The Effects of Picloram on *Sphagnum fuscum* (Schimp.) Klinggr. in Peatlands Traversed by Electrical Transmission Lines in Manitoba.

By
Donelda E. McInnes

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THE EFFECTS OF PICLORAM ON Sphagnum fuscum (Schimp.) KLINGGR. IN PEATLANDS TRAVERSED BY ELECTRICAL TRANSMISSION LINES IN MANITOBA

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Abstract

Picloram herbicides (trade name Tordon) are used by Manitoba Hydro for brush control within rights-of-ways through peatlands. A time series study compared the effects of Tordon 22K on *Sphagnum fuscum* at three peatland sites, a) a string fen bog complex typified by Black Spruce/Ericoid/*Sphagnum* association along a transmission corridor at Sprague, b) an uncleared mature bog at Elma with similar associations and c) a mature bog which borders a transmission corridor at Devil's Lake. Three concentrations of Tordon 22K (2.2 kg/ha, 1.1 kg/ha and 0.55 kg/ha) were applied and the effects recorded. Crankwires and chlorophyll content were used to monitor the relative growth of *S. fuscum* during treatments. The results indicated that environmental conditions such as water table levels, rainfall and amount of shading influence the effectiveness of picloram in eliminating *Sphagnum* species from the habitat.

Conductivity observations were used to obtain a better understanding of how picloram was affecting *Sphagnum* by measuring the slow leakage of electrolytes from actively metabolizing capitula. Culturing techniques were used to illustrate how picloram affected the capitula of the *Sphagnum* causing extensive expansion until no recognizable capitula remained. Algae, associated with *Sphagnum* colonized the surrounding agar medium. Micrographs of the treated branches from the capitula illustrated how picloram caused morphological defects in the growing tips of the moss similar to susceptible vascular plants.

Picloram is an extremely persistent herbicide and may cause unacceptable ground water contamination and/or the elimination or reduction of non-targeted plant species. Therefore it is important to determine the parameters affecting the persistence of the picloram in peatland soils. A technique was developed to detect picloram residues using a high pressure liquid chromatograph. The results indicated that humic substances in the peat interfered with detection even though traces of picloram residues were detected in peat one year after application.

Picloram has a adverse effect on *Sphagnum fuscum* and remains in peat soils for an undetermined length of time. The drying effect and the removal of the susceptible species changes the natural succession. This is desirable from a management point of view in producing a vegetation community which does not interfere with the transmission of electricity and allows ready and easy access for maintenance.

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General Introduction

Rights-of-ways (ROW) are cleared corridors through biological communities used for the transportation of goods, energy and people (Wagner, 1971). Electrical transmission corridors comprise about 32 thousand hectares of the 265,000 ha or 8% of all the right-of-ways in Manitoba (MacLellan, 1982). The rights-of-ways traverse many different vegetation zones and of particular interest to this study are those which intersect peatland communities.

Clearance and management along the transmission corridors is essential in preventing vegetation from interfering with the conductance of electrical current and the electromagnetic field which surrounds the lines, and also allowing easy accessibility for maintenance (MacLellan, 1982; Magnusson, 1986). Vegetation management in Manitoba is carried out primarily through the use of herbicides, which are commonly applied by broadcast techniques (Sims, 1977; Magnusson, 1986). This application technique results in non-targeted shrub species and other sensitive species being removed or greatly reduced in the community (Niering and Goodwin, 1974; Magnusson, 1986). Many peatlands in the northern hemisphere are characterized by a *Sphagnum* moss ground cover. The clearance of the communities and subsequent maintenance by Manitoba Hydro has an ecological impact on both the vegetation and the underlying soils (Magnusson, 1986).

Sphagnum fuscum is the dominant moss of hummocks in both open and treed bogs in southeastern, central and northern Manitoba (Reader, 1971;

Sims, 1977; Magnusson, 1986). Treed *Sphagnum* bogs are considered among the most stable of peatland vegetation types (Jeglum, 1973). The *Sphagnum* hummocks are of particular importance in the bogs because they provide a raised relatively dry substrate which allows for the colonization of other plant species (Reader and Stewart, 1972). The removal of the hummock community leads to an increase in wetter or lawn areas with a fen type vegetation in the short term, which in turn can reduce the accumulation of peat in the long term (Magnusson and Stewart, 1987).

