One Year Results for a Coastal British Columbia Glyphosate Conifer Release Trial

File Report No. 81 1987

P.E. Reynolds, K. King, R. Whitehead, T. MacKay

Director
Forest Pest Management Institute
Canadian Forestry Service
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

One Year Results for a Coastal British Columbia Glyphosate Conifer Release Trial

PHILLIP E. REYNOLDS[1], KEITH KING[2], ROGER WHITEHEAD[2] and TIMOTHY S. MacKAY[1]

Abstract. In early September 1984, portions of the Carnation Creek Watershed, located on the west coast of Vancouver Island (48°54'N, 125°01'W), were aerially treated with 2 kg ai/ha of glyphosate [N-(phosphonomethyl) glycine] using a Bell-47 helicopter equipped with a MICROFOIL BOOM to minimize herbicide drift into an adjoining salmon-bearing stream. Since 1970, the watershed has been a focal point for interagency cooperative research designed to assess the effects of forest practices (i.e., harvesting, prescribed burning, herbicide use) on resident salmonid fish populations. The present herbicide study was undertaken in support of this overall objective. From 1975 to 1981, portions of the watershed were logged, and various post-harvesting silvicultural treatments, inclusive of scarification, prescribed burning and planting, were carried out commencing in the fall of 1976 and continuing through the spring of 1983. Crop species

---

[1]Research Scientist and Herbicide Technician, Forest Pest Management Institute, Canadian Forestry Service, 1219 Queen Street East, Sault Ste. Marie, Ontario, P6A 5M7.

[2]Research Technician and Forestry Officer, Pacific Forestry Centre, 506 West Burnside Road, Victoria, British Columbia, V8Z 1M5.

planted consisted of sitka spruce [Picea sitchensis (Bong.) Carr.], western hemlock [Tsuga heterophylla (Raf.) Sarg.], western red cedar (Thuja plicata Donn), Douglas fir [Pseudotsuga menziesii (Mirb.) Franco.], amabilis fir [Abies amabilis (Dougl.) Forbes.] and some grand fir (Abies grandis). Notable hemlock, cedar and amabilis fir natural regeneration occurred following harvesting. Prior to glyphosate treatment, major weed competition consisted of red alder (Alnus rubra Bong. #[3]) and salmonberry (Rubus spectabilis Pursh. #[3] RUBSP). Weed efficacy following glyphosate treatment was species dependent, being generally high for most species present. Although salmonberry control was quite satisfactory after one post-spray growing season, control of red alder was quite variable, ranging from no control (i.e., completely healthy) to total control (i.e., totally dead). Salal (Gaultheria shallow Pursh. #[3]) was uncontrolled by the herbicide treatment. Despite variable alder control throughout the 45 ha treated watershed, higher alder control was observed on upslope microsites as contrasted with alders growing throughout the watershed valley bottom. A similar trend was noted for other important weed species including salmonberry, thimbleberry (Rubus parviflorus Nutt. #[3] RUBPA), stink currant (Ribes bracteosum Dougl. #[3]) and three fern species. The trend suggests that certain weed species growing on upslope microsites may be more physiologically stressed,

---

[3]Letters following this symbol are a WSSA-approved computer code from Important Weeds of the World, 3rd. ed., 1983. Available from WSSA, 309 West Clark St., Champaign, IL.

and more susceptible to herbicide damage. The same weed species growing on valley bottom sites may be less stressed, and more resistant to herbicide damage. Some minor crop tree injury resulted following glyphosate treatment for western hemlock and to a lesser extent for western cedar. Initial injury consisted of death or dieback of the primary leader and was unobserved for other crop trees (i.e., sitka spruce, amabilis fir and Douglas fir) present. After one year, trees exhibiting initial injury showed full recovery with the damaged primary leader replaced by a more vigorously growing lateral. Height growth for the hemlock or cedar laterals, assuming dominance in 1985, far exceeded 1984 height growth for the original primary leader, often being upwards of two times the length of the original leader. A similar height growth increase was unobserved for treated sitka spruce. However, height growth response for untreated hemlock, cedar and spruce was quite variable. A slight decrease in growth was observed for hemlock in 1985, whereas untreated cedar showed an increase in growth for 1985. Height growth for untreated spruce declined in 1984 from 1983, but increased in 1985 over that observed in 1984. Although height growth increases were observed for treated amabilis fir and Douglas fir in 1985, only a limited number of individuals were measured, and no untreated individuals were observed. The variability in height growth response for untreated crop trees confirms that additional growth measurements are necessary in 1986 and subsequent years to substantiate the apparent dramatic height growth increase noted for treated hemlock and cedar in 1985. Continued monitoring of crop tree growth response may ultimately demonstrate that other species such as sitka spruce also show a growth response to herbicide treatment.

