USE OF HERBICIDES IN FOREST MANAGEMENT

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INFORMATION REPORT NOR-X-282

NORTHERN FORESTRY CENTRE
CANADIAN FORESTRY SERVICE
1986

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Catalogue No. Fo46-12/282E
ISBN 0-662-15037-6
ISSN 0704-7673

This publication is available at no charge from:

Northern Forestry Centre
Canadian Forestry Service
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Malik, N.; Vanden Born, W.H. 1986. *Use of herbicides in forest management.* Can. For. Serv., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-282.

ABSTRACT

The current status of forestry in North America is briefly reviewed and the urgent need for judicious use of herbicides as an effective tool for intensive forest management is discussed. The scientific literature on the environmental chemistry and impact of herbicides with potential for forest resource management is reviewed. The major emphasis is on four new herbicides evaluated in Canadian forest regions. The gaps in knowledge of the environmental fate and environmental impact of the new herbicides are identified. The current status of herbicides and herbicide research in Canada is reviewed. Factors limiting the use of herbicides in Canadian forestry are discussed, and recommendations for further research are made.

RESUME

Bref survol de la situation actuelle de la foresterie en Amérique du Nord et discussion sur l'urgence d'utiliser judicieusement les herbicides comme moyen efficace dans l'aménagement forestier intensif sont présentés. Les auteurs font un bref survol des publications scientifiques sur la chimie de l'environnement et les effets des herbicides qui intéressent l'aménagement des ressources forestières. Ils s'attardent sur quatre nouveaux herbicides évalués dans les régions forestières canadiennes. Ils précisent les lacunes, au niveau des connaissances du devenir et des effets environnementaux des nouveaux herbicides. Ils font un survol de la situation actuelle des herbicides et de la recherche à cet égard au Canada. Ils traitent des facteurs qui limitent l'utilisation des herbicides en foresterie, au Canada, et formulent des recommandations sur les recherches à faire.

PREFACE

This report is based on the literature survey, *Herbicide use in North American forestry*, which was prepared by W.H. Vanden Born and N. Malik, Department of Plant Science, University of Alberta, Edmonton, Alberta. The study was sponsored by the Canadian Forestry Service under a PRUF contract. This report has been reviewed by the Canadian Forestry Service and approved for distribution. Approval does not necessarily signify that the contents reflect the views and policies of the Canadian Forestry Service. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

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NOTE

The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by the Canadian Forestry Service.

INTRODUCTION

The increasing demand for softwood timber products, the shrinking forest land base, and the urgent need for rehabilitation of vast tracts of potentially productive forest lands across North America call for extensive reforestation operations and rapid implementation of intensive forest management practices. Prudent use of herbicides should be an integral part of forest resource management practices, but because of public concerns about their potential environmental and health hazards, the negative impact of media reports, and inadequate research and development efforts, the potential of herbicides for improving forest productivity has not been realized. Herbicides have been used in North American forestry ever since the discovery of the phenoxyacetic acids; however, herbicide use in forestry is not as common or as widely accepted as it is in agriculture. Industry and government involvement in research and development of herbicides for forestry has been minimal. This has probably been due to a minimal application need in forestry—one or two applications over an 80–100 year period over small areas.

Nonchemical methods of vegetation control are now widely employed in the U.S. and Canada, but they may not be efficient or economical and may be counterproductive in selective situations where they encourage the resprouting of brush. Mechanical and prescribed burning methods of brush control are also ineffective on certain soils and topography and under certain climatic limitations. In these situations the impact of these methods may be greater, longer-lasting, and more disruptive to the forest ecosystem than chemical methods. Insufficient data are available at this time to make judgments on different methods of vegetation control.

The objectives of the present review were as follows: 1) to assess the need for herbicides in forest resource management practices, with particular emphasis on Canadian forestry; 2) to review current knowledge of the environmental fate and impact of the new herbicides that have potential in forest management practices; 3) to review the registration status of the new herbicides in Canada; 4) to identify factors limiting use of herbicides in Canadian forestry; and 5) to make recommendations for future research.

PRESENT STATUS OF FORESTRY IN NORTH AMERICA

United States

The total forest land base in the United States is 299 million ha, and the commercial forest land base covers 197 million ha. Only about half of this area is actually available for timber production because of changing ownership objectives and land classification. The U.S. is a net importer of timber. The present downward trend in harvests will continue and contribute to predicted shortages in softwood timber supplies (Anonymous 1978). Severe shortfalls in softwood timber supplies are likely in the Pacific northwest by 1990. The U.S. Forest Service has predicted that demand for wood may double by the year 2000 and that much of this increased supply must come from nonindustrial private forest land. Vast areas of this land, however, have been producing far below capacity (Dierauf 1978).

Canada

The total forest land base in Canada is 436 million ha, which includes 342 million ha of inventoried and 94 million ha of noninventoried forest land (Canadian Forestry Service 1984). About 290 million ha of forest land fall within the 10 provinces. The productive forest land is estimated to be 200 million ha (Reed 1979).

Currently about 800 000 ha are logged annually. The provincial governments and companies that own 80% of the forest land replant about 200 000 ha annually, an additional total area of 200 000 ha regenerates itself naturally, and the remainder, about 400 000 ha, are neglected. This trend has resulted in a backlog of 30 million ha of unregenerated forest land in Canada (Manville 1983). Losses of the forest land base area to industrial, urban, and recreational uses are estimated at a quarter of a million ha annually (Manville 1983; Sundaram and Prasad 1983). Losses to competing vegetation are estimated at one-fifth of the annually harvested area (Manville 1983).

Damage to forest resources is also considerable. About 90 million m^3 of timber are damaged by insects and diseases, 40 million m^3 are lost because of inept regeneration practices, and 15 million m^3 are destroyed by fire. The annual allowable cut (AAC) for softwoods has already been exceeded in some regions of Canada, resulting in shortage of wood, closure of mills, and creation of economic problems in many rural communities. The critical local shortages of timber are not obvious to the casual observer, and this is one of the reasons why the productivity of forests has been allowed to deteriorate. Recent federal studies indicate that one-tenth of Canada's once-productive forest land is no longer growing marketable timber (Keating 1983).

The current level of AAC is set at 165–175 million m^3 (Green 1982), but the Canadian Council of Resource and Environment Ministers (CCREM) has set a target for the year 2000 of 210 million m^3. Our national goal is to increase the timber harvest by 50% over the next 25 years (Canadian Forestry Service 1981). This goal challenges forest managers to consider all aspects of forest management, including utilization standards for currently commercial species, increasing range of species acceptability, efficient processing technology, and improved management strategies for crop establishment, release, and tending using mechanical, manual, chemical, and biological options.

VEGETATION MANAGEMENT IN FORESTRY

Historical Background on the Use of Herbicides

Inorganic salts such as sodium arsenate and ammonium sulfate were used as herbicides for vegetation management as early as 1915 (Sutton 1958), but the use of herbicides did not gain momentum until after 1945. Although work began on phenoxyacetic acids in 1938, it was not until 1944 that the use of 2,4,5-T on woody vegetation was announced, and within a few years after the war, its use was widely accepted. A few years later a large number of organic herbicides such as chloro-s-triazines, amitrole, and chlorpropham (CIPC) were produced. In 1954 about 27 500 ha of brush were treated in Canada (Suggit 1956), and this increased to 34 000 ha in 1955 (Suggit 1957).

