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

By
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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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Acknowledgements

This research has been carried out with the much appreciated assistance of many various individuals.

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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 effectively remove the unwanted vegetation but not long enough to prevent the growth of subsequent crops. Picloram is restricted in its application because of its persistence in the soil at such levels that are phytotoxic to many plants (Fryer *et al.,* 1979). There is little adsorption of picloram on neutral or alkaline sandy loam soils (low organic matter), however adsorption increases with a decreasing pH and increasing organic matter content (Foy, 1980). Many of the following factors contribute to the disappearance of herbicides from the soil: soil type, precipitation, temperature, exposure to sunlight, percentage of organic matter and rate of application (Grover 1967, Moffat 1968). However, the most important factor responsible for herbicide degradation is the microorganisms within the soil matrix (Meikle, 1973).

As previously mentioned there are restricted groups of microorganisms found in the highly organic peatland soils which are active adsorbents for a wide variety of herbicides (Khan, 1973). Humic substances are products of incomplete decomposition of cellulose and lignin consisting of humic and fulvic acids and an undetermined component called humin (Crum, 1988). Humic substances are effective chelators holding cations by chemical bonds rather than by adsorption. The complexing of humic substances with cations by chelation holds metal ions, (such as $K+$) and releases them slowly (Crum, 1988). This property of peat soils will further reduce the rate of degradation of picloram from peatland soils, although little work has been done on soils with high organic matter due to their complex nature.

Chapter 1

The Effects of Picloram on *Sphagnum fuscum*

Introduction

Sphagnum mosses are important components of the surface vegetation in most bog communities of the Boreal Forest, and are often most abundant in wetter habitats. Sphagna characteristically have a high water retaining capacity and are able to control and impede water drainage in the community (Crum, 1976, 1988). This enables *Sphagnum* mosses to colonize wet acidic environments, slowing the decomposition rate and contributing significantly to the accumulation of peat (Clymo and Hayward, 1982).

Sphagnum is distributed along hummock-hollow gradients which are further modified by moisture, water chemistry, pH and light gradients (Andrus *et al.*, 1983). The drier hummock communities in the peatland are considered more stable floristically than the wetter hollows (Jeglum, 1973). *S. fuscum* is a hummock species and is one of the most common *Sphagnum* species of the circumboreal-subarctic peatland (Jeglum, 1973).

This study was instituted to verify the observation that the "chlorophyll content and the growing tips of *S. fuscum* were damaged by application of picloram-based herbicides" Magnusson (1986). Measurements of the effect of picloram at three concentrations to the chlorophyll content and growth of *S. fuscum* were observed on Devil's Lake and Sprague peatland communities traversed by hydroelectric transmission lines. As well culturing and conductivity observations were performed in the laboratory.

Study Area

Location

The three peatland sites selected for this study were located as follows:
A) in the southeastern area of the Middlebrow bog (Bannatyne, 1980) approximately 10 Km north of Highway #12 and 10 Km east of Sprague (49º 05' N latitude and 90º 35'W). This is the only site directly below a High Voltage Alternating Current line.

B) at Elma located south of highway #15 and west of Highway #11 in the northeast corner of the Elma bog (49º 56' N and 95º 56' W) (Bannatyne, 1980); and

C) on the HVDC transmission corridor in a clearing opposite tower 1323 approximately 1 Km east of Highway #6 and 5 Km south of Devil's Lake (52º 06' N and 98º 49' W) (Magnusson, 1986) (Figure 1).

Geology & Topography

The three study sites are within two major physiographic regions, namely the Manitoba lowland and the Canadian Precambrian Shield. The Devil's Lake site is in a generally flat and poorly drained area of the Manitoba Interlake Region. The bedrock of this region is primarily composed of dolomite and limestone of the Paleozoic era (Weir,1983). The Elma and Sprague site are located in the Precambrian Shield, which is characterized by an undulating topography (Smith, 1975; Bannatyne, 1980; MacLellan, 1982; Magnusson, 1986). The bedrock of the Shield is predominantly composed of granite and gneiss (Weir, 1983).

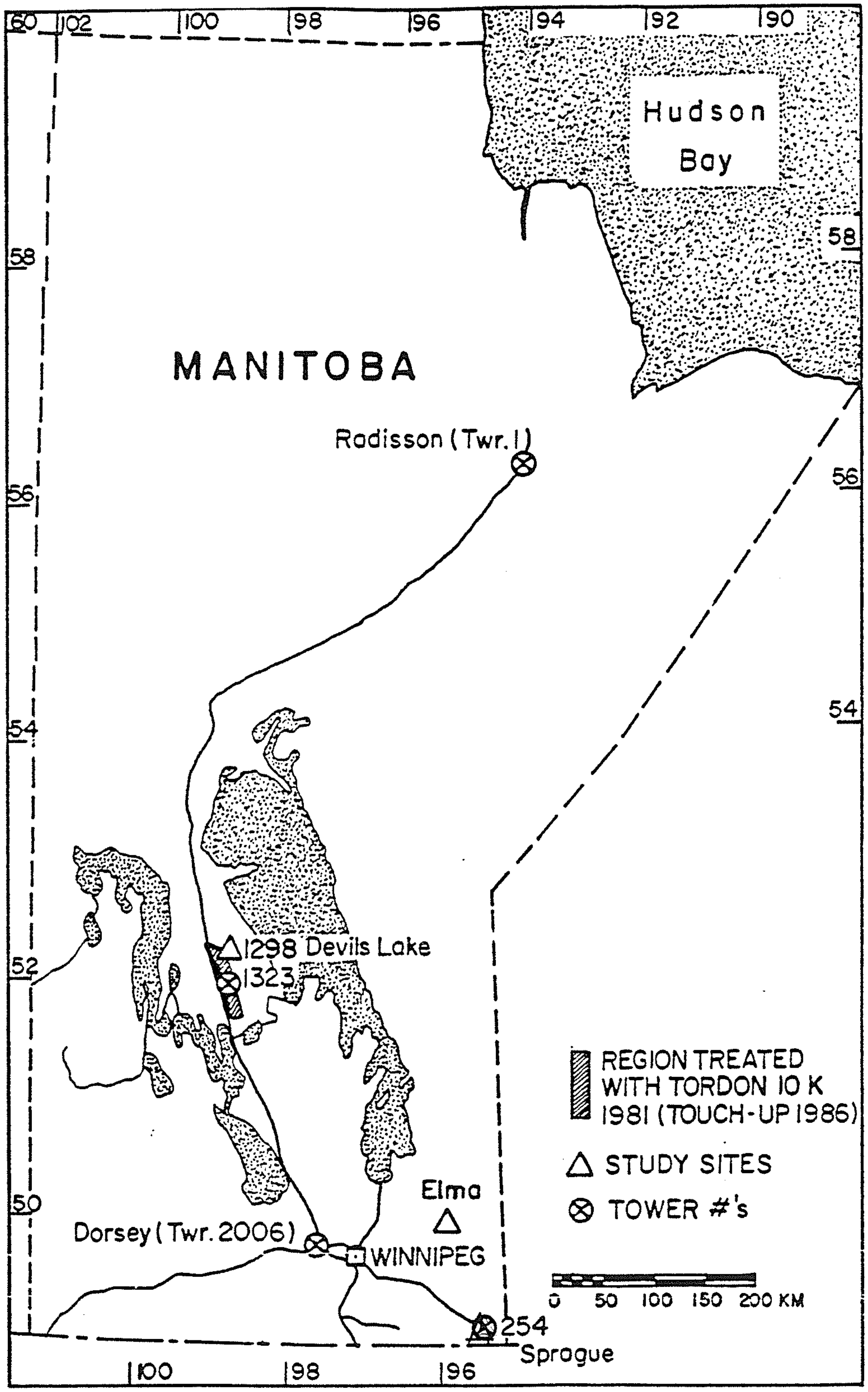


Figure 1 Location of the three sites sampled during 1988. Showing the Radisson- Dorsey (N/S) and the Dorsey - Forbes (S/E) Transmission Lines.