Additional index words. RUBPA, RUBSP, CHAAN, BLESP, ATUFF, POIMU, SAMRA.

INTRODUCTION

Canada's forests are the nation's most valuable natural resource. Nearly one out of ten Canadians is directly or indirectly employed in the forest sector. Despite the importance of Canadian forestry, Canada's recent annual harvest has been declining and there is currently a backlog of approximately 26 million hectares of inadequately stocked productive forest land in Canada (7, 8). This is increasing at a rate of about 270,000 hectares each year. In British Columbia alone, there is approximately 2.9 million hectares of nonsatisfactorily restocked forest land, and this is being added to at a rate of 48,000 hectares per year (2). The significance of the British Columbia brush problem is paramount, since approximately half of Canada's forest production is derived from British Columbia forests, and approximately half of the wood fibre produced in British Columbia is derived from the fertile, highly productive coastal forests (1).

Successful attempts to renew Canada's forests are plagued by a lack of registered forestry herbicides. This lack of registered herbicides is due in large measure to environmental concerns, and the problem is especially acute in British Columbia where notable fisheries resources (i.e., pacific salmon) are located within coastal forest sites which would benefit most from herbicide use. At present only two herbicides, including glyphosate, are fully registered (i.e., inclusive of aerial applications) for forestry use in Canada. One herbicide, hexazinone [3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4 (1H, 3H)-dione], has a temporary registration for ground applications only. This compares with nearly a dozen registered forestry herbicides in the United States.

A role of the Canadian Forestry Service is to assist in the collection of weed efficacy, crop injury and environmental impact data, specific to Canadian plant species and environmental conditions, needed to fully register additional herbicides and forestry herbicide use patterns for Canadian use. Since provincial permits are required to use registered herbicides, and since issuance of such permits has been hampered by a lack of regional data specific to registered herbicides, the Canadian Forestry Service is playing a significant role in helping to answer regional silvicultural and environmental concerns which extend beyond federal registration data requirements. Silviculturally, herbicide conifer release is generally performed two to five years after planting. It is intended to release the newly established conifers from competing forest weeds and to ensure that the crop trees achieve a free-to-grow status.

Study area. The Carnation Creek Watershed is located on the west coast of Vancouver Island. The watershed is located near the town of Bamfield on the south side of Barkley Sound (48°54'N, 125°01'W) and is approximately 10 km^2 in area. Since 1970, the watershed has been a focal point for interagency cooperative research designed to assess the effects of forest practices (i.e., harvesting, prescribed burning, herbicide use) on resident salmonid fish populations.

Elevation of the watershed ranges from sea level to 670 metres, although most of the drainage is located below 450 metres and the level of snowfall (4, 6). Prior to harvesting, the watershed consisted of an overmature western hemlock-amabilis fir-western red cedar forest growing on colluvial materials (6). Annual precipitation at the watershed ranges from 250 cm to 380 cm (1). Carnation Creek, the primary creek draining the watershed, is approximately 6 km in length (6). Stream discharge for the creek ranges from approximately 0.017 m^3/sec in late summer to around 48 m^3/sec in the winter (1). Spawning fish populations consist of coho salmon, steelhead and cutthroat trout, chum salmon and pink salmon, and range in numbers from a few individuals to 4200 (1).

From 1979 to 1981, portions (i.e., approximately 404 ha) of the watershed were logged, and various post-harvesting silvicultural treatments inclusive of scarification, prescribed burning and planting, were carried out commencing in the fall of 1976 and continuing through the spring of 1983 (3). Crop species planted consisted of sitka spruce, western hemlock, western red cedar, Douglas fir, amabilis fir and some grand fir. Post-harvest revegetation of the watershed has been described in detail elsewhere (5). Notable hemlock, cedar and amabilis fir natural regeneration occurred following harvesting. Prior to herbicide treatment, major weed competition consisted of red alder and salmonberry. The present herbicide study was undertaken to assess environmental impacts on resident salmonids, to monitor weed efficacy and crop injury resulting from glyphosate treatment, and to monitor long-term crop tree growth response resulting from conifer release. The present report focuses on preliminary silvicultural considerations resulting from glyphosate treatment.