The use of phenoxy herbicides in North American forestry received setbacks in the early 1970s because of concern over their suspected environmental hazards. The RPAR (Rebuttable Presumption Against Registration) process initiated by the Environmental Protection Agency (EPA) in the United States in 1978 restricted the use of 2,4,5-T and 2,4,5-TP, and the EPA banned all uses of these herbicides in October 1983. A Nova Scotia court case in 1983 and most recently the ruling of a British Columbia court against the use of herbicides in the Skeena River area have shaken the confidence of the general public in the safe use of herbicides.

Herbicide Use in U.S. Forestry

As many as 70 herbicides, alone and in combination, find some use in U.S. forestry, but only 15 herbicides are commonly used (Cutler 1978). In 1978 it was estimated that of the 2.7 million kg of 2,4,5-T and the 18 million kg of 2,4-D manufactured each year, less than 0.9 million kg of the two combined was used for silvicultural purposes on approximately 400 000 ha of forest land (Carter et al. 1978). In sharp contrast, about 80 million ha of corn, wheat, and soybeans planted annually receive 1 kg/ha or more of herbicide. Thus, the amount of herbicide use in U.S. forestry represents only a small fraction of the total herbicide usage. Approximately 0.2% of the commercial forest land may be treated with herbicides in any one year.

Because of increasing environmental concerns about the use of 2,4,5-T in the 1970s, a new generation of herbicides was developed. Although none is likely to be a substitute for 2,4,5-T, four new promising herbicides have been registered over the last 6 years. These are glyphosate, hexazinone, fosamine ammonium, and triclopyr. The registration of these herbicides does not mean that forest managers prefer the use of herbicides to other management methods, or that they expect herbicide usage in forestry to be at par with agriculture use. The use of herbicides in forestry is recommended only in special situations where it is environmentally safe and their use is the best alternative. One must emphasize that application may be once or twice over a period of 80-100 years, as opposed to annual applications in agriculture.

The USDA Forest Service's use of herbicides on National Forest Systems (NFS) lands for the decade of 1974–84 averaged about 87 000 ha/yr. (USDA Forest Service 1984). A total of 156 265 kg of herbicides was applied by the Forest Service to 57 427 ha of NFS lands in 1984. Only 3352 kg of this total was applied by air to 846 ha of forest land. This amount constituted only 1% of the total amount of forest management chemicals applied by air.

Herbicide Use in Canadian Forestry

The need for prudent use of herbicides as an effective tool in silvicultural operations has been recognized by the CFS since the introduction of the phenoxy herbicides (Sutton 1958, 1970), although herbicide studies have never been of a high priority with the CFS until recently (Carlson and Prasad 1981). The use of herbicides as well as other chemicals in forestry has lagged far behind their use in agriculture. Agricultural uses of all chemicals total 24.7 million kg; the forestry uses of all chemicals is 0.45 million kg, or less than 2% that of agricultural uses. The total amount of herbicides used in Canadian forestry is about 0.5% of the total used in agriculture. Currently, 3.5 million kg active ingredient of 2,4-D is used in the four western provinces. Only 15 500 kg of this total was used for forestry operations in British Columbia in 1983. Herbicides account for only 18% (90 000 kg) of the total amount of all pesticides used in Canadian forestry. The area treated annually is variously estimated at over 50 000 ha (Manville 1983; Sundaram and Prasad 1983) to 75 000 ha (CFPFA 1983; Rennie et al. 1985), which represents about 0.2% of the 30 million ha of unregenerated forest lands. Individual treatment areas usually do not exceed 100 ha. Herbicide use in forestry, though still very limited, is more common in British Columbia and the eastern provinces than in the prairie provinces (Carlson and Prasad 1981).

The first survey of herbicide use in Canadian forestry was conducted by Ayling and Graham in 1978. Statistics on herbicide use by the British Columbia Ministry of Forests and the British Columbia forest industry in 1982 were summarized by Humphreys (1983).

Alternative Methods of Vegetation Management

Manual

Manual methods of vegetation management consist of hand-slashing with chain saws, brush saws, and machetes. Manual control is feasible only in sparsely vegetated areas and is recommended in environmentally sensitive areas. It is useful in conifer release operations because of its selective nature. Its practical application is limited by transportation and logistics costs of a large number of workers and the monotonous and intensive nature of the work. Mechanical damage of the crop species is inevitable and the risk of injury to the workers is always present. In situations where there is a rapid regrowth of brush species, it is less effective than chemical or prescribed burning practices.

The economic advantage of chemical (2,4-D) over manual control of competing vegetation in a 136-ha area of red pine—black spruce in Wisconsin can be used as an example (USDA Forest Service 1977). Five manual operations (chain saw, ax, etc.) at a total cost of $85,000 were needed to obtain the level of conifer release produced by one chemical treatment at a total cost of $6,120 by aerial application or $30,000 by ground equipment. In Ontario the cost of chemical release operations for 1981-82 was $900,000. If the operation had been attempted manually it would have required 1300 workers to complete the task at a total cost of $15,000,000 (Green 1982), clearly illustrating the economic advantage of the release program using chemicals. Despite the drawbacks of manual weeding, it may be the best method to use in "areas which are in close proximity to northern communities, and in areas which may be particularly environmentally sensitive" (Rennie et al.1985).

Mechanical

Mechanical methods include bulldozing, shearing, crushing, chopping, disking, bedding, scalping, and scarification. Mechanical methods are feasible and most efficient on gentle topography and on relatively dry soils lacking large rocks, boulders, stumps, or large decaying logs. Because heavy machinery is used, it may not be suitable on selected slopes and topography because of a possible erosion hazard. Because of compaction problems, mechanical methods have limited application on fresh to wet soils. Where scalping is practiced, below-ground components are only partially removed and lateral roots from the surrounding vegetation of the scalp usually remain active. Small scalps may not be effective in providing relief from moisture and competition. Because of reinvasion by weeds (Newton 1974) under many circumstances, scalping does not ensure survival of the seedling conifers. In scarification operations, the exposure of mineral soil and abundant light may encourage the regeneration of several annual grasses and weed species. Manual and mechanical methods have had little success in vegetation management in coastal British Columbia. According to Jones and Boateng (1983), "we cannot depend solely on these methods to alleviate all our vegetation problems as believed by some people." Mechanical scarification techniques are employed in most areas in the boreal forest; however, their cost-effectiveness over other methods needs consideration to develop an integrated forest management strategy.

Fire

Burning residual brush and slash after harvest is a common practice that assists in the establishment of a new stand. Burning must be timed to avoid extremely dry or wet conditions. The brown and burn technique is increasingly favored where the vegetation is desiccated after very light aerial application of herbicides and then set on fire to remove the aerial biomass. This technique is effective for site preparation, but competition from sprouting vegetation may necessitate herbicide application for release operations (Carter et al. 1978). Prescribed burning is most easily used on level or gently rolling terrain. In broken topography and on steep slopes it is difficult to burn uniformly and to control the fire. Proper weather and fuel conditions for a successful prescribed fire are infrequent and may not occur at all in some locations in a given season; this leaves workers and equipment idle for days or weeks awaiting proper atmospheric conditions. Only when topography, fuel conditions, and weather are appropriate can fire be effectively used, so it is not very reliable for continuing operations. Additional mechanical and chemical operations are therefore needed for adequate site preparation and conifer release operations (Carter et al 1978).