Climate

Manitoba has a continental climate, which is characterized by a large range in temperature (-20º Jan to 20º C July means) over 11 of degrees latitude throughout the year (Weir, 1983). Temperature and precipitation data were collected from six meteorological stations (Elma, Gypsymville, Falcon Lake, Sprague, Grand Rapids, and Ste. Anne) and are thought to best represent the general conditions of the three study sites. The monthly temperatures observed in 1988 were compared to the 30 year averages (Figure 2). There is a strong similarity, although the temperatures in 1988 were slightly higher, they were within the calculated variances (AES, 1988).

The mean monthly precipitation in 1988 decreased in a Northly direction when compared to the precipitation history of the three stations (Figure 3). The precipitation recorded for the 1988 growing season when contrasted with the 30 year averages, is slightly lower for Devil's Lake, lower at Elma and generally lower at Sprague except for a series of cloudbursts during July (Figure 3). The yearly precipitation at Sprague and Devil's Lake was similar to the 30 year average whereas Elma was below average.

Vegetation

The three study sites are situated in peat soils located within the Mixed Forest and the Northern Coniferous Forest zones, which Rowe (1972) refers to jointly as the Boreal Forest. The vegetation of the Boreal forest grows on various soil types, moisture regions and contrasting topography.

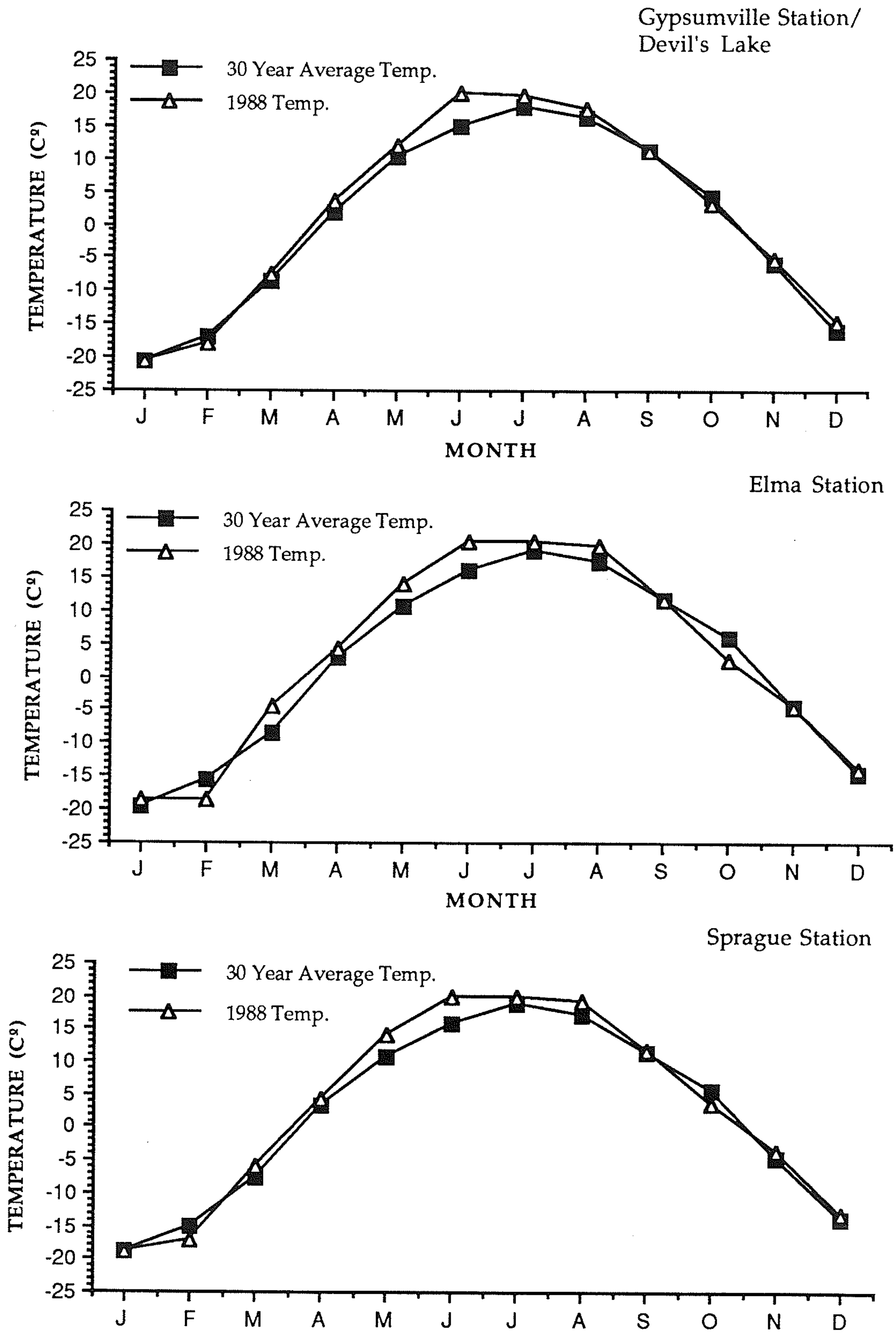


Figure 2.

A comparison for the three representative meteorology stations monthly temperature mean (Cº) with the averaged monthly means over the stations' 30 year history (AES.1988).