MATERIALS AND METHODS

Glyphosate (2 kg ai/ha) was aerially applied to a 45 ha portion of the watershed as described in Table 1. Treatment was performed in September 1984 using a Bell-47 helicopter equipped with a MICROFOIL BOOM[4] to minimize herbicide drift into an adjoining salmon-bearing stream. The watershed was operationally sprayed by dividing the spray area into ten spray blocks easily delineated by natural topographic features. Untreated control areas were located throughout the sprayed watershed, and their locations and boundaries were delineated by orange garbage bags tied to wooden markers or tree tops.

Weed efficacy, crop injury and crop tree growth response were assessed from September 18 to 20, 1985 by establishing circular vegetation sample quadrats (1.8 m radius for herbaceous and 25 m for brush) at 50 to 75 metre intervals along transects running throughout the watershed. Where possible, most of transects were located within the watershed valley bottom, since most of the herbicide treatment occurred within the floodplain of Carnation Creek. Changes in transect compass bearing or sampling interval were minimized, and were necessitated by changing terrain features mediated by the natural course of Carnation Creek itself (i.e., the watershed is essentially a ravine, with Carnation Creek flowing through the valley bottom). A total of 36 permanently marked treated sample quadrats were established. Five untreated quadrats were established. The 41 quadrats will be monitored in subsequent years for additional vegetation changes associated with glyphosate spraying.

---

[4]Registered trademark of Union Carbide, Inc., Ambler, Pennsylvania.

Table 1. Treatment conditions

Herbicide (a.i.)	glyphosate (356 g/L)
Treatment rate	2.0 kg/ha
Spray volume	258.25 L/ha
Aircraft	Bell-47 helicopter
Boom and nozzles	MICROFOIL BOOM, 26 ft in length, .060 hayrake nozzles
Orientation of nozzles	180°
Boom pressure	172.5 kPa
Airspeed	40.2 km/hr
Swath width and altitude	12.2 m; 6 to 18 m
Weather (prior)	Sunny and calm winds immediately prior to Sept. 6; intermittent showers on Sept. 7 and each day from Sept. 9 through Sept. 12; sunny and very windy on Sept. 13
(at times of spraying)	Sept. 6 - time: 1900-2005 hr; air temperature: 15 °C; wind conditions: calm, E to W; skies: cloudy, overcast, intermittent sun; precipitation: none
	Sept. 8 - times: 1416-1445 hr and 1913-1940 hr; wind conditions: gusty to calm, E to W; skies: overcast, black clouds, threatening showers; precipitation: none
	Sept. 14 - time: 1430-1931 hr; air temperature: 21 °C; wind conditions: gusty to calm, E to W; skies: sunny, overcast, white clouds; precipitation: none
	Sept. 15 - time: 1041-1101 hr; air temperature: 14 °C; wind conditions: calm, E to W; skies: sunny; precipitation: beginning at 1345.
(after)	Winds increasing in speed and changing direction (W to E) by 1130 hr on Sept. 15; cloudy and overcast, with rain clouds moving in from sea by 1200 hr; rain showers began at 1345 hr on Sept. 15, and heavy rain continued through 1500 hr on Sept. 16.

Weed efficacy or crop injury were rated on a scale of 0 to 10, 0 being no control or injury and 10 being total weed kill or maximum crop injury. Representative (i.e., silviculturally superior) crop trees were tagged in each sample quadrat, and height and diameter measurements for all tagged specimens recorded. Height measurements consisted of recording 1985 terminal leader length, and measuring 1983 and 1984 internodal length where feasible. In instances where the 1985 terminal leader was found to be dead or partial dieback was evident, the length of any lateral having assumed dominance was measured. In addition, the extent of dieback or the length of the dead terminal leader was measured.