Adverse Ecological Effects of Nonchemical Alternatives

Although mechanically prepared sites revegetate rapidly, potential drawbacks of this method include greater fire hazards through fuel concentration, soil compaction and erosion, and subsequent nutrient leaching. Mechanical damage to the crop trees is often unavoidable. Bernstein and Brown (1978) conducted a study in Oregon using chain saws. Over 30% of Douglas-fir and western pine were damaged or covered with slash by workers trying to release them from brush competition. The slash hazard created could be extreme. The mechanical methods physically changed the wildlife habitat by eliminating all site protection and removing all shelter for animals. Other adverse effects include "localization of nutrients and maximization of microclimate extremes" (Newton 1975). In some cases mechanical site preparation removes litter and exposes the mineral soil, which contributes to erosion and nonpoint pollution of water. In other situations, however, mechanical site preparation provides a mix of litter and mineral soil resulting in suitable planting and seeding areas with minimum erosion.

Slash burning results in ecological changes such as mineralization of forest litter, nutrient loss, and erosion; however, the extent of these changes is variable depending on the properties of fuel, soil type, site, and prevailing atmospheric conditions when the fire is set (Ahlgren and Ahlgren 1960). A complete assessment of the complex ecological changes resulting from burning practices is beyond the scope of this review. The reader is referred to comprehensive reviews of the effects of fire on fauna (USDA Forest Service 1978) and flora (USDA Forest Service 1981). Application of slash burning in the U.S. is limited by logistic, legal, and environmental constraints. Changes in air pollution regulations may further limit this practice (Dierauf 1978).

Justification for the Use of Herbicides

Forest productivity is dependent on intensive, economical, yet environmentally safe management practices. Intensively cultured forest stands have produced more than twice the yield of natural stands (Wahlenberg 1965; Hansbrough 1970). The economic benefits and production rates for various alternatives to herbicides in two regions of the U.S. were studied by Carter et al. (1978). In the Douglas-fir region, typical treatment costs for site preparation with chemical, mechanical, manual, and burning methods were $37, $173, $247, and $126 per hectare, respectively, and the treatment rates were 162, 4, 0.4, and 16 ha/day, respectively. Mechanical and manual methods of vegetation management obviously necessitate a large capital investment. Chemical methods are generally preferred not only for their lower cost but also for greater efficiency and safety compared to other treatments.

The alternative methods to herbicides have certain limitations and cannot be applied under all circumstances. Moreover, they have "unacceptable human and environmental impacts that are frequently ignored by the public. These include physical injuries and death to forestry workers, reduction or loss of soil organic layer, contribution to the global CO_2 situation, soil compaction and erosion, and site occupancy by undesirable plants" (Manville 1983). The application of mechanical methods in established stands may be damaging, and their use is also restricted by topography and soil conditions. Mechanical methods are not selective for release of softwood vegetation from hardwood competition in mixedwood cutovers where the two are intimately associated, as in the mixed wood stands of western Newfoundland (Richardson 1979). Winter scarification, which became as common as summer and fall scarification by 1975 in Alberta, has led to heavy vegetation reinvasion (Hellum 1977). Prescribed burning cannot be used for release operations until conifers have matured beyond the stage of sensitivity to low ground fire; it is therefore most useful primarily as a site preparation treatment (Lawrence and Walstad 1978).

The versatility and selectivity of herbicides could serve all phases of forest management, ranging from site preparation to stand release and improvement. The herbicides used in forestry are seldom intended to kill the competing vegetation (Newton 1975); they suppress weed species so that growth of conifers is favored for a brief period. Unlike agricultural crop production, which receives at least one herbicide treatment every year, a forest stand receives one or two applications every 40-60 years. Aerial application of herbicides for site preparation rarely kills more than 80% of the woody stems (Carter 1972). The surviving vegetation produces browse and shelter valuable to wildlife, whereas mechanical methods remove all existing stems. Mast (the fruit of forest trees) production is delayed for a longer time on mechanically prepared sites. Carter et al. (1975) demonstrated that wildlife habitat was more diverse on chemically prepared sites than on mechanically prepared sites in an Alabama survey. Depending on specific sites, herbicide applications may have no physical impact and may modify wildlife habitat toward favored food species remaining (Newton 1975).

Herbicide treatments tend to conserve water and protect watersheds, whereas mechanical methods may result in soil compaction, erosion of the slopes, and destabilized soil conditions. In an assessment of the ecological impacts of alternatives to the use of herbicides, Kimmins (1975) concluded that "unfortunately, we do not know enough about the potential environmental consequences of these alternatives to claim with confidence that they will necessarily be ecologically superior to the careful use of herbicides."

FORESTRY USES OF HERBICIDES

Site Preparation

Control of grasses and forbs either before or concurrent with planting is normally needed for adequate survival of conifers. In the U.S., successful herbicide prescriptions for site preparation prior to planting or seeding have been developed. Several types of ground and aerial application equipment can be used to suppress unwanted woody vegetation, grasses, and forbs.

Conifer Release

Release of conifers from competing hardwood vegetation is essential during the critical years of establishment in order to ensure survival and improve growth rates. For this purpose, aerial application of herbicides tends to be most effective, and is often the only alternative, especially where roads are lacking or where large areas are to be treated within a short time.

In conifer release, the main aim is to divert the resources of the site, such as soil moisture, nutrients, and sunlight, from the competing hardwood vegetation to conifer seedlings. The complete removal of a number of plant species from a plant community is not considered desirable for several reasons, including the fact that other species may invade, which may pose serious competition or may be difficult to control. The animal-use pressure on the target plants to be controlled may be transferred to the desirable woody plants.

Timber Stand Improvement

Thinning of dense stands, where low-quality trees are removed, is a standard silvicultural operation carried out several times during the life of a commercial stand in order to provide optimum growth conditions for crop trees. Thinning is defined as "the removal of trees primarily for the benefit of the increment or quality of the balance of the stand" (Finnis 1967). Conventional thinning is carried out with a saw or ax. The chemical methods are basal spraying or the "hack and squirt" method. In cases where use of salvaged wood from thinning is not anticipated, chemical thinning has several important advantages over conventional felling methods. Because chemical methods eliminate the main task of pulling down and dragging stems, they reduce investment costs in equipment, improve safety, provide additional shelter and nesting sites for birds, and eliminate long-distance hauling of heavy supplies and equipment. Reduction of combustible fuel on the ground, resistance of treated stands to damage by wind and snow, reduction of slash hindrance, protection against sun-scald, and resistance to insect attack are additional advantages of chemical thinning (Finnis 1967).

Other uses of herbicides include the following: weed control in nurseries and young plantations; maintenance of utility rights-of-way; maintenance of fire breaks; preharvest killing of commercial timber; control of noxious weeds; improvement of water yield by modifying stand density and species; habitat improvement for fish by controlling weeds along lakes and water courses; and increased forage production for livestock in pasture and rangeland.

NEW FOREST MANAGEMENT HERBICIDES

Glyphosate (Roundup)

Lange et al. (1973) referred to glyphosate as probably the most promising new herbicide since the discovery of 2,4-D. Glyphosate is seen as an effective and promising alternative to the increasingly restricted 2,4,5-T. In the Maritimes, trials have been conducted with glyphosate since 1977 as a substitute for brush-killer formulations of 2,4-D and 2,4,5-T (Hallet and Dufour 1983). Possible applications of glyphosate in forest management practices include in nurseries, during site preparation and thinning, and in release operations because of partial tolerance of conifers to the herbicide. The long-term herbicidal effect of glyphosate does not reach a maximum until about 2 years after treatment.