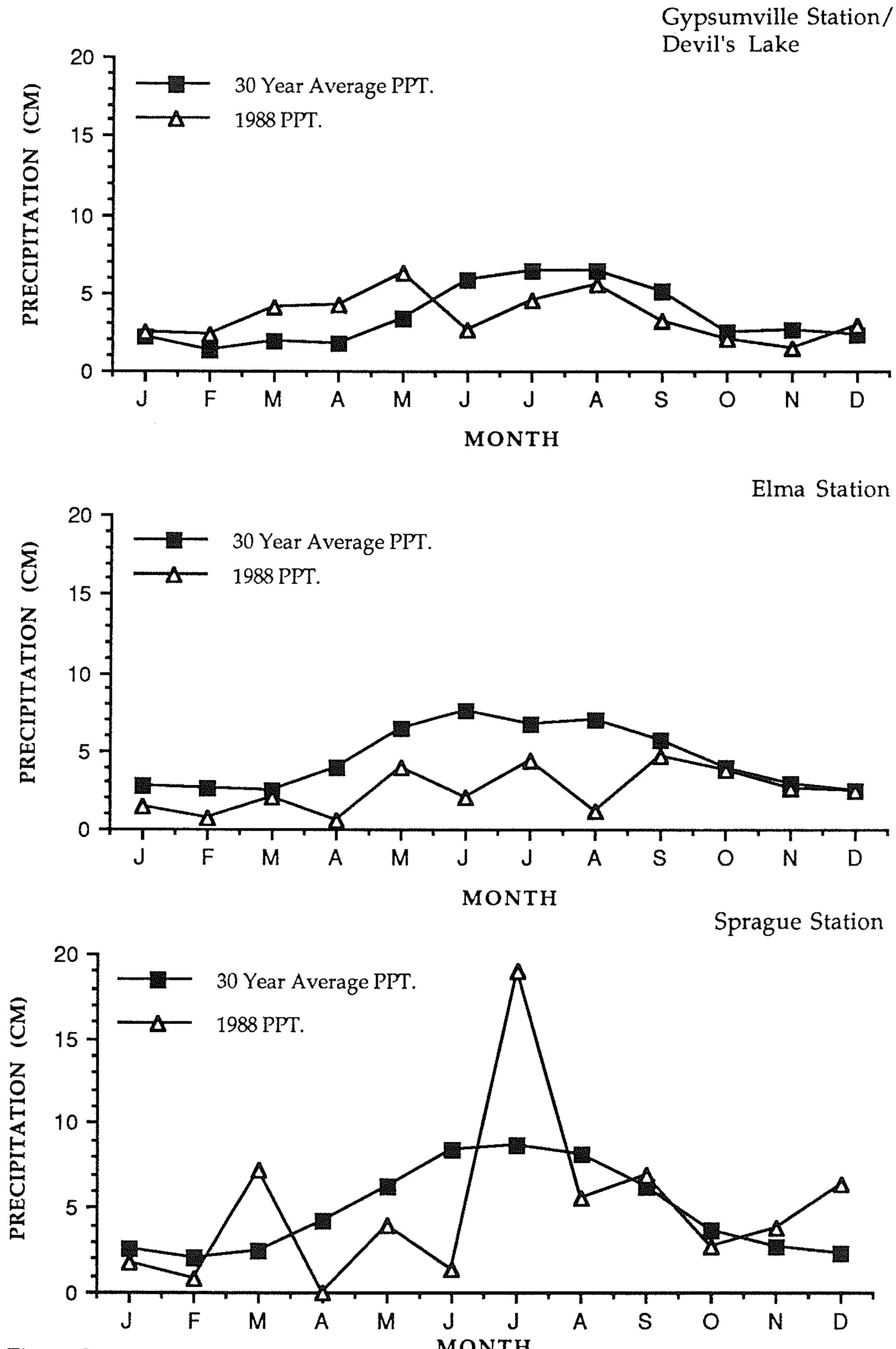


Figure 3.

A comparison for the three representative meteorology stations of monthly precipitation mean (cm) using the averaged monthly means over the stations' 30 year averages (AES. 1988).

The Sprague site is located on the southeast of a string fen bog complex typified by Black Spruce/ Ericoid/ *Sphagnum* association surrounded by the mixed forest. The Elma site is a treed bog (Black Spruce/ Ericoid/ *Sphagnum* association) which borders on the mixed forest and the Northern Coniferous Forest (Reader and Stewart, 1972). Devil's lake is within the Northern Coniferous Forest and is characterized by the presence of Black spruce *(Picea mariana)*, Tamarack *(Larix laricina)* in the wetter areas and White spruce *(P. glauca)*, Balsam fir *(Abies balsamea)*, and Jack pine *(Pinus banksiana)* in the drier areas (Sims, 1977; MacLellan, 1982).

All three study sites fall within low lying wetland areas of the two vegetation zones. The Devil's lake and Sprague sites have been manually cleared of trees but only the Devil's lake site has been sprayed with herbicides to maintain clear corridors with low lying (<1 m) vegetation along the corridors (Magnusson,1986). Elma was not cleared manually (Figure 4) but the vegetation is similar to the uncleared vegetation bordering the cleared right-of-way at Devil's Lake and Sprague.

Figure 4. Black Spruce and Tamarack trees shade the Ericacious shrubs and *Sphagnum* moss ground cover (May, 1988).

Sample sites

a) Sprague Bog

This site is directly beneath the 500 KV High Voltage Alternating Current line (D-602-F, Dorsey-Forbes, tower #254). An open area to the North of the maintenance tracks was chosen for its uniformity and extensive patches of *Sphagnum fuscum* with a frequency of occurrence of 81% (Table 1). This site was cleared mechanically of all Black Spruce (*Picea mariana*) and Tamarack (*Larix laricina*) in the winter of 1977-78. Swamp birch (*Betula glandulosa*) has replaced the conifers and currently the frequency of occurrence is ~ 21 % on and between the *Sphagnum* hummocks (Table 1). Grasses, sedges and cattails increase in frequency of occurrence towards the northern edge of the ROW (Figure 5 a,b). Hydrophilic representatives of the Liliaceae, Salicaceae, Sarraceniaceae, and the Primulaceae families occur with low frequency (< 5 %) in the low lying wet areas of this site (Appendix 1). The peat depth is ~2.2 m. The water table was high throughout the growing season, except in August when it fell to approximately 25 cm below the hummock surface. An undrained string fen lies to the north of the study site (Figure 5 a). The uncut vegetation bordering the right-of-way is dominated by a dense cover of Black Spruce and Tamarack. The maintenance tracks which border the sample sites are dominated by sedges and cattails (Figure 5 b).

b) Elma

This site is in the northeastern portion of an extensive treed bog located next to a recent burn site. It was chosen to represent a typical mature

Table 1.

List of the vegetation at the three study sites recorded as a percentage of the species frequency of occurrance. (nomenclature of vascular plants is according to Scoggan (1978, 1979) and the Bryophyte nomenclature follows Ireland *et al* 1980).

Vascular plants	Sprague	Elma	Devil's Lake
Betulaceae			
Alnus rugosa (Duroi) Sprengel	0.25	0.00	0.00
Betula glandulosa Michx	21.60	0.14	4.19
Cupressaceae			
Juniper horizontalis Moench.	0.00	0.00	5.25
Cyperaceae			
Carex sp.	0.00	0.00	0.69
Eriophorum viridi-carinatum L.	0.00	0.45	33.90
Droseraceae			
Drosera rotundifolia L.	0.04	0.00	1.19
Ericaceae			
Ledum groenlandicum Oeder	5.41	25.50	31.10
Kalmia polifera Wang.	3.11	5.19	0.44
Chamdaedaphne calyculata (L.) Moench.	18.50	24.20	0.63
Andromeda glaucaphylla Link.	15.96	3.18	0.00
Vaccinium oxycoccus L.	12.90	10.23	6.75
V. vitis-ideae L.	0.00	7.66	5.38
Gentianaceae			
Menyanthes trifoliata L.	2.01	0.00	0.00
Gramineae			
unidentified Grasses	11.10	0.24	0.00
Liliaceae			
Smilacina trifolia (L.) Desf.	5.50	0.00	6.81
Myricaceae			
Myrica gale L.	0.18	0.00	0.00
Orchidaceae			
Cypridedium acaule Ait.	0.00	0.00	0.63
C. calceolus L.	0.00	0.00	0.63
Pinaceae			
Larix laricina (Du Roi) Koch	0.40	2.85	0.31
Picea mariana (Mill.) BSP.	1.27	0.32	8.38
Rosaceae			
Potentilla palustris (L.) Scop.	0.14	0.00	0.00

