.92763617	0.10307069	0.73	0.6776
HERB	1	0.01601260	0.01601260	0.11	0.7442
BLOCK*HERB	3	0.65424483	0.21808161	1.54	0.2699
HERB*TIME	3	0.52318159	0.17439386	1.23	0.3535

Appendix 41. AOV table for blueberry bud counts in Glasgow Mountain crop tolerance to clopyralid trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	5724.8333333	715.6041667	0.93	0.5218
Error	15	11571.7916667	771.4527778		
Corrected Total	23	17296.6250000			

R-Square	C.V.	Root MSE	BUD Mean
0.330980	30.14930	27.775039	92.125000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	2570.4583333	856.8194444	1.11	0.3757
TRT	5	3154.3750000	630.8750000	0.82	0.5556

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	2570.4583333	856.8194444	1.11	0.3757
TRT	5	154.3750000	630.8750000	0.82	0.5556

Appendix 42. AOV table for crop injury ratings at 30 dat in Earltown crop tolerance to clopyralid trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	53.75000000	6.71875000	7.90	0.0003
Error	15	12.75000000	0.85000000		
Corrected Total	23	66.50000000			

R-Square	C.V.	Root MSE	RPHY1 Mean
0.808271	26.34156	0.9219544	3.5000000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
TRT	5	53.75000000	10.75000000	12.65	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
TRT	5	53.75000000	10.75000000	12.65	0.0001

Appendix 43. AOV table for crop injury ratings at 60 dat in Earltown crop tolerance to clopyralid trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	53.50000000	6.68750000	8.72	0.0002
Error	15	11.50000000	0.76666667		
Corrected Total	23	65.00000000			

R-Square	C.V.	Root MSE	RPHY2 Mean
0.823077	25.01700	0.8755950	3.5000000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
TRT	5	53.50000000	10.70000000	13.96	0.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	0.00000000	0.00000000	0.00	1.0000
TRT	5	53.50000000	10.70000000	13.96	0.0001

Appendix 44. AOV table for blueberry stem density in Earltown crop tolerance to clopyralid trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	178.04166667	22.25520833	0.39	0.9098
Error	15	857.58333333	57.17222222		
Corrected Total	23	1035.62500000			

R-Square	C.V.	Root MSE	STEM Mean
0.171917	21.99631	7.5612315	34.375000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	106.79166667	35.59722222	0.62	0.6113
TRT	5	71.25000000	14.25000000	0.25	0.9337

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	106.79166667	35.59722222	0.62	0.6113
TRT	5	71.25000000	14.25000000	0.25	0.9337

Appendix 45. AOV table for blueberry yield in Earltown crop tolerance to clopyralid trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	21.10901317	2.63862665	6.62	0.0009
Error	15	5.98054549	0.39870303		
Corrected Total	23	27.08955865			

R-Square	C.V.	Root MSE	TYIE Mean
0.779231	13.32498	0.6314294	4.7386899

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	2.67270666	0.89090222	2.23	0.1263
TRT	5	18.43630651	3.68726130	9.25	0.0004

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	2.67270666	0.89090222	2.23	0.1263
TRT	5	18.43630651	3.68726130	9.25	0.0004

Appendix 46. AOV table for blueberry bud counts in Lakelands crop tolerance to clopyralid trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	8966.4000000	1280.9142857	2.02	0.1355
Error	12	7600.6000000	633.3833333		
Corrected Total	19	16567.0000000			

R-Square	C.V.	Root MSE	BUD Mean
0.541220	24.55328	25.167108	102.50000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	4205.4000000	1401.8000000	2.21	0.1393
TRT	4	4761.0000000	1190.2500000	1.88	0.1789

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	4205.4000000	1401.8000000	2.21	0.1393
TRT	4	4761.0000000	1190.2500000	1.88	0.1789

Appendix 47. AOV table for blueberry stem counts in Lakelands crop tolerance to clopyralid trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	801548.80000	114506.97143	4.03	0.0169
Error	12	340838.40000	28403.20000		
Corrected Total	19	1142387.20000			

R-Square	C.V.	Root MSE	STEM Mean
0.701644	24.18664	168.53249	696.80000

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	741721.60000	247240.53333	8.70	0.0024
TRT	4	59827.20000	14956.80000	0.53	0.7185

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	741721.60000	247240.53333	8.70	0.0024
TRT	4	59827.20000	14956.80000	0.53	0.7185

Appendix 48. AOV table for blueberry yield in Lakelands crop tolerance to clopyralid trial.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	22.06798108	3.15256873	7.67	0.0012
Error	12	4.93477453	0.41123121		
Corrected Total	19	27.00275561			

R-Square	C.V.	Root MSE	TYIE Mean
0.817249	17.58522	0.6412731	3.6466587

Source	DF	Type I SS	Mean Square	F Value	Pr > F
BLOCK	3	4.53740643	1.51246881	3.68	0.0436
TRT	4	17.53057465	4.38264366	10.66	0.0006

Source	DF	Type III SS	Mean Square	F Value	Pr > F
BLOCK	3	4.53740643	1.51246881	3.68	0.0436
TRT	4	17.53057465	4.38264366	10.66	0.0006