The first documented study on the use of glyphosate for vegetation control in coniferous plantations in the prairies was by Corns and Cole (1973). The efficacy and selectivity of glyphosate have been widely tested for forestry purposes in British Columbia and the eastern provinces of Canada over the last 7 years.

Hexazinone (Velpar, Pronone)

Hexazinone is a new triazine herbicide that gives contact as well as residual control. It is applied as a preemergence or postemergence foliar spray during active plant growth. Moisture is essential for activation of preemergence applications. Hexazinone is readily absorbed through roots and foliage. Its translocation is apoplastic and its mechanism of action appears to be the inhibition of photosynthesis (WSSA 1983). The commercial formulations used in U.S. forestry are Velpar L (miscible liquid, 25% hexazinone), Pronone 10 G (granular, 10% hexazinone), and Pronone 5 G (granular, 5% hexazinone). In the U.S., hexazinone formulations are used for conifer release, site preparation, and the maintenance of utility rights-of-way.

In Canada, efficacy, selectivity, and residual activity of hexazinone have been studied for forestry purposes by many researchers since 1978. The granular formulations have shown considerable potential in silvicultural practices. The Northern Forest Research Centre in Edmonton, Alberta, has established a number of experiments at several sites in Alberta and Manitoba for release of white spruce, jack pine, and red pine. Broadcast treatments of granular hexazinone at the rate of 2 to 4 kg of active ingredient per hectare resulted in excellent release of white spruce. The new granular formulations, Pronone 10 G and Pronone 5 G, formulated by Pro-Serve, Inc., are superior to the old Velpar G 10%.[1] The Pronone formulations generate less dust and need less moisture to release the active ingredient. Large-scale applications of Pronone 5 G and 10 G were tested at Calling Lake, Alberta in June 1985.

Triclopyr (Garlon)

Triclopyr is an auxin-type selective herbicide for control of woody plants and broadleaf weeds. Compared to other auxin-type herbicides, it is more effective in controlling oak, ash, and other root-sprouting species. Triclopyr is readily absorbed by both leaves and roots, is translocated basipetally as well as acropetally, and accumulates in the meristematic tissues. Its mechanism of action appears to be similar to that of phenoxyacetic acids (WSSA 1983). Triclopyr was initially developed for industrial use, including the maintenance of utility rights-of-way. Over 50 woody species are controlled at 1.1–2.2 kg/ha (Byrd and Colby 1978). The water-soluble triethylamine salt formulation has been favored for industrial purposes, while the oil-soluble, water-emulsifiable ethyleneglycol butyle ether ester as well as the amine formulation have been found to be effective for forestry purposes (Gratkowski et al. 1978). In the U.S., triclopyr (Garlon) is registered for site preparation and for rights-of-way (Warren 1980; Heinrichs 1982). Triclopyr also has been known as XRM-4021, XRM-3724, and Dowco 233. In Canada, triclopyr has been tested for site preparation, conifer release, thinning, and stump treatment by several researchers since 1979.

Fosamine Ammonium (Krenite)

Fosamine ammonium, also known as DPX 1108, is a slow-acting herbicide similar to glyphosate. It is applied to woody vegetation during the 2-month period prior to autumn coloration. The herbicide is then absorbed by leaves, buds, and stems of deciduous plants with little or no effect until the following spring, when susceptible woody plants fail to develop leaves and eventually die. Pines and herbaceous vegetation may show a response soon after application. Suppression of terminal bud growth is observed on moderately susceptible to resistant species. Acropetal and basipetal translocation of ^{14}C-labeled material has been observed; however, normal

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field results with nonlabeled herbicide indicate that complete coverage of all parts of the woody species is necessary for effective control under field conditions (WSSA 1983).

In the U.S., fosamine is registered for site preparation and maintenance of utility rights-of-way. In the southern U.S., the herbicide has caused mortality, especially among southern pines, when used for release purposes. Fosamine is nonetheless increasingly used for site preparation in the Pacific northwest (Heinrichs 1982). In Canada, knowledge of the efficacy and selectivity of fosamine is very limited, especially in relation to the boreal forest region.

Karbutilate (Tandex)

Karbutilate is used for control of annual and perennial broadleaf weeds and grasses and woody species. It can be applied at the pre- or postemergence stages and is absorbed primarily through the roots. Its mode of action is inhibition of the Hill reaction (WSSA 1983).

In Alberta, karbutilate has been tested for control of herbaceous vegetation in site preparation (Blackmore 1978) and as streak treatments for possible opening of over-dense lodgepole pine (Corns 1979). Broadcast treatments of Tandex 4% granules tested at the rate of 7.8 and 15.7 kg/ha for site treatment were not safe on white spruce and lodgepole pine seedlings. Streaks 2.5–5.0 cm wide spread outward and killed trees in strips 1.0–1.4 m wide. These experiments indicate that aerial application of streak or band treatments could have more-uniform results than general broadcast application of herbicide pellets.

Because broadcast application of karbutilate at rates intended for vegetative control cannot be selective, grid placement as opposed to the more complete coverage achieved with sprays, pellets, or granules is receiving research attention (Scifres et al. 1978).

Metsulfuron Methyl (Ally)

Metsulfuron methyl, known as DPX T6376, appears to have potential as a conifer site-preparation herbicide in forestry. In addition to its effectiveness on common brush species, it can be applied all season as long as active foliage is present. Sajdak (1982) evaluated the performance of this herbicide for site preparation purposes in northern lake states. In Alberta, Drouin (1983b) tested spring application of metsulfuron methyl at 0.5 kg/ha near Lesser Slave Lake. Excellent control of all herbaceous plants was observed, but control of grasses and fireweed was poor. Severe chlorosis of white spruce was observed. In another trial (Drouin 1983a), seasonal applications of metsulfuron methyl were evaluated at 70, 250, and 500 g/ha. White spruce and lodgepole pine (14 cm in height) were planted in treated soil 1, 3, and 5 weeks after spraying. Crop tolerance scores for white spruce at 70 and 250 g/ha were 6 and 9 for spring and summer, respectively. Lodgepole pine was severely injured by fall applications. Heavy rains and excessive soil moisture also contributed to the reduced vigor of pine trees. Differences between the 1-, 3-, and 5-week postspray planting were negligible. Adequate weed control ranging from tolerance scores of 7 to 8 was observed on herbaceous weeds, but control of grasses and fireweed was poor.

THE FATE OF HERBICIDES IN THE FOREST ENVIRONMENT

A bibliography of 1614 references on herbicides in the forest ecosystem was prepared by Kimmins and Fraker (1973), and the ecological effects of herbicide usage in forestry were later reviewed by Kimmins (1975). This section reviews selected references on adsorption, leaching, degradation, persistence, and off-site movement of the new herbicides that have become available for forest resource management practices over the last decade.

Adsorption

Sprankle et al. (1975) studied the adsorption of glyphosate on a clay loam and muck soil. Up to 56 kg/ha (25 times the recommended rate for conifer release) of the herbicide was rapidly inactivated. The initial inactivation of glyphosate in soil is by reversible adsorption to clay minerals and organic matter.