Vascular plants	Sprague	Elma	Devil's Lake
Salicaceae			
Salix sp.	1.13	0.00	0.00
Sarraceniaceae			
Sarracenia purpurea L.	1.78	0.00	0.44
Typhaceae			
Typha latifolia L.	0.374	0.00	0.00
<u>Bryophytes</u>			
Aulacomniaceae			
Aulacomnium palustre (Hedw.) Schwaegr.	2.48	0.50	0.00
Endodontaceae			
Pleurozium schreberi (Brid.) Mitt.	2.68	0.00	11.40
Sphagnaceae	81.42	72.8	80.90
(*Sphagnum fuscum* (Schimp.) Kliggr. primary species identified)			
Polytrichaceae			
Polytrichum strictum Brid.	4.63	14.60	9.88

Figure 5 Sprague Site:

a) Aerial view (May 1988) of the study site with a string bog (see arrow) in the background and the last corner tower (tower #234) prior to the line crossing the United States/Canadian border .

b) A ground view of the right-of-way and sampling area (May 1988), showing Black Spruce and Tamarack bordering the ROW, the *Typha* sp. on the maintenance tracks and Swamp Birch shading the *Sphagnum* carpet of the sample areas.

drier bog, typified by an abundance of Black Spruce and Tamarack trees, Ericoid shrubs and bog mosses (Figure 6). However, the treatment lines were placed in order to avoid the tree species and therefore the vegetation frequency of these tree species is not representative (Table 1). The water level at this site is much lower than at the Sprague site being approximately 50-60 cm below the hummock level in the spring of 1988. The drought experienced that summer resulted in a further drop of the water level to ~1 m below the surface vegetation in August.

c) Devil's Lake

This site is within 100 m of tower 1323 along the HVDC transmission line which runs from Nelson River (56º 32' N 94º 37' W) to Winnipeg, Manitoba. The dead *Sphagnum* hummocks on the herbicide-treated ROW were colonized by *Polytrichum strictum* and sedges (Figure 7). Whereas, the hummocks just off the ROW are dominated by *Sphagnum fuscum* (Figure 8a). The composition of the low lying vegetation is typical for the area and differs only in density from the southern sites (Table 1). Similar to the Sprague site members of the Liliaceae, Salicaceae, Sarraceniaceae, and the Primulaceae families grow at this site, as well as member(s) of the Droseraceae, Orchidaceae and Compositae (Appendix 1). The hummocks with their Ericoid/ *Sphagnum* associations are shaded by open canopies of Black Spruce and Tamarack (Figure 8 b).

Figure 6 Elma Site:

A ground view of the sampled areas (June 1988), showing the cover of Ericacious shrubs and Black Spruce and Tamarack trees shading the *Sphagnum* ground cover .

Figure 7 Devil's Lake Site:

A ground view of the right-of-way previously sprayed in 1986, now dominated by grasses and sedges. In the background is the border of the ROW with Black Spruce and Tamarack trees shading ericoid and *Sphagnum* ground cover.

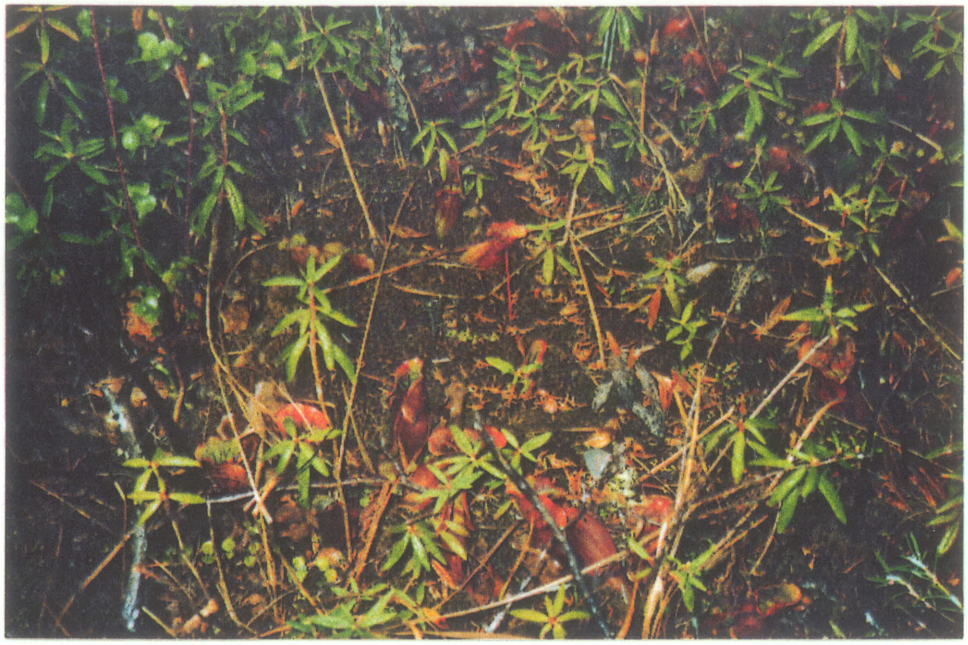


Figure 8 Devil's Lake Site.

a) A view of the surface vegetation in May 1988 illustrating the compact *Sphagnum* carpet with Labrador tea and Pitcher plant scattered on the hummock surface.

b) A test quadrat placed on a *Sphagnum* hummock located in an opening between the Black Spruce and Tamarack trees which border the right-of way (May 1988).

Materials and Methods

Experimental Design and Herbicide Application

At Sprague and Elma 3 transects were laid across a homogenous *Sphagnum* cover at 2 week time intervals. Four 1 x 1 m^2 quadrats, designated A, B, C, and Control were randomly placed along each line. The transects at Sprague ran in a North-South direction, whereas at Elma they ran in an East West direction. At Devil's Lake the *Sphagnum* cover was not continuous and 50 x 50 cm^2 plots were randomly placed at 4 week time intervals on selected hummocks with a near-complete cover of *S. fuscum* .

At each time interval vegetation frequencies were recorded at Sprague and Elma. A fifty meter tape measure was extended the length of the line and every other meter was used to determine the frequency of the vegetation. At Devil's Lake the tape was placed through the center of randomly placed quadrats. It should be noted that the test lines were placed in areas of high *Sphagnum* cover and tree species were avoided. Therefore the frequencies represent the test areas and not the overall vegetation (Table 1).

Crankwires were positioned with the horizontal poriton of the wire parallel to the capitula at each time interval, to monitor the growth of *S. fuscum* in the quadrats (Clymo, 1970). The quadrats were then treated with picloram at the following dosages: A=0.92ml/m^2 (2.2 kg ai / ha), B=0.46ml/m^2 (1.1 kg ai / ha) and C=0.23ml/m^2 (0.55 kg ai / ha). These application levels are equivalent to 2X, 1X and 1/2X, the level of picloram in Tordon 101 (65g picloram and 240g of 2,4-D per L) applied by Manitoba Hydro (Table 2). 250 ml of the herbicide was applied to the appropriate quadrat using a one gallon hand tank sprayer (Continental, Model 050).