RESULTS AND DISCUSSION

Weed efficacy following glyphosate treatment was species dependent, being generally high for most species present (Table 2). Weed efficacy values ranged from 7 to 10 for stink currant (Ribes bracteosum Dougl. #[3]), red elderberry (Sambucus racemosa L. #[3] SAMRA), lady fern [Athyrium filix-femina (L.) Roth. #[3] ATUFF], bitter cherry [Prunus emarginata (Dougl. ex Hook.) Walp. #[3]], salmonberry (Rubus spectabilis Pursh. #[3] RUBSP), deer fern [Blechnum spicant (L.) With. #[3] BLESP], false azalea (Menziesia ferruginea Smith #[3]) and Pacific crabapple (Pyrus fusca #[3]). Although salmonberry control was quite satisfactory after one post-spray growing season, control of red alder was quite variable, ranging from no control (i.e., completely healthy) to total control (i.e., totally dead). Salal was uncontrolled by the herbicide treatment. Some minor crop

Table 2. Mean weed efficacy and crop injury values following glyphosate treatment.

Species	0 kg/ha		2 kg/ha	
	Value[a]	n[b]	Value	n
red alder (*Alnus rubra*)	0	5	6.8	36
salmonberry (*Rubus spectabilis*)	0	5	8.2	39
thimbleberry (*Rubus parvifolium*)	0	5	5.6	17
salal (*Gaultheria shallor*)	0	5	0.0	30
red huckleberry (*Vaccinium parvifolium*)	0	5	2.4	34
tall huckleberry (*Vaccinium ovalifolium*)	0	1	3.9	22
evergreen huckleberry (*Vaccinium ovatum*)	-	0	0.0	3
false azalea (*Menziesia ferruginea*)	0	1	9.3	18
bitter cherry (*Prunus emarginata*)	0	2	7.9	8
stink currant (*Ribes bracteosum*)	-	0	7.1	5
Pacific crabapple (*Pyrus fusca*)	-	0	10.0	1
red elderberry (*Sambucus racemosa*)	0	3	7.4	25
willow (*Salix* sp.)	-	0	2.2	6
deer fern (*Blechnum spicant*)	0	5	8.3	39
lady fern (*Athyrium felix-femina*)	0	5	7.5	20
sword fern (*Polystichum munitum*)	0	5	4.4	34
fireweed (*Epilobium angustifolium*)	0	5	1.8	35
sitka spruce (*Picea sitchensis*)	0.2	5	0.0	37
western hemlock (*Tsuga hetrophyla*)	0	4	0.9	35
western cedar (*Thuga plicata*)	0	5	0.3	36
amabilis fir (*Abies amabilis*)	-	0	0.0	5
Douglas-fir (*Pseudotsuga menziesii*)	-	0	0.0	1
western yew (*Taxus brevifolia*)	-	0	0.0	1

[a] Mean value based upon number of individuals observed.

[b] Number of individuals observed.

tree injury resulted following glyphosate treatment for western hemlock and to a lesser extent for western red cedar (Table 2). Initial injury consisted of death or dieback of the primary leader and was unobserved for other crop trees (i.e., sitka spruce, amabilis fir and Douglas fir) present.

Despite variable alder control throughout the 45 ha treated watershed, higher alder control was observed on upslope microsites as contrasted with alders growing throughout the watershed valley bottom (Table 3). A similar trend was noted for salmonberry, thimbleberry, stink currant, deer fern, lady fern and sword fern [Polystichum munitum (Kaulf.) Presl. #[3] POIMU]. Other weed species growing throughout the watershed valley bottom, including red huckleberry (Vaccinium parvifolium Smith. #[3]), tall huckleberry (Vaccinium ovalifolium Smith. #[3]), false azalea and fireweed (Epilobium angustifolium L. #[3] CHAAN), were observed to have higher efficacy control values as contrasted with the same species growing on upland microsites. Weed species such as salal, evergreen huckleberry (Vaccinium ovatum Pursh. #[3]) or red elderberry exhibited no notable difference in weed efficacy for the two microsites. Similarly, no noteworthy difference in crop injury was observed for the two microsites.

Microsite differences (e.g., moisture, solar radiation, wind, temperature, nutrients) throughout the watershed may be expressed as physiological differences within individual plants, and may explain why some weed species are better controlled on one microsite (i.e., hillside) as opposed to another (i.e., valley bottom). Certain weed species growing on upslope microsites may be more stressed, and more susceptible to herbicide damage, due to dessication resulting from

Table 3. Influence of watershed microsite on weed efficacy or crop tree injury.