It was perceived but not proven by Magnusson (1986) that the application of picloram herbicides adversely affected *Sphagnum* moss and may have a long term effect on the bog community structure (Magnusson and Stewart, 1987). Prior to 1986 it was believed that *Sphagnum* species and other non-vascular plants were resistant to these herbicides (Sims, 1977; Suffling, 1975; Suffling & Smith, 1979). The longevity of picloram in mineral soil was shown to vary between 5 months and several years (Youngson *et al.*, 1967). Little is known about the persistence of picloram residues in organic and peat soils. The objectives of this research project were to:

1). observe and measure the effect of Tordon 22K (picloram) on the chlorophyll content, subsequent growth, conductivity and culturing of *S. fuscum*.

2). observe the longevity of picloram in peat soils through analysis of residues from pretreated peat samples.

Literature Review

a) Distribution of Peatlands

Peatlands are unbalanced wetland systems in which the rate of production of organic material exceeds its rate of decomposition and whose surface vegetation overlies an accumulation of undecomposed plant material (Manuel, 1984). Classification of peatlands is complicated by the intangible differences between marshes, sedge meadows, fens and bogs (Crum, 1988). In terms of vegetation Crum (1988) divided the fen-bog succession into four peatland communities, sedge fens, *Sphagnum* lawns, open bog and Black spruce muskegs. A conservative estimate puts the total peatland area at approximately 5% of the total land surface of the earth or ~ 500 million hectares (Matthews and Fung, 1987). In North America there are approximately 210 million hectares of peat, of which about 110 million are in Canada. Peatlands in Manitoba are estimated to cover 20.6 million hectares comprising 38 percent of the provincial land area and 19 percent of the total area of the peatlands in Canada (Mills, 1982; Manuel, 1984).

Peatlands and their products, such as peat and humic acids, are used in such diverse economic endeavors as horticulture, agriculture, forestry, energy, industrial chemicals, sewage treatment, scientific study and water filtration (Mills, 1982; Richardson, 1981). The primary peat builders in the peatlands of the Northern hemisphere are the *Sphagnum* mosses. The value of the *Sphagnum* peat from the peatlands was recognized thousands of years ago in Europe as a source of fuel and is still one of its primary uses today in many countries (eg. Ireland, USSR, Finland). In Manitoba the majority of the peatlands are located in the inaccessible northern regions of the province, whereas those accessible peatlands of the central and southeastern Manitoba are either mined for horticultural peat export, cleared for agricultural use, or remain untouched (Mills, 1982; Manuel, 1984).

Sphagnum mosses are important components of most bog communities in the North Temperate and Boreal Forest zones where they are abundant in the surface vegetation (Magnusson, 1986; Gaberscik & Martincic, 1987). *Sphagnum* peatlands form on poorly or very poorly drained areas, isolated from nutrient rich ground waters, and thus contribute significantly to the accumulation of the peat as a result of their ability to slow decomposition rates (Clymo and Hayward, 1982). The genus grows in many diverse habitats such as variously coloured hummocks and 'lawns' in bogs, fens, marshes, pools, wet woodlands, moors and damp grassland but rarely in localities with a pH exceeding 6.0 (Hill, 1978). Distribution of the genus is world-wide, with the exception of Africa (Smith, 1978). The greatest abundance of *Sphagnum* occurs in the cooler temperate portion of the northern hemisphere. *Sphagnum fuscum* (Schimp.) Klinggr., the target species in this study, is distributed circumpolarly throughout Alaska, Yukon, Northwest Territories, Greenland, Labrador, U.S.S.R. and Scandinavia. It extends south through most of Canada to the Northern United States as well as into much of Europe, Asia and in Japan where it is found further south in mountainous regions (Hill,1978).