Samples were collected from the Sprague and Elma sites 2, 4, and 6 weeks after the application of the herbicide and every 4 weeks at Devil's Lake and analyzed for the effect of picloram on the chlorophyll content of *S. fuscum*. Samples were collected until August 20th at Devil's Lake and until September 22nd, at Sprague and Elma. The crankwires were removed on these dates (Aug 20 and Sept 22) from the quadrats. The experiment was terminated at Sprague 4 weeks after the last application on August 25.

Statistical analysis of the chlorophyll data involved using comparisons of the treated and untreated plants in a one-way Anova. Treatment levels were subjected to pairwise Scheffe's multiplecomparison tests. Data means and standard errors were calculated using SAS (1979).

Table 2.
Herbicide application levels and the calculations of the stock solutions used in the application of Tordon 22K in the field.

Manitoba Hydro Levels	Herbicide Stock ml Tordon 22K/L distilled water	Final Application Levels (ml Tordon 22K/m^2)	Level in Kg per hectare
Control	-	-	-
0.5X	0.261	0.23	0.55
1.0X	0.522	0.46	1.10
2.0X	1.044	0.92	2.20

Chlorophyll Determinations

Samples of *S. fuscum* were randomly collected from the experimental quadrats at Sprague and Elma from June through to September of 1988 and at Devil's Lake the samples were randomly collected once in June, July and August. Trial experiments were performed in May and early June to finalize the experimental design.

Samples were brought to the laboratory in plastic bags in order to retain moisture content and stored at -20º C until processed. In order to avoid problems in determining which portion of the *Sphagnum* was photosynthesizing and which was not, only the capitula were used in the chlolorphyll determinations. The capitula were separated into 6 one gram (fresh weight) subsamples. Three of the subsamples were dried at 95º C for 24 hours to determine the dry weight and the percent moisture. The other 3 subsamples were used to determine the chlorophyll content. Samples were macerated in a mortar and extracted with 90% methanol (Marker *et al.*, 1980). The homogenized extracts were placed into vials and covered with aluminum foil to prevent chlorophyll breakdown by light (Brunsma, 1963). The vials were stored in the dark at 4º C for 24 hours. The samples were then filtered through Whatman GF/A filters. The filtrate was made up to 50 ml with 90% methanol. Four ml of the filtrate was dispensed into a 1 cm cuvette with a 5 ml syringe.

The total chlorophyll content was calculated by measuring the chlorophyll extracts with an LKB Ultrospec 11 spectrophotometer at 3 wavelengths 650, 665, and 750 nm. The cholorphyll content was calculated according to the following formula (after Haden, 1965 and Marker *et al*, 1980):

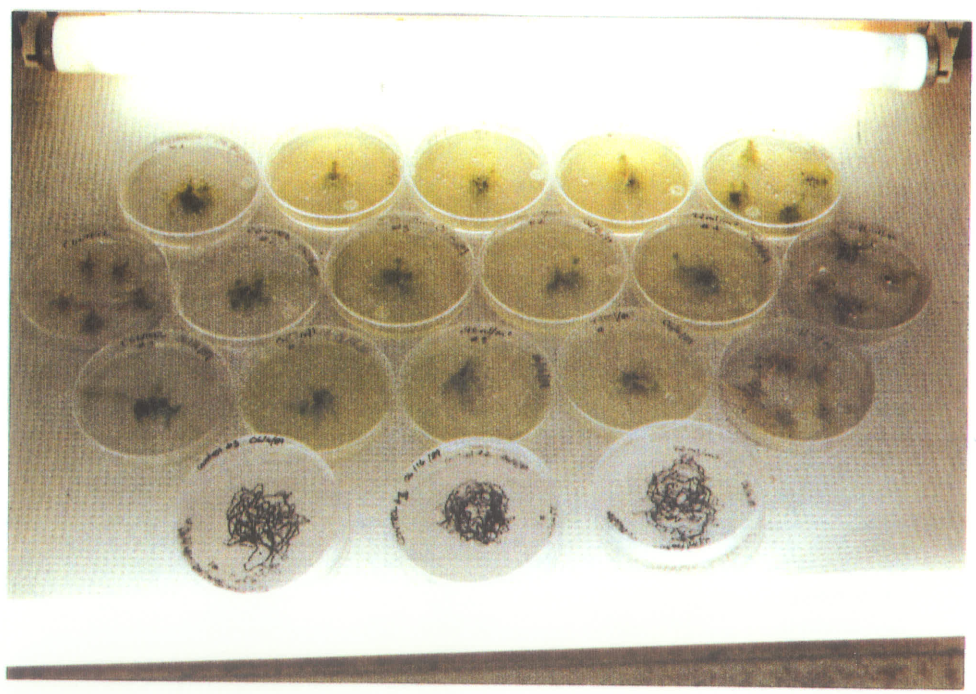
$$\text{mg Chl x g-1dry weight} = \frac{(A650 - A750) \times 25.5 + (A665 - A750) \times 4}{\text{Volume x Dry weight}}$$

The averages of the 3 subsamples were calculated for each sample. The three replicate samples were then averaged and expressed as a percentage of the control (Appendix 3).

Elongation

The elongation of *S. fuscum* was measured using crankwires (Clymo, 1970) at all three study sites. Three crankwires were placed in each quadrat prior to the application of Tordon 22K at each treatment date. The crankwire is ca. 17 cm long and made of stainless steel (Figure 9 a). One end of the wire is about 10 cm long and is driven vertically into the *Sphagnum* population, until the horizontal portion (1 cm long) is parallel with the *Sphagnum* capitula, and the free end of the wire has an approximate length of 6 cm. The capitula can grow up around the crankwire and the amount of growth calculated by measuring the portion of the crankwire which remains above the surface of the *Sphagnum* carpet at the end of the growing season. All measurements of the crankwires were taken and removed from the quadrats at Devil's Lake on August 18, 1988 and at Sprague and Elma on September 22,

Figure 9 a) The Crankwire used in the field to measure the growth of *Sphagnum*. An arrow points to the horizontal portion of the crankwire used in the placement of the wire to reference the start of growth.



b) The arrangement of the *Sphagnum* culture dishes in the growth chamber, illustrating the light sources and the tracings (foreground) used in measuring the diameter expansion.

1988. The amount of elongation of the *Sphagnum* was plotted against the date of treatment (or insertion) to observe the effect of picloram on the elongation of *S.fuscum* .

<u>Culture</u>

S. fuscum was collected from the study sites several weeks prior to the experiment and the capitula were cultured to observe the effect of Tordon 22K. Uniform capitula (ca. 4 mm diameter) were separated from the plants and rinsed in distilled water, then shaken in sterile distilled water for approximately 1 minute. Four to five capitula, approximately 5 mm in diameter, were transferred with a flamed bioloop to a petri dish containing 10 ml sterile culture medium (solidified with 1.25% Agar), which had been prepared from nutrient stocks two to three days prior to the transferring of the capitula. The transfer was performed in a laminar flow hood, which had been allowed to run for > 10 minutes and then swabbed with 70% ethanol.