Fosamine ammonium, which is a highly water-soluble herbicide, is rapidly adsorbed onto soil particles (WSSA 1983). The discrepancy between high TLC R_f values and actual leaching under field conditions may indicate that it forms insoluble salts or complexes with soil minerals (Han 1979).

The Freundlich isotherm constants (K-values) for hexazinone were 0.2 (slope 0.95) and 1.0 (slope 1.05) for a sandy loam and a silt loam (Rhodes 1980a). These values suggest low adsorption.

Adsorption of triclopyr is not very strong, and the degree of adsorption depends on soil organic matter and pH (WSSA 1983).

Leaching

Due to very strong adsorption, glyphosate is nonleachable in field soils (Rueppel et al. 1977)

Han (1979) studied leaching of fosamine ammonium under field conditions in Florida, Delaware, and Illinois. Despite the very high water solubility of 120 g per 100 g (179 g/(100 g) water, WSSA Herbicide Handbook) and high TLC R_f values, very little or no leaching of this compound or its ^{14}C-labeled degradation products was observed under actual field conditions or in soil column studies. This discrepancy between R_f values and leaching studies may indicate that this herbicide forms insoluble salts or complexes with divalent cations in a natural soil environment.

The soil thin-layer chromatography data obtained by Rhodes (1980a) indicated that hexazinone was more mobile than terbacil and diuron in four light-textured soils. Triclopyr may leach in light soil under high rainfall conditions (WSSA 1983).

Degradation

Complete and rapid degradation of glyphosate occurs in soil and water microbiologically and through chemical breakdown processes (Rueppel et al. 1977). Aminomethyl phosphonic acid, the only significant metabolite, also undergoes rapid degradation in soil. Losses through photodegradation or volatilization are negligible.

Lab biometer flask studies showed that microbial decomposition of fosamine ammonium to $^{14}CO_2$ was 45–75% complete after 90 days of incubation in the dark (Han 1979). Some reincorporation of ^{14}C into soil organic matter was observed, especially in forest soils. Fosamine disappearance from bottom sediment occurred over a period of 3 months or less (Environmental Protection Agency 1977).

Hexazinone is degraded by microbial action (Rhodes 1980a). No degradation occurred when herbicide-treated sandy loam and silt loam were incubated under anaerobic conditions for 60 days. Degradation of triclopyr is also microbial. The herbicide is rapidly photodegraded with a half-life of 10 hours in water at 25°C (WSSA 1983).

Persistence

Up to 90% of glyphosate was dissipated in two out of three soils in 12 weeks (Rueppel et al. 1977).

The half-life of fosamine applied at recommended rates was about one week under field conditions in Florida, Delaware, and Illinois (Han 1979). A metabolite, carbamoylphosphonic acid (CPA) was found several days after application, but 3-6 months later, all ^{14}C-fosamine and its metabolite, ^{14}C-CPA, had disappeared completely. According to another source documented by the EPA (Environmental Protection Agency 1977), fosamine is converted to CPA in 2 weeks, which is then oxidized to CO_2 and humic acid fraction within 8 weeks.

Rhodes (1980a) studied persistence of hexazinone under field conditions with 3.7 kg/ha applications. The half-life of intact hexazinone was 1 month in Delaware, 2 months in Illinois, and 6 months in Mississippi. Time for 50% loss of total radioactive residues was 3–4 months in Delaware, 6.7 months in Illinois, and 10–12 months in Mississippi. In greenhouse studies, the half-life of intact hexazinone was less than 4 months in a silt loam and sandy loam. Neary et al. (1983) monitored the persistence of hexazinone (10% pellets) applied at 1.7 kg/ha in 60- to 80-year-old pine-hardwood mixed forest in Georgia. The concentration of residues was quantified periodically in the forest litter. Intact hexazinone constituted about 71–76% of the residues in the litter. Small amounts were detectable in the litter up to one year after date of application.

Triclopyr has a half-life of 46 days, depending on soil and climatic conditions (WSSA 1983).

Entry and Fate in Aquatic Environment

Glyphosate has a low propensity for off-site movement (Rueppel et al. 1977). The maximum amount of glyphosate transported in runoff, after treatment of four watersheds in Georgia with 9 kg/ha, was 1.85% of the amount applied. The first runoff accounted for 99% of the total amount transported (Edwards et al. 1980). Very little, if any, glyphosate or its decomposition products would reach the watersheds (Sprankle et al. 1975).

Studies with ^{14}C-fosamine ammonium salt in water have indicated that it is stable for extended periods in neutral or alkaline water, but is slowly hydrolyzed under weakly acidic conditions to carbamoyl phosphonic acid. Sunlight and photosensitizers have little effect on its stability (Han 1979).

A water solubility of 33 000 mg/kg at 25°C makes hexazinone susceptible to leaching and off-site movement in storm runoff. Neary et al. (1983) studied off-site movement of hexazinone (10% pellets), applied at 1.7 kg/ha to four watersheds in Georgia, in storm flow and base flow. The total amount of hexazinone transported in runoff averaged 0.53% of the applied amount. Two metabolites were also found in low to trace amounts in runoff for up to 7 months after application. Subsurface movement of hexazinone appeared in streamflow 3–4 months after application and accounted for 0.05% of the amount applied. A second-order perennial stream below the treated watershed periodically contained residues of less than 44 μg/L.

In another study in Alabama, Miller and Bace (1980) found concentrations of up to 2400 μg/L from direct fall of pellets into a forest stream during an aerial application. Concentrations decreased to 110 μg/L within 24 hours and to less than 20 μg/L after 10 days.

Rhodes (1980b) studied decomposition of ^{14}C-hexazinone in water. Based on 5-week data, the amount of decomposition under both artificial and natural sunlight was about three times greater in standard reference water and four to seven times greater in natural river water compared to distilled water. Degradation in natural river water with bottom sediments or in distilled water containing 20 mg/kg anthraquinone was three times the amount in distilled water. After a 5-week exposure period, about 10% of the ^{14}C in the river water with sediment was found in the sediments.

Triclopyr has a water solubility of 440 mg/kg at 25°C. Once in water, it stays in solution and will not be absorbed onto sediment or organic matter. Its rate of degradation in water is quite high because of its susceptibility to photodegradation and microbial attack (Dow Chemical 1983).

Data Gaps

Almost all data available on adsorption, leaching, persistence, and off-site movement of glyphosate, fosamine, triclopyr, and hexazinone come from U.S. sources. Persistence data under Florida conditions, for example, would hardly have any application in the boreal forest. Persistence studies are in progress at several universities in eastern Canada. Future research efforts should be directed to the environmental chemistry of these herbicides in the boreal forest zone.

IMPACT OF HERBICIDES ON THE FOREST ENVIRONMENT

Effects on Aquatic Organisms

Glyphosate has a minimal effect on microflora (Rueppel et al 1977). Hildebrand et al. (1980) studied the effects of glyphosate on a population of *Daphnia magna* in a forest pond at the University of British Columbia. *Daphnia*, which feeds on algae, forms a significant part of the diet of fish. The results indicated that survival of these organisms did not show any significant variation between control and experimental treatment at field dose (2.2 kg/ha), at 10 times and 100 times the field dose, and at three exposure times. Hildebrand et al. (1980) found that diatom and testation populations, which are food sources of *Daphnia*, were not adversely affected by glyphosate.