b) *Sphagnum* Life History

Sphagnum is the single genus of the family Sphagnaceae, commonly known as peat moss, less often as bog moss (Crum, 1976). One hundred and fifty species are easily recognizable, although more than 300 species have been described (Haavisto, 1974; Schofield, 1985). Certain species in the genus have a reputation for being very difficult to identify, partly due to the gametophyte having a strong tendency to be structurally altered, when growing under environmental extremes, particularly in drought and flood conditions (Schofield, 1985). As a result many species of *Sphagnum* are repeatedly misclassified, a condition further complicated by the lack of a standard key for the highly variable morphological characteristics (Crum, 1976, 1988). *Sphagnum fuscum* (Schimp.) Klinggr., unlike many *Sphagnum* species, is easily recognized in the field by the formation of very compact hummocks and a distinct brown coloration of the stem (Smith, 1978).

A mature *Sphagnum* gametophyte has an erect branched stem, varying in length from 5 - 10 cm with the non-living portion of the stem often being several decimeters long (Smith, 1978). The stem in cross-section consists of three distinct layers, a central column of thin walled parenchyma, thicker walled pigmented cells, and one or more layers of translucent non-living hyaline cells, encompassing the inner two layers. The hyaline cells may have fibril thickenings forming bands on the inner surface of the cell wall, as well as pores on the walls of the adjacent inner cells of the cortex (Schofield, 1985). In *S. fuscum* the cortical or hyaline cells are without fibrils and the outer surface lacks pores. Such empty hyaline cells give the living and non-living gametophytes of *Sphagnum* the ability to absorb large quantities of water, up to 20 times their own weight in some species (Schofield, 1985; Shotyk, 1989). The combination of the absorptive power and the structure of the gametophyte results in an efficient capillary wick, or continuous water column. This allows *Sphagnum* to expand away from its water source, and colonize new areas. However, if the water column is broken then the *Sphagnum* will dry out and die.

Branches of the gametophyte arise spirally from the stem in fasicles, (2-4 in *S. fuscum*) which crowd together at the apex of the stem to form a head or capitulum; this is the morphological structure with the greatest metabolic activity (Schofield, 1985). The fasicles consist of 2 or more pendant branches which lie parallel with the stem and assist in the conduction of water. The branches bear the main photosynthetic leaves in an overlapping spiral arrangement. The cells of these leaves are composed of a network of elongated chlorophyllose cells, 5 or 6 which enclose a hyaline cell. The hyaline cells of the branch leaves, like those of the stem may or may not have rounded or elliptical pores and or spiral thickenings (Crum, 1976; Schofield, 1985). These characteristics are often used to identify the species.

Both the branch and stem leaves are unistratose (one cell thick) and possess no thickened midrib or costa (Schofield, 1985). The stem leaves, like the branch leaves, are spirally arranged but are less crowded than the branch leaves and are usually clearly differentiated in size and shape (Crum, 1976). The stem leaves also possess hyaline cells with less developed pores and fibrils. Also the stem leaves show extensive reabsorption of water in the walls of the hyaline cells (Crum, 1976).

The colonization of new areas and the maintenance of the population is achieved primarily by rapid vegetative growth of the *Sphagnum* gametophyte, from May through to September (Andrus, 1986). There are several methods of asexual reproduction employed by *Sphagnum* mosses; however asexual structures such as gemma cups have not been observed in the field, although culturing techniques have shown that the protenema will produce gemma-like structures (Schofield, 1985). A second type of asexual production results from the senescence of the gametophytic branches and stem which occurs acropetally, and when the senescencing tissue reaches the junction of an innovation with the main stem, the two become separate individuals (Baker & Boatman, 1985). This type of vegetative growth is found typically in hummock species (*S. fuscum*), whereas hollow species produce numerous "juvenile" side shoots (Andrus, 1986). Vegetative growth may also result from an injury to the gametophyte which will initiate a thallus, with the capability to develop into a new gametophyte. Finally, the apex or capitula of a *Sphagnum* plant may at times be replaced by two or multiple smaller ones (Clymo & Hayward, 1982).