The culture medium consisted of Landolt's macronutrients (1957) and Nichol's Woods Hole MBL micronutrients (1973) and vitamins followed Bowker *et al* (1980) (Appendix 2). The closed petri dishes were incubated in an enclosed growth chamber at 22º C in continuous light. After three weeks, the capitula, which were approximately 15 mm in diameter, were transferred to new plates (one capitulum per plate) and treated with 5 ml of picloram solution at levels equivalent to those used in the field. The differences between the control and the treated capitula were recorded every 2 days to observe the effect of the picloram on the capitula. The petri dishes were rotated daily to evenly distribute the light (Figure 9 b). Tracing of the patterns of growth were used as a measurement of the expansion of the diameter. Two weeks after application of the herbicide, photographs were taken to observe the effect on the capitula.

Conductivity

Picloram induces cell wall loosening and damages the integrity of the cell membranes (Bachelard and Ayling, 1971; Chang and Foy, 1971a). This allows electrolytes to leak from the cells into the surrounding media and to increase the conductivity of the media. Conductivity can therefore be used as a rapid measurement of herbicide injury (Vanstone and Stobbe, 1977).

S. fuscum samples were collected, cleaned and cut to 8 cm lengths in the laboratory and then placed into 150 ml beakers, with a density approximately equal to that found in the field (wet weight ~50 g). One gram of capitula (~50) was separated and one gram of stems (~20) was cut to 2 cm lengths and placed into separate 150 ml beakers. Four replicates of each were prepared, one of which was placed in 100 ml of deionized water (> 2 μs) to act as control. A blank of deionized water was used to monitor any changes due to environmental changes or contamination. The remaining replicates were treated with 100 ml of picloram at 1.104 ppm, which is equivalent to the level applied by Manitoba Hydro in the field, 1.1 kg/ha assuming sprayed for a depth of 10 cm. The beakers were covered with parafilm to prevent evaporation and maintained in a 14 hour light at 25º C and 10 hour dark at 18º C cycle. The conductivity was measured after a 20 hour equilibration period every two hours during the day with a Radiometer (Copenhagen) conductivity meter (Type CDM 2e) for a 2 week period. A second experiment was set up similarily to the first, except that 25 grams of *Sphagnum* was weighed out and compacted to a density equivalent to the field (~125 plants per beaker). In this run there was no equilibration period and no parafilm was used in order to determine any effects of evaporation. Readings were taken every hour from 8 am to 5 pm over a two week period. The treated conductivites were subtracted from the control conductivities (Δ conductivity) and plotted against time.

Results

Chlorophyll Content

Two weeks following treatment with picloram *S. fuscum* became yellower and drier than the untreated plants. The chlorophyll content of the treated plants was lower than the untreated at all times and for all treatment levels at Elma and Devil's Lake. At Sprague the chlorophyll content of the treated plants was decreased in all but one dosage, 0.46 ml/m^2 (1.1 kg / ha) on June 28 when the chlorophyll content of the treated *Sphagnum* exceeded that of the untreated (Figure 10b).

Analysis of variances (ANOVA) confirmed significant differences between the chlorophyll content of the untreated and the treated plants at various times throughout the study. Scheffe's multiplecomparison test was performed simultaneously to determine whether there was a significant difference between the treatments (Appendix 4). There was no significant difference($P<0.05$) between the treatments at Elma, although there were significant differences between treatments at both Sprague and Devil's Lake.

Application of picloram at Sprague generally decreased the chlorophyll content of the *S.fuscum* (Table 3). The chlorophyll content values are tabulated for Sprague from June through September, 1988 at the three sampling times and four treatment levels [A-0.92 ml/m^2, (2.2 kg/ha) B-0.46 ml/m^2, (1.1 kg/ha) C-0.23 ml/m^2,(0.55 kg/ha) and Control-0.0 ml/m^2]. There was no significant differences between the control and the dosages when the picloram was applied on June 15 (Table 3). Two weeks later on June 28, treatment produced variable results with 2.2 kg/ha of picloram

Table 3.

The effect of picloram on the chlorophyll content (mg Chl g^{-1} dry weight) of *S.fuscum* (capitula) at Sprague from June to August (1988) 2, 4, and 6 weeks after the treatment date.

Treatment Date	2 weeks				4 weeks				6 weeks			
	Control	0.92 ml/m^2	0.46 ml/m^2	0.23 ml/m^2	Control	0.92 ml/m^2	0.46 ml/m^2	0.23 ml/m^2	Control	0.92 ml/m^2	0.46 ml/m^2	0.23 ml/m^2
June 15	1.000 (.04)	0.682 (.14)	0.598 (.09)	0.842 (.10)	0.981 (.12)	0.821 (.08)	0.861 (.02)	0.668 (.07)	0.938 (.04)	0.755 (.04)	0.707 (.12)	0.793 (.07)
June 28	0.981 (.12)	0.719 (.05)	0.991 (.14)	0.916 (.11)	0.938 (.04)	0.573* (.06)	0.688 (.09)	0.770 (.10)	1.046 (.06)	0.610 (.14)	0.574* (.11)	0.831 (.19)
July 14	0.938 (.04)	0.488* (.07)	0.534* (.04)	0.595* (.12)	1.046 (.06)	0.477* (.05)	0.437* (.03)	0.363* (.06)	1.227 (.09)	0.613* (.12)	0.483* (.07)	0.475* (.13)
July 26	1.046 (.06)	0.390*† (.06)	0.657* (.03)	0.795† (.04)	1.227 (.09)	0.664* (.09)	0.751* (.06)	0.646* (.10)	1.097 (.07)	0.474* (.12)	0.791 (.11)	0.679* (.13)
Aug 8	1.227 (.09)	0.579* (.02)	0.557* (.10)	0.720* (.12)	1.097 (.07)	0.578* (.11)	0.573* (.04)	0.591* (.15)	1.180 (.18)	0.675 (.02)	0.697 (.15)	0.654 (.11)
Aug 25	1.097 (.07)	0.502* (.13)	0.843 (.13)	0.793 (.14)	1.180 (.18)	0.636 (.05)	0.644 (.15)	0.480* (.12)	-	-	-	-

Standard errors shown in brackets. Treatment means with * within a date differ significantly from the control at $p < 0.05$ (N=3).
Treatments with † are significantly different from one another, determined by Scheffe's multicomparison test (Appendix 3).

causing a significant reduction 4 weeks after treatment (having 38.9% less chlorophyll than the control) and 1.1 kg/ha of picloram, 6 weeks after treatment with 45.1% less chlorophyll (Table 3). When applied on July 14 all treatments were significantly decreased at all three sampling times. *Sphagnum* treated on July 26 produced similar results to those on July 14, the highest dosage reduced the chlorophyll to 0.390 mg Chl g^{-1} dry wt and the lowest dosage to 0.795 mg chl g^{-1} dry wt differing significantly ($p<0.05$) from one another after 2 weeks. *Sphagnum* treated at the lowest dosage had 38.72% more chlorophyll than *Sphagnum* treated at the highest level (Table 3). After 6 weeks plants treated with 0.46 ml/m^2 (treatment B) showed a slight increase in chlorophyll from 0.751 to 0.791 mg Chl g^{-1} dry wt. The chlorophyll content of the control plants increased in August. Herbicide applied on August 8 reduced the chlorophyll significantly after 2 and 4 weeks and some recovery occurred by week 6. Application on August 25 produced variable results with treatment A causing a significant decrease after 2 weeks and treatment C after 4 weeks.