	2 kg/ha			
	Valley bottom		Upland microsite	
Species	Value[a]	n[b]	Value	n
red alder (*Alnus rubra*)	6.3	26	7.8	10
salmonberry (*Rubus spectabilis*)	8.0	27	8.4	12
thimbleberry (*Rubus parvifolium*)	4.5	12	8.0	5
salal (*Gaultheria shallor*)	0.0	19	0.0	11
red huckleberry (*Vaccinium parvifolium*)	2.9	18	2.3	12
tall huckleberry (*Vaccinium ovalifolium*)	3.9	14	3.8	8
evergreen huckleberry (*Vaccinium ovatum*)	0.0	2	0.0	1
false azalea (*Menziesia ferruginea*)	9.8	10	8.8	8
bitter cherry (*Prunus emarginata*)	7.9	6	7.8	2
stink currant (*Ribes bracteosum*)	6.6	4	9.0	1
Pacific crabapple (*Pyrus fusca*)	10.0	1	-	0
red elderberry (*Sambucus racemosa*)	7.4	19	7.4	6
willow (*Salix* sp.)	2.2	5	2.0	1
deer fern (*Blechnum spicant*)	8.1	27	8.8	12
lady fern (*Athyrium felix-femina*)	7.7	17	8.8	3
sword fern (*Polystichum munitum*)	4.0	25	5.3	9
fireweed (*Epilobium angustifolium*)	2.1	24	1.2	11
sitka spruce (*Picea sitchensis*)	0.0	26	0.0	11
western hemlock (*Tsuga hetrophyla*)	0.9	23	0.8	12
western cedar (*Thuga plicata*)	0.3	25	0.2	11
amabilis fir (*Abies amabilis*)	0.0	1	0.0	4
Douglas-fir (*Pseudotsuga menziesii*)	0.0	1	-	0
western yew (*Taxus brevifolia*)	-	0	0.0	1

[a] Mean value based upon number of individuals observed.

[b] Number of individuals observed.

greater wind exposure and less available water. By contrast, the same weed species growing on valley bottom sites may be less stressed and more resistant to herbicide damage.

Such differences could result in the use of different herbicide rates depending upon microsite. This practice could have high operational and environmental advantages. Differences in plant physiological stress, mediated by microsite variations, may be the key to explaining frequently observed differences in herbicide efficacy or crop injury reported by operational foresters. Where such differences are noted, foresters often look for all sorts of explanations for why herbicide x didn't work for location y when the same herbicide worked great just over the hill on location z. Frequently alleged causes such as plugged-up nozzles, morning versus evening treatment, rain or no rain shortly before or after the application, etc. may not be the true causative agent(s) for the efficacy differences. Clearly, more in-depth investigations of the influence of plant stress and microsite on herbicide efficacy are warranted. Vegetation studies focusing on whole watersheds or ecosystems may be of greater value in detecting differences in plant susceptibility than replicated treatments consisting of small (i.e., 2-4 ha), homogenous spray blocks, since microsite differences are likely best expressed over large geographic areas. Should plant stress be positively implicated, operational foresters will need to be better educated concerning plant growth and development, and pay greater attention to these details in developing herbicide prescriptions.

Height growth for hemlock and cedar in 1985, following glyphosate treatment, far exceeded that attained in 1984 (Table 4). After one growing season, hemlock and cedar trees exhibiting initial injury following glyphosate treatment showed full recovery with the damaged primary leader replaced by a more vigorously growing lateral. Height growth for hemlock or cedar laterals, assuming dominance in 1985, far exceeded 1984 height growth for the original primary leader, often being upwards of two times the length of the original leader. This is reflected in Table 4 which encompasses 1985 growth for uninjured crop trees as well as those damaged by the glyphosate spraying. A similar height growth increase for treated sitka spruce was unobserved in 1985. Height growth response for untreated (0 kg ai/ha glyphosate) hemlock, cedar and spruce was quite variable. A slight decrease in growth was observed for untreated hemlock in 1985, whereas untreated cedar showed an increase in growth for 1985. Height growth for untreated spruce declined in 1984 from 1983, but increased in 1985 over that observed in 1984. Although height growth increases were observed for treated (2 kg ai/ha glyphosate) amabilis fir and Douglas fir in 1985, only a limited number of individuals were measured, and no untreated individuals were observed.