Sexual reproduction by *Sphagnum* is common when growth occurs under environmentally stressed conditions (eg. drought). Most *Sphagnum* species are dioecious (e.g *S. fuscum*), some are monoecious (e.g *S. squarrosum*), and others are either monoecious or dioecious (e.g *S. russowii*), (Crum, 1976; Schofield, 1985). The sporophyte matures within the security of specialized leaves (perichaetal leaves) and is dependent upon the gametophyte for water and nutrition. The mature sporangium is elevated above the gametophyte by the elongation of the gametophytic stalk-like pseudopodium (Schofield, 1985). Concurrently, a tetrad of spores are produced by meiosis with a visible triradiate scar (Hill, 1978). Once elevated the mature sporangium differentiates and an operculum (lid) is formed at the apex.

The spores are dispersed after the sporangium dries, thus shrinking in diameter which leads to the columella disintegrating. The shrinking diameter of the sporangium places the gaseous interior under pressure which increases to a point where the operculum and the spores are violently blown into the air and are carried by the wind (Crum, 1976; Schofield, 1985). The spores are the first cells of the haploid gametophyte generation (Crum, 1988) and will germinate when the conditions are conducive and give rise to the juvenile stage, a thallose protenema that develops into the gametophytic moss (Crum, 1976). The time between fertilization and the maturation of the spore is approximately four months. Capsules are produced by all *Sphagnum* species in abundance and spore dispersal will vary between species from June to mid-August (Crum, 1988).

c) *Sphagnum* Ecology

Sphagnum species are distributed along chemical, moisture and pH gradients in peatlands (Andrus, 1986). There is a vertical zonation of the species along hummock-hollow gradients which results in some species growing at higher elevations. *S. fuscum* is a principal hummock species, and a builder of the most extensive and highest hummocks of any *Sphagnum* species (Rydin, 1985; Magnusson, 1986). Hummock species have the ability to grow in the hollows, but tend to be out-competed by the faster growing wet hollow species, which are physiologically and morphologically unable to grow at the higher drier hummock levels (Andrus, 1986). Moreover

Sphagnum species which grow further away from the water table have a decreased growth (Rydin, 1985) and photosynthetic rate (Gaberscik and Martincic, 1987).

Rydin (1985) observed that undo drought conditions, hollow species begin to dry out before hummock species. Luken (1985) explained that hummock species reduced the rate of drying out by increasing dichotomous branching of the gametophyte in times of water stress. This maintained a high volume and spatial density, thus preventing the water column from breaking. *S. fuscum* was observed to survive in the driest regions of peatlands (Magnusson, 1986). Hollow species such as *S. papillosum* have spreading branches and do not form a wick for conducting water (Clymo and Hayward, 1982; Rydin, 1985). During a growing season there is often a drying trend in mid summer and hummock species adapt to the desiccation by reducing their photosynthetic rates (Rydin 1985; Andrus 1986). Hollow species are able to adapt at times of desiccation by fixing CO_2 more readily than hummock species at lower water contents (Titus *et al.*, 1983; Andrus, 1986).

Sphagnum species are important pioneers in the formation of floating vegetation mats, raised bogs and hummock-hollow topography (Titus *et al.*, 1983; Schofield, 1985). They control and impede water movement and have the ability to direct succession through acidification and paludification (Andrus, 1986). *Sphagnum* species are generally located in communities in which there are low concentrations of inorganic solutes, particularly N and P (Clymo, 1970). *Sphagnum* produces and maintains these acidic and nutrient poor conditions through a cation exchange mechanism, which in combination with the anaerobic conditions inhibits or retards decomposition.

These abiotic conditions present extreme conditions to which only a few microorganisms have adapted (Untiedt and Muller, 1984). This, in conjunction with the inability of many fungi and bacteria to decompose the cell walls of *Sphagnum* (Berch and Fortin, 1983) results in an accumulation of organic material, and ultimately formation of peat (Clymo and Hayward, 1982).