To adjust for the differences of the chlorophyll content in the untreated *S. fuscum*, the samples of the treated plots were calculated as a percentage of the control values. Figure 10a illustrates the chlorophyll content of *S.fuscum* treated at Sprague with 2.2 kg/ha (treatment A) 2, 4, and 6 weeks after herbicide application from June to August, 1988. The general trend indicates that the application in June is the least effective and treatment in July being the most effective with application in August falling in between.

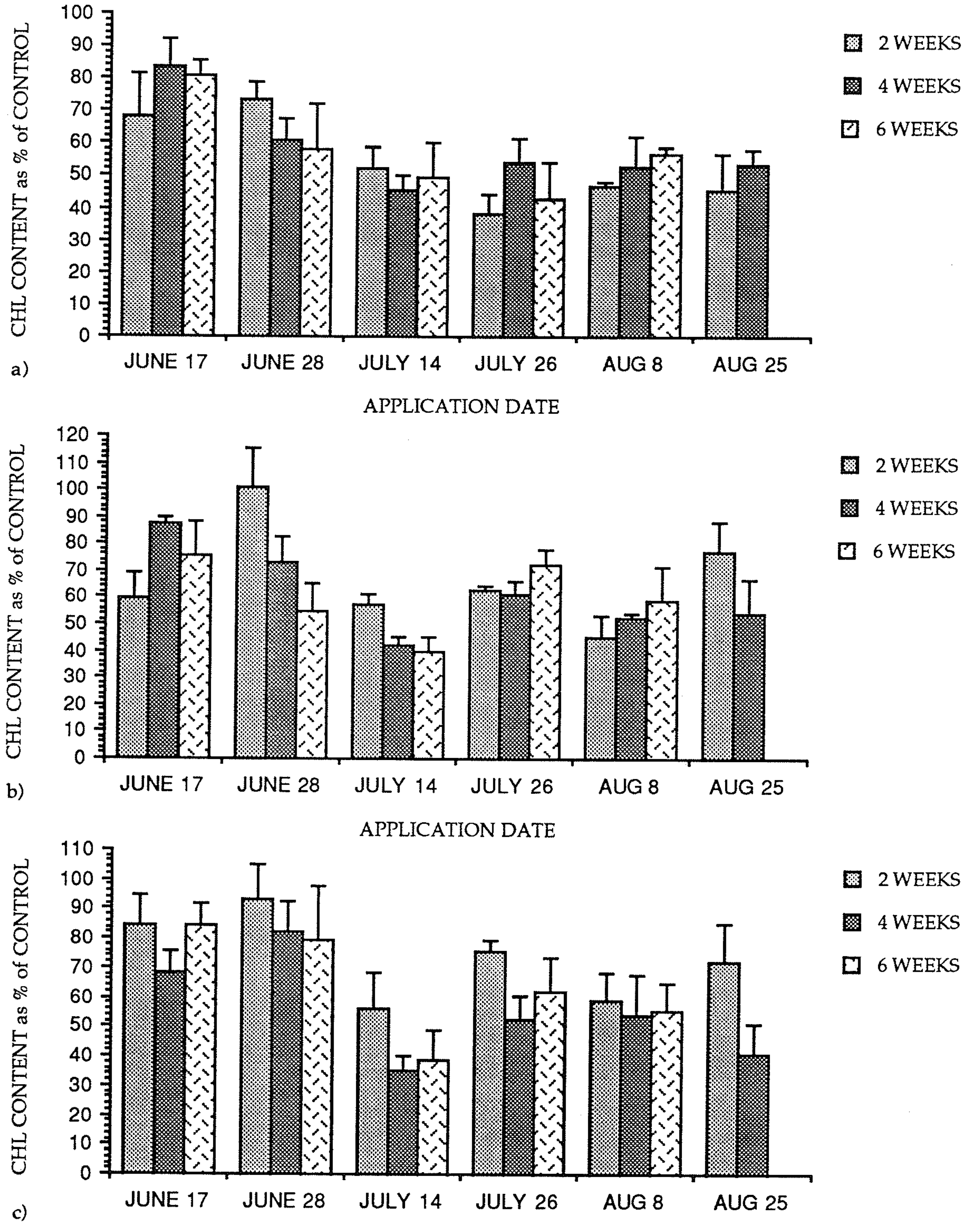


FIGURE 10

Picloram Application at Sprague Site. Chlorophyll Content of Capitula of *Sphagnum fuscum* from plots treated at various times with a) 2.2 kg/ha b) 1.1kg/ha and c) 0.55 kg/ha of picloram collected 2, 4, and 6 weeks after application. Each bar +/- Standard Error (N=3).

Picloram applied at 1.1 kg/ha (Figure 10b) demonstrated a similar trend as the *Sphagnum* treated with 2.2 kg/ha, although there was greater variability. Application on June 17 is more effective than on June 28. Two weeks after treatment on June 28 the treated plants showed greater chlorophyll content than the untreated plants. This occurred as a result of the treated plants having a higher initial chlorophyll content than the untreated plants. As with treatment A the greatest decrease occurred when picloram was applied on July 14. The chlorophyll content of the treated plants increased slightly with treatment from the end of July to the end of August.

Treatment C (0.55 kg/ha or 0.23 ml/m^2) (Figure 10c) showed even greater variability than *Sphagnum* treated with 1.1 kg/ha. Although, the general trend was similar, the magnitude of change was smaller and the greatest decrease occurred when the herbicide was applied on July 14.

Application of picloram at Elma reduced the chlorophyll content at all three herbicide rates and sampling times. The chlorophyll content of the control plants at Elma was higher than the control plants at Sprague and significant reductions in the chlorophyll content were observed at Elma.

Picloram at all three rates significantly decreased the chlorophyll content of the treated plants at Elma 2 and 4 weeks after application on June 17 (Table 4). Although, 6 weeks after 1.1 kg/ha of picloram was applied the chlorophyll content of the treated plants was not significantly lower than that of the untreated, being 33.5% less than the untreated. The chlorophyll content of the treated *Sphagnum* had decreased from 0.953 mg Chl g^{-1} dry wt

Table 4.

The effect of Tordon 22K on the chlorophyll content (mg Chl g^{-1} dry weight) of *S.fuscum* (capitula) at Elma from June to August (1988) 2, 4, and 6 weeks after the treatment date.