Residues of ^{14}C-hexazinone in bluegill sunfish exposed to water containing hexazinone at 0.01 and 1.0 mg/kg for 28 days were found to reach maximum after 7–14 days of exposure (Rhodes 1980b). The maximum bioaccumulation at both exposure levels was in the viscera. The fish were then transferred to fresh water for 2 weeks. There were no adverse effects observed on fish during the course of the experiment.

Neary et al. (1983) monitored hexazinone residues in streams below treated watersheds in Georgia during the course of 13 months when 26 storms occurred. It was concluded that the low and intermittent concentrations of hexazinone and its metabolite (less than 44 μg/L, mainly intact hexazinone) in the stream did not expose aquatic organisms to toxic levels. Mayack et al. (1982) confirmed this conclusion by a concurrent study of benthic organisms in the stream. No bioaccumulation of hexazinone or its residues occurred in aquatic invertebrates and macrophytes. No species composition and diversity shifts were observed. Neary et al. (1983) concluded that application of hexazinone at recommended rates for vegetation management should not produce any adverse environmental effect on water quality or aquatic ecosystems.

Toxicity of fosamine to the few organisms tested was negligible. Bioaccumulation has not been observed in aquarium studies. Residues in fish were comparable to concentrations in water (Environmental Protection Agency 1977).

Behavior in the environment and toxicity of 2,4-D, picloram, atrazine, MSMA, fosamine, glyphosate, and dinoseb to anadromous fish habitats in western North America were reviewed by Norris et al. (1983).

Impact on Soil Microflora

Han and Krause (1979) studied the effect of foramine on soil-nitrification bacteria under laboratory conditions in soil incorporated with 0.5, 5, and 20 mg/kg. There was no adverse effect on the microorganisms during a 5-week period. Populations and species of soil bacteria and fungi in three agricultural soils treated with 10 mg/kg were found to be unaltered over an 8-week period. In agar plates, fosamine showed no fungicidal effect even at 100 mg/kg. It appears that at the concentrations normally used for vegetation management, and with the susceptibility to microbial attack that is characteristic of many of the organic herbicides, the risk of serious and permanent interference with normal soil microbiological processes is remote (Kimmins 1975).

Effects on Terrestrial Wildlife

Indirect effects from herbicide applications include ecological changes in vegetation cover and diversity. At certain successional stages, such alterations in vegetation result in changes in small mammal distribution and abundance. Sullivan and Sullivan (1981) studied the effects of forest application of glyphosate on reproduction, growth, and survival responses of a deer mouse (*Peromyscus maniculatus*) population at Maple Ridge, British Columbia. They concluded that field application of glyphosate did not have any apparent effect on the dynamics of deer mouse population.

The effect of glyphosate on food preference and consumption of captive-raised black-tailed deer was studied by Sullivan and Sullivan (1979) at the University of British Columbia. Deer given a choice of control or glyphosate-treated (2.2 kg/ha) alder and alfalfa browse showed no preference or ate more of the treated foliage. The authors concluded that spraying brush with glyphosate should not prevent deer from feeding on foliage in the affected area, but according to P. Mineau, who reviewed the data, "these conclusions are somewhat naive."[2]

Borrecco et al (1972) reported that black-tailed deers' use of treated areas increased during the period of vegetation recovery from herbicide applications in Oregon.

Human Health Concerns

The intense controversies surrounding the health risks of herbicides in forestry, and in particular the environmental implications of the contaminants of some of the phenoxyacetic herbicides, the dioxins, have resulted in heated debates over the last 15 years. The biological and economic assessment of 2,4,5-T alone has resulted in voluminous reviews of over 500 scientific investigations in both Canada and the U.S. (National Research Council of Canada 1978; U.S. Department of Agriculture 1979). A review of 304 of the most authoritative scientific records on the health risks of herbicides in forestry operations was recently summarized by Walstad and Dost (1984).

Data Gaps

With the exception of a few research reports from British Columbia, knowledge of the environmental impact of herbicides comes from U.S. sources. There is a definite need for research on the environmental impact of herbicides in Canadian forest regions.

HERBICIDE RESEARCH IN CANADA

Forest Pest Management Institute

As a national institute, the Forest Pest Management Institute (FPMI) was given the mandate in 1981 to initiate herbicide research for forest resource management purposes in Canada. The aims of the institute's Herbicide Research Project are to accelerate the development of new herbicides, to refine and improve methods of utilizing existing products, and to improve application technology and formulation characteristics to enhance effectiveness of the herbicides while keeping their impact on the forest ecosystem to a minimum (Sundaram and Prasad 1983).

The FPMI herbicide research and development team has established contact with Canadian Forestry Service (CFS) regional research centers and provincial forestry agencies in order to assess the vegetation

[2] Personal communication with P. Mineau, Canadian Wildlife Service.

management needs of each region. The team is actively involved in coordinating all research efforts on herbicides with other provincial and federal agencies. The FPMI herbicide R & D team has also established contact with its counterparts in Forest Pest Management of the USDA Forest Service. These contacts facilitate exchange of information on pesticide registration, impact evaluation, technology transfer, social and environmental concerns, data gaps in available knowledge of forest pesticides, and sharing of pesticide use data. Possibilities of joint research between the CFS and the U.S. Forest Service have also been discussed (Green and Reynolds 1983).

CFS Research Centers

Available literature, such as the research reports of the Expert Committee on Weeds (ECW) and technical notes of the CFS research centers, indicates that research has been conducted on forest herbicides, including the new herbicides with potential for forestry use. The current research efforts under way, however, are not adequate for the pressing needs of each area. The herbicide research capabilities of the regional centers must be developed further; their research efforts are aimed mainly at generating efficacy and selectivity data. The environmental chemistry of the herbicides, such as persistence, movement, degradation, and fate of the forest herbicides in aquatic and terrestrial environment, have received little attention.

Most of the research reports abstracted in ECW summaries come from the Pacific Forest Research Centre (Victoria), the Maritimes Forest Research Centre (Fredericton), and the Newfoundland Forest Research Centre (St. John's). At the Northern Forest Research Centre in Edmonton, some research has been carried out, mainly on phenoxyacetic herbicides since the 1960s; however, it was not until 1981 that the urgent need for herbicide research in the prairies was realized and research on new herbicides was initiated in Alberta and Manitóba (Drouin 1983b). The Northern Forest Research Centre is currently in the process of establishing a herbicide research team and setting up an analytical laboratory for environmental chemistry studies.

Provincial Agencies

The research activities of the provincial agencies are limited mainly to operational uses of the very few herbicides that are registered or have temporary use permits. The B.C. Ministry of Forests has had far greater involvement in operational uses of herbicides than other provincial agencies. The current needs of the prairie provinces where operational uses of herbicides have been minimal are briefly discussed below.

Alberta

The current needs of the province are extreme to critical for control of aspen/poplars and grasses in conifer release and site preparation operations. Considerable areas of harvested sites have not been satisfactorily restocked because of perennial grasses such as marsh reed grass (Hellum 1977; Blackmore 1978). In 1982, a total of 4410 ha were treated with 2,4-D and glyphosate for site preparation and release operations. Current provincial plans include aerial application of hexazinone and glyphosate, and establishment of demonstration sites (in cooperation with companies) involving priority herbicides with various dosages, formulations, and techniques.