The variability in height growth response for untreated crop trees confirms that additional growth measurements are necessary in 1986 and subsequent years to substantiate the apparent dramatic height growth increase noted for treated hemlock and cedar in 1985. Continued monitoring of crop tree growth response may ultimately demonstrate that other species such as sitka spruce also show a growth response to herbicide treatment.

Table 4. Crop tree growth response to glyphosate treatment.

Treatment	1983		1984		1985	
	height[a]	n[b]	height	n	height	n
<u>0 kg/ha</u>						
western hemlock	-	0	45.0	4	43.5	4
western cedar	-	0	39.0	2	49.5	2
sitka spruce	40.3	6	29.7	6	51.0	6
amabalis fir	-	0	-	0	-	0
Douglas-fir	-	0	-	0	-	0
<u>2 kg/ha</u>						
western hemlock	-	0	34.3	25	44.4	30
western cedar	-	0	23.9	15	40.5	25
sitka spruce	36.7	24	48.5	26	52.2	26
amabalis fir	-	0	53.0	2	59.5	2
Douglas-fir	-	0	49.0	1	60.0	1

[a] Mean annual incremental leader growth based upon number of individuals observed.

[b] Number of individuals observed.

Results of the Carnation Creek trial should be very encouraging to operational foresters, since they clearly demonstrate that crop injury, although unavoidable for certain species, is of a temporary fleeting nature, and that notable growth increases are likely to be achieved within one growing season following a conifer release treatment. The dramatic increase in hemlock and cedar growth following glyphosate treatment suggests that significant growth gains may be achieved by releasing naturally regenerated conifers from weed competition and that these growth gains may far exceed those attainable by releasing plantations from similar competition. If this is true, a greater growth advantage may result from using herbicides on naturally regenerated sites rather than on man-made plantations.

ACKNOWLEDGMENT

We wish to thank Mr. Ron Rowe (Rotor Vegetation Control, Calgary, Alberta) and Mssrs. Dave Gubbels and Don Chollca (Alpine Helicopters, Calgary, Alberta) for their assistance in aerially applying glyphosate at the Carnation Creek Watershed. In addition, we thank Mr. Jack Dryburgh (MacMillan & Bloedel Ltd.) for his assistance in marking areas of the watershed to be sprayed. We are grateful to the British Columbia Ministry of Forests for providing funding for this research. Finally, we reserve special thanks for Mr. Henry Benskin (B.C. Forest Service) for his untiring devotion to the success of this project.

LITERATURE CITED

1. Anonymous. 1984. Canada's Forests 1984. Environment Canada Publication. DSS Cat. No. FO51-1/1984E.
2. Boateng, J.O. 1984. Estimates of forest brush problems in British Columbia. B.C. Ministry of Forests Publication No. BCMF-SH-R84001, 58 p.
3. Dryburgh, J.G. 1982. Carnation Creek logging and silvicultural treatment program. Pages 36-44 _in_ G.F. Hartman, ed. Proceedings of the Carnation Creek Workshop, a 10 Year Review. Malaspina College, Nanaimo, British Columbia, February 24 to 26, 1982.
4. Hartman, G.F. 1982. The study area: an initial description. Page 15 _in_ G.F. Hartman, ed. Proceedings of the Carnation Creek Workshop, a 10 Year Review. Malaspina College, Nanaimo, British Columbia, February 24 to 26, 1982.
5. King, R.K. and E.T. Oswald. 1982. Revegetation of Carnation Creek Watershed. Pages 110-128 _in_ G.F. Hartman, ed. Proceedings of the Carnation Creek Workshop, a 10 Year Review. Malaspina College, Nanaimo, British Columbia, February 24 to 26, 1982.
6. Oswald, E.T. 1982. Preharvest vegetation and soils of Carnation Creek Watershed. Pages 17-35 _in_ G.F. Hartman, ed. Proceedings of the Carnation Creek Workshop, a 10 Year Review. Malaspina College, Nanaimo, British Columbia, February 24 to 26, 1982.

7. Reynolds, P.E., T.S. MacKay and M.L. McCormack, Jr. 1986. Results of a hexazinone-mechanical site preparation trial. Proceedings of the Northeastern Weed Science Society. Vol. 40: 222-229.

8. Reynolds, P.E., T.S. MacKay and M.L. McCormack, Jr. 1986. One year results for a hexazinone conifer release trial. Proceedings of the Northeastern Weed Science Society. Vol. 40:218-222.