The ecological significance of the genus *Sphagnum* to peatland development is both a product of its structure and life history traits (Schofield, 1985). A major ecological concern in the exploitation of peat is the destruction of living *Sphagnum* and the associated vegetation. A problem in Ireland and the U.S.S.R. is that the generation of electric power by peat can result in the production of toxic gases, (eg. SO_2) which contribute to the formation of acid rain (Richardson, 1981). These compounds can have a harmful effect on the growth of *Sphagnum* mosses by promoting toxic accumulations of such metals as Ca, Fe, Zn, Pb and Cu in the surface vegetation (Pakarinen, 1981). Although *S. fuscum* is shown to regenerate in a few decades after fire destruction of the peatlands (Jasieniuk & Johnson, 1982), it has not been observed to recover from toxic contamination.

d) Right-of-Way Ecology

Manitoba Hydro is second to Quebec in the production of Hydro electric power in Canada, having a total generating capacity of 3.9 megawatt hours annually (Manitoba Hydro, 1989). The electricity produced is transmitted along cleared right-of-ways (ROW) corridors, which optimize the carrying capacity of the power lines by preventing trees and shrubs from disrupting the electromagnetic field which surrounds the lines. Initially the ROWs are cleared mechanically with subsequent maintenance of the corridors being primarily achieved through the use of various herbicides, except near agricultural areas where picloram use is restricted.

Manitoba Hydro currently uses the following picloram (4-amino-3,5,6-trichloropicolinic acid) based herbicides in line maintenance:
A) Tordon 10K, a pellet formulation of picloram (10%; 4-amino-3,5,6-trichloropicolinic acid) (Ross & Lembi, 1985),
B) Tordon 101 a formulation containing 240 g of active ingredient (ai) /L of 2, 4-dichlorophenoxy-acetic acid (2,4-D) and 60 g ai/L of picloram.
Tordon 101 is recommended for control of unwanted brush and broadleaf weeds on ROW's. The production of Tordon 10K has been discontinued since 1987 (Dow Chemical, 1987). Tordon 22K was used in this research. It is a dissolved potassium salt of 240 g ai/L of picloram used for controlling deep-rooted perennial and biennial weeds on rangeland, grass pastures and non-cropland areas. It is used in this study to avoid complications of formulations.

Picloram-based herbicides are classified as synthetic growth hormones along with the phenoxy and benzoic acids (Eisinger and Morre, 1970; Ross and Lembi, 1985). Picloram is one of the most effective plant growth regulators on dicotyledonous plants (Foy, 1980; Fryer *et al.*, 1979) producing elongation and epinasty in the growing tips. These structural changes are similar to those produced by 2,4-D and are responsible for its classification as an auxin type herbicide. However, picloram is 100 times more potent than 2,4-D on susceptible plants (Hamaker *et al.*, 1963; Ashton and Crafts, 1981). This is attributed to the translocatablility and comparative resistance of picloram to breakdown (Foy, 1980).

Picloram is applied to either the foliage or soil and is readily absorbed by both the foliage and root systems, although the root systems are more susceptible than the shoots (Foy, 1980). Application of picloram at low levels may cause distortions in leaf shape, production of narrower leaf tips, lesions along the midrib and/or thickening of the mesophyll tissue as well as an increase in fresh weight of dicotyledons (Ashton and Crafts, 1981). Higher dosages decrease the fresh weight and may produce cupping or stunting of the leaf growth, termination of apical growth and/or abnormal elongation, cell wall loosening as well as root deterioration (Chang and Foy, 1971a; Ashton and Crafts, 1981). Chang and Foy (1971a) noted that the effect of picloram on a plant was dependent on the stage of growth as well as the dosage. Younger vegetation is more active metabolically and as a result greater damage is observed on younger plants. Manitoba Hydro applies picloram-based herbicides when it is necessary to remove conifer species such as Black Spruce and Tamarack on electrical transmission corridors. Picloram-based herbicides affect the targeted conifers in much the same manner as dicotyledons, often causing termination of the growing points, twisting of the apical shoot and abnormal elongation (Magnusson, 1986).

e) Picloram Residues and Degradation

The persistence of a herbicide is not a fixed property, being influenced by such factors as soil type and weather conditions following application (Hurle and Walker, 1980). An ideal herbicide would persist long enough to