Saskatchewan

Herbicides are desperately needed for control of aspen/poplars in conifer release and site preparation operations. The current operational use of herbicides is negligible. Small-scale aerial applications of 2,4-D and hexazinone by the Prince Albert Pulp and Paper Company (PAPCO) have been tried.

A special task force on the use of herbicides in forest management, headed by D.A. Rennie, Dean of the College of Agriculture at the University of Saskatchewan, has just concluded that "herbicides offer as much or more to the forest industry in Saskatchewan as they have elsewhere in Canada" (Rennie et al. 1985). The task force recommended that PAPCO and other forest industries should be allowed to test the effectiveness of herbicides in forest management operations. PAPCO intends to test glyphosate in the autumn of 1985. The task force also recommended that a technical advisory committee and a forest advisory committee be established and that research grants be awarded to encourage scientists to initiate pilot-scale experiments (Rennie et al. 1985). Environmentalist groups such as the Forest Herbicide Moratorium Association, who are bitterly opposed to the use of herbicides in forestry operations, have reacted strongly to the recommendations of the task force. A review of the 53 briefs submitted to the task force shows that "this opposition to a very large degree is based on fear of the unknown and a serious lack of awareness of the technical information which has been obtained from well designed experiments" (Rennie et al. 1985).

Manitoba

Herbicide needs for stand improvement, plantations, and nurseries are critical. Operational uses of herbicides are limited and research on new herbicides or new techniques is nonexistent. In 1982, a total of 1664 ha were treated with 2,4-D for conifer release and site preparation by Abitibi-Price of Pine Falls, and 1526 ha were treated with 2,4-D and picloram formulations by Manitoba Hydro.

Research at Universities

Research on forestry uses of herbicides by the universities has been minimal until recently. Most forestry schools do not even offer a course in vegetation management as part of their undergraduate curricula. The FPMI is participating in the Program of Research by Universities in Forestry (PRUF). The CFS has allocated funds to PRUF that have been awarded to universities for the purpose of undertaking herbicide research in forestry (Ennis 1983).

The Role of the Expert Committee on Weeds

The Expert Committee on Weeds (ECW) plays an important national role in documenting, summarizing, and disseminating research data to research workers in provincial and federal agencies, agro-chemical industries, and universities. Until recently, standards for reporting and evaluation of research results in forestry were not satisfactory. It was during the 36th Annual Meeting of the ECW (Western Section) in November 1982 that a new silvicultural section was added to the research report. A total of 25 abstracts appeared in the ECW Research Report in 1984 (Drouin 1984).

REGISTRATION OF HERBICIDES IN CANADA

The Registration Procedure

Contrary to the general belief held by the anti-herbicide environmentalist groups, Canada's registration process is one of the most stringent in the world (CFPFA 1983), and that is one of the main reasons why, as late as December 1983, there were only two herbicides registered for forestry uses. There are four federal acts governing the registration, marketing, and application of any pesticide in Canada, and provincial legislation may impose further restrictions on pesticide use. All or part of data submitted will be reviewed by the following seven agencies: Pesticide Section, Agriculture Canada; Laboratory Services Division, Agriculture Canada (for confirmation or development of analytical methodology); Pest Control Products Section, Environmental Health Directorate, Health and Welfare Canada (for review of occupational and environmental health aspects); Canadian Wildlife Service, Environment Canada (for review of impact studies on wildlife); Environmental Protection Service, Environment Canada (for review of disposal and decontamination methods); Fish Habitat Management Branch, Fisheries and Oceans Canada (for review of impact on aquatic life); and Canadian Forestry Service, Agriculture Canada (for review of efficacy and selectivity data and environmental safety of the herbicide by the FPMI).

Registered Herbicides

The following herbicides have been registered in Canada:

1. Forest Management Category (>500 ha)

   (a) For site preparation and conifer release by ground and aerial application: 2,4,5-T, 2,4-D + 2,4,5-T, two formulations of 2,4-D, glyphosate.

   (b) For site preparation by aerial application: 2,4-D + 2,4,5-T.

   (c) For individual tree treatment (hack and squirt): two amine formulations of 2,4-D.

2. Woodlands Management Category (<500 ha).

For site preparation by ground application: hexazinone, asulam, amitrole, six formulations of simazine.

Status of New Forest Herbicides in Canada

The Canadian Council of Resource and Environment Ministers (CCREM) established a task force that first met in December 1981. The aims of the task force were to facilitate field testing of pesticides with potential for forest resource management and to hasten the registration review process for these chemicals (CCREM 1982). Twelve pesticides, including glyphosate, hexazinone, triclopyr, and fosamine ammonium, were placed on Agriculture Canada's priority list for registration.

Fosamine Ammonium (Krenite)

Efficacy data: adequate.

Environmental toxicology: data available on general toxicity to wildlife and fish, acute toxicity, subacute toxicity, dermal, eye, and inhalation toxicity.

Data gaps: chronic toxicity.

Environmental chemistry: data available on adsorption and leaching characteristics, microbial breakdown, loss from photo decomposition or volatilization.

Data gaps: persistence and movement under Canadian edaphic and climatic conditions.

Registration status: registered for industrial brush control only. No agricultural uses registered. Temporary registration granted in 1980 for forestry use expired in 1982. In order to register this herbicide for forestry use, Health and Welfare Canada (HWC) and the Canadian Wildlife Service (CWS) require data on a 2-year chronic feeding study and the Environmental Protection Service (EPS) needs more data on persistence. Krenite is no longer on Agriculture Canada's priority list, and FPMI has discontinued further field tests on this product.

Triclopyr (Garlon)

Efficacy data: adequate

Environmental toxicology: data available on general toxicity to fish and wildlife, acute oral toxicity, subacute toxicity, dermal toxicity, and danger through inhalation.

Data gaps: chronic toxicity.

Environmental chemistry: to be determined; appears to be inadequate.

Registration status: registration package for industrial brush control was submitted in 1980 by Dow Chemical Canada Inc. Registration package for forestry uses was submitted in late 1982 after completion of some environmental impact studies. HWC requires outstanding data from Dow. Fisheries and Oceans, CWS, and EPS have not yet concluded their review of the data submitted.

Hexazinone (Velpar)

Efficacy data: adequate.

Environmental toxicology: data available on general toxicity to wildlife and fish, acute, subacute, and chronic toxicity, dermal toxicity, and possible danger through inhalation and exposure to eyes.

Data gaps: fish accumulation and metabolism.

Environmental chemistry: data available on decomposition by UV light, metabolism and persistence in plants, microbial breakdown under controlled conditions.

Data gaps: leaching, adsorption/desorption, long-term field dissipation, aquatic impact, anaerobic soil metabolism, aerobic and anaerobic aquatic metabolism, drift studies. Experiments aimed at generating the required data are in progress at FPMI and several universities.

Registration status: Velpar (soluble powder, 90% hexazinone) is registered for use on noncropland areas and lowbush blueberries. Velpar L (water dispersible solution, 240 g/L) is registered for site preparation by ground application. Du Pont Canada expects full aerial registration by the end of 1986. EPS requires data on drift studies, leaching, field persistence in sediment, and aquatic habitat.

Hexazinone (Pronone)

In cooperation with Pro-Serve, Inc., Pfizer has embarked on an extensive research and development program to generate the required data to support registration of Pronone in Canada.

Other Herbicides

Other herbicides that have potential forestry uses in Canada but have not yet been considered for registration include metsulfuron methyl, karbutilate, dicamba, atrazine, picloram, tebuthiuron, and dalapon.

FACTORS LIMITING HERBICIDE USE IN CANADIAN FORESTRY

Lack of Registered Herbicides

Until the beginning of 1984, 2,4-D and 2,4,5-T were the only herbicides registered for forestry uses. Because some provinces have banned the use of 2,4,5-T, 2,4-D was the only herbicide available. Production of 2,4,5-T has stopped, and existing stocks will not last long. The forestry community is very pleased to have access to glyphosate now, even though it cannot serve as an exact substitute for 2,4,5-T. In the U.S. at least 12 herbicides have been registered for forestry uses in all states and up to 18 herbicides have been registered in Washington State (Jones and Boeteng 1983). The Canadian forest manager needs available to him a large range of registered herbicides that will allow for more-effective treatments, more selectivity in weed eradication, and lower toxicity where treatments might have an adverse impact on fish and wildlife. Because herbicides act selectively, if the forest manager has a variety of herbicides at his disposal, he can select the one that will control the most-competitive weed species with minimum disturbance to other flora and fauna on the site.

The Registration Process

One of the main obstacles to registration is the registration process itself. Lack of registration standards for forest herbicides and lack of close coordination among the various federal agencies involved in the process of registration are other factors that contribute to the long delay experienced in registration of herbicides.

Because of additional requirements unique to Canada in documenting the safety of chemicals for use on noncrop lands, it appears less likely that some of the promising herbicides like triclopyr and fosamine ammonium will be registered in the near future. In order to help the manufacturers decide whether to pursue registration of herbicides for forestry, there is a critical need for federal regulatory personnel to define the protocols of required data in advance to facilitate industrial decision-making and to assure that research funds are not wasted (ECW 1983).

Reluctance of Agricultural Chemical Companies

Because the market potential is very limited in forestry, manufacturers are reluctant to invest in research and development of new products for forestry uses. The manufacturers maintain that in order to obtain forestry registrations in Canada, they have to provide more data than they did to obtain a U.S. registration (ECW 1983). It appears that as long as the herbicides used in agriculture make up a large percentage compared to forestry usage, the unwillingness of the manufacturers to invest in forestry research will not change. A similar attitude prevails in the U.S. (Newton 1975). Manufacturers are also reluctant to register a use pattern that will represent a small segment of the market but potentially generate a lot of controversy (ECW 1983).

Reluctance of Foresters

The political climate relating to pesticides in general, and the unfortunate analogies that have been drawn over the past 10 years in reference to military use of herbicides in Vietnam, have limited the acceptance of herbicides in forestry. Timber companies are hesitant to promote practices that would attract unfavorable publicity (Newton 1975). Because of this reluctance some timber companies are not very keen on conducting research on herbicides.

Other factors that have limited the research and development of herbicides for vegetation management include the lack of foresters trained in herbicide use; the lack of forest weed control researchers; inadequate teaching and research on vegetation management at forestry schools; and the negative impact of the media, which has reinforced more imaginary than real dangers of the consequences of rational use of herbicides in forestry.

RECOMMENDATIONS

Registration

It is recommended that there be greater coordination among the federal agencies involved in the registration process. A national advisory committee on registration of forest herbicides should be set up, composed of scientists from the federal regulatory agencies, herbicide specialists, and environmental scientists from FPMI and other CFS research centers, and representation from universities.

Education

The following recommendations are made for the education sector:

- Universities and forestry schools should have a required undergraduate course in vegetation management.

- More research grants should be provided to universities through PRUF grants so that research can be initiated in the interdisciplinary fields of forest science, soil science, and weed science.

- Public forums should be set up so that the public is fully briefed on the issues, choices, benefits, and risks involved in forest herbicide projects. In the absence of such informative forums, the confidence of the general public in the prudent use of herbicides could be further eroded by the activities of the antiherbicide environmentalist groups and incomplete, however objective, reporting by the media.

Research

Available information on environmental chemistry and on the environmental impact of forest herbicides under Canadian climatic conditions, particularly in the boreal forest, is very limited. Research should be initiated in the following areas:

- Persistence, lateral and downward movement, degradation and adsorption/desorption characteristics of hexazinone, triclopyr, fosamine, metsulfuron methyl, tebuthiuron, karbutilate, and picloram in selected forest soils under controlled and field conditions.

- Fate of the potential forest herbicides in streams, lakes, and sediment.

- Impact on browsing animals during the transient period when their food is in short supply.

- Impact on aquatic organisms.

Herbicide application technology should be improved in order to obtain maximum effectiveness while keeping or reducing the risks to the applicator and the environment to a minimum.

Research should be coordinated with the herbicide research teams of the U.S. Forest Service, possibly through a bilateral, cooperative agreement. There should be exchange of information through joint workshops.

Who Should Fill Data Gaps?

Agricultural chemical companies do not have the material incentive to conduct research on the environmental impact and environmental chemistry of promising herbicides with forestry potential because of limited market opportunities for such products, so the burden falls on federal agencies. Lack of required environmental data on herbicide use in Canadian forest regions is one of the main reasons that so few herbicides are available today. Since the CFS alone cannot finance such studies, a jointly funded research program should be initiated by the federal departments of Environment, Agriculture, Energy, Mines and Resources, Health and Welfare, and Fisheries and Oceans.

The herbicide research capabilities of FPMI and the CFS regional research centers should be improved and expanded. Provincial agencies should be encouraged to conduct herbicide research and there should be cooperative research projects between provincial and regional forestry personnel.

Universities that possess the analytical instrumentation for residue detection should be provided with funds so that they can get involved in environmental chemistry studies.

Research Needs of the Northern Region

There is no doubt that research as well as operational uses of herbicides in the northern forest region have lagged far behind British Columbia and the eastern provinces of Canada. Vast areas of the harvested sites that have been replanted or allowed to regenerate naturally are insufficiently restocked. Competition from perennial grasses and aspen/poplars have significantly contributed to poor stand establishment and survival (Hellum 1977; Blackmore 1978). The experimental and operational uses of even the traditional vegetation management herbicides, 2,4-D and 2,4,5-T, by provincial agencies have been minimal. In view of the critical needs of the northern region for forestry herbicides and the lack of initiative and competence by provincial agencies, it is recommended that the Northern Forest Research Centre establish its own herbicide research team and develop the analytical capability for environmental chemistry studies independently of FPMI while maintaining coordination with that institute.

ACKNOWLEDGMENTS

The assistance of a number of individuals in the industry, and the provincial and federal agencies who were contacted for background information on the use of herbicides in Canadian and U.S. forestry is gratefully acknowledged. Special thanks are to to J.A. Drouin, Research Technician, Northern Forest Research Centre; R. Prasad, Research Scientist, Forest Pest Management Institute; and F.W. Honing, Assistant Director for Pesticide-Use Management and Coordination, U.S. Forest Service.

The advice and guidance of the scientific authority for this study, S.S. Malhotra, Deputy Director, Northern Forest Research Centre, is gratefully acknowledged. Special acknowledgment is given to the reviewers, in particular, S. Sidhu, Research Scientist, Northern Forest Research Centre, whose painstaking efforts in the final preparation and review contributed substantially to the accuracy and completeness of this report.

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