	2 weeks				4 weeks				6 weeks			
Treatment Date	Control	0.92 ml/m2	0.46 ml/m2	0.23 ml/m2	Control	0.92 ml/m2	0.46 ml/m2	0.23 ml/m2	Control	0.92 ml/m2	0.46 ml/m2	0.23 ml/m2
June 17	1.590 (.14)	0.841* (.18)	0.990* (.12)	0.719* (.09)	1.480 (.08)	0.697* (.12)	0.953* (.16)	0.766* (.07)	1.379 (.11)	0.478* (.13)	0.917 (.16)	0.709* (.14)
June 28	1.480 (.08)	0.690* (.09)	0.642* (.06)	0.793* (.10)	1.379 (.11)	0.622* (.06)	0.701* (.11)	0.852 (.26)	1.615 (.09)	0.935* (.09)	0.989* (.25)	1.318 (.13)
July 12	1.379 (.11)	0.773* (.15)	0.818 (.08)	0.891 (.11)	1.615 (.09)	0.716* (.04)	0.580* (.06)	0.945* (.12)	1.468 (.09)	0.548* (.07)	0.696* (.05)	0.662* (.10)
July 26	1.615 (.09)	0.712* (.10)	1.085* (.13)	1.148 (.11)	1.468 (.09)	0.540* (.03)	0.803* (.16)	0.964* (.07)	2.235 (.19)	0.872* (06)	0.919* (.08)	1.043* (.12)
Aug 8	1.468 (.09)	0.952* (.08)	1.081* (.03)	1.158* (.12)	2.235 (.19)	0.826* (.06)	1.082* (.15)	0.857* (.10)	2.072 (.06)	0.941* (.08)	1.202* (.25)	1.333* (.13)

Standard errors shown in brackets. Treatment means with * within a date differ significantly from the control at $p < 0.05$ (N=3) (Appendix 3).

at 4 weeks to 0.917 mg Chl g^{-1} dry wt at 6 weeks (percentage calculations based on table 4). However, when the chlorophyll content is expressed as a percentage of the untreated, there was an ~ 2 % increase in the chlorophyll (Figure 11b). Picloram applied at the 2.2 and 1.1 kg/ha on June 28 reduced the chlorophyll of the treated plants significantly at all sampling times. Treatment C (0.55 kg/ha) only decreased the chlorophyll significantly 2 weeks after treatment and increasing to 80% of the control after 6 weeks (Figure 11c). When *Sphagnum* was treated on July 12 only treatment A reduced the chlorophyll content after 2 weeks by 46.9%, however by 4 weeks all three rates had caused a significant decrease and no recovery was observed by the sixth week (Table 4). Similar results were obtained for July 26, when only treatment C did not result in a significant decrease until the fourth week after application. Unlike Sprague, all three rates applied on August 8 significantly reduced the chlorophyll content at all sampling times. Similarly at Sprague the chlorophyll content of the untreated plants increased in August. The values obtained for the chlorophyll content of the untreated plants at Elma were generally higher than those observed at Sprague.

At Elma 2.2 kg/ha (Figure 11a) significantly reduced the chlorophyll content at all treatment and sampling times. There was some variation observed between the application dates. For example, treatment on June 17 showed a continuous decrease in the chlorophyll content over the 6 week sampling period, while treatment 2 weeks later on June 28 showed recovery of the chlorophyll content after 6 weeks. In general the chlorophyll content of the treated plants was reduced from ~64 and ~44 percent of the control in

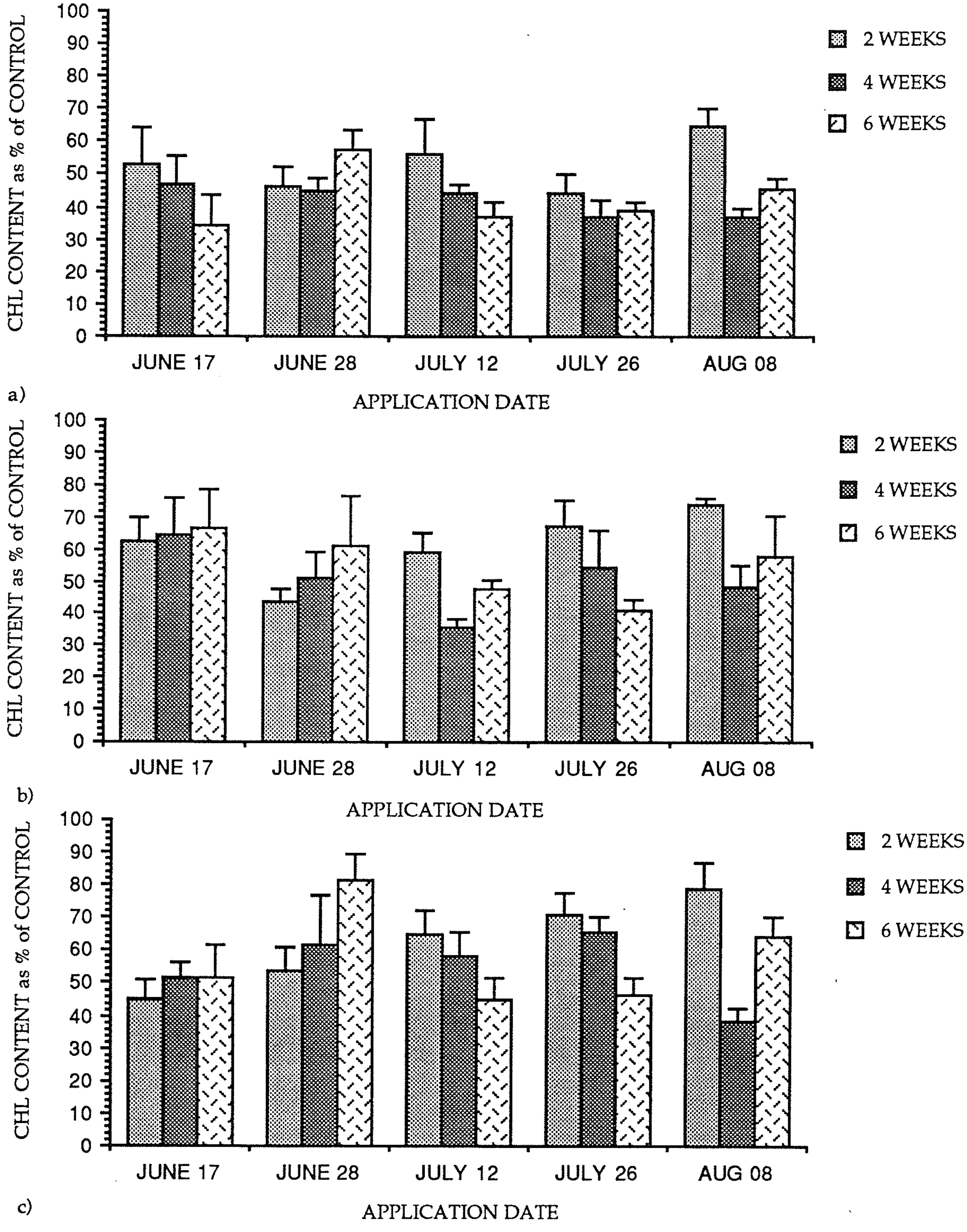


FIGURE 11

Picloram Application at Elma Site. Chlorophyll Content of Capitula of *Sphagnum fuscum* from plots treated at various times with a) 2.2 kg/ha b) 1.1 kg/ha and c) 0.55 kg/ha of picloram collected 2, 4, and 6 weeks after application. Each bar +/- Standard error (N=3).

the first 2 weeks after the herbicide was applied with little change occurring after 4 and 6 weeks.

Treatment B (1.1 kg/ha) at Elma (Figure 11b) illustrated greater variability in results than treatment A. The chlorophyll content was reduced from ~73 to ~43 percent of the control after the first 2 weeks. The general trend indicated that application of picloram at Elma will reduce the chlorophyll content of *S.fuscum* regardless of the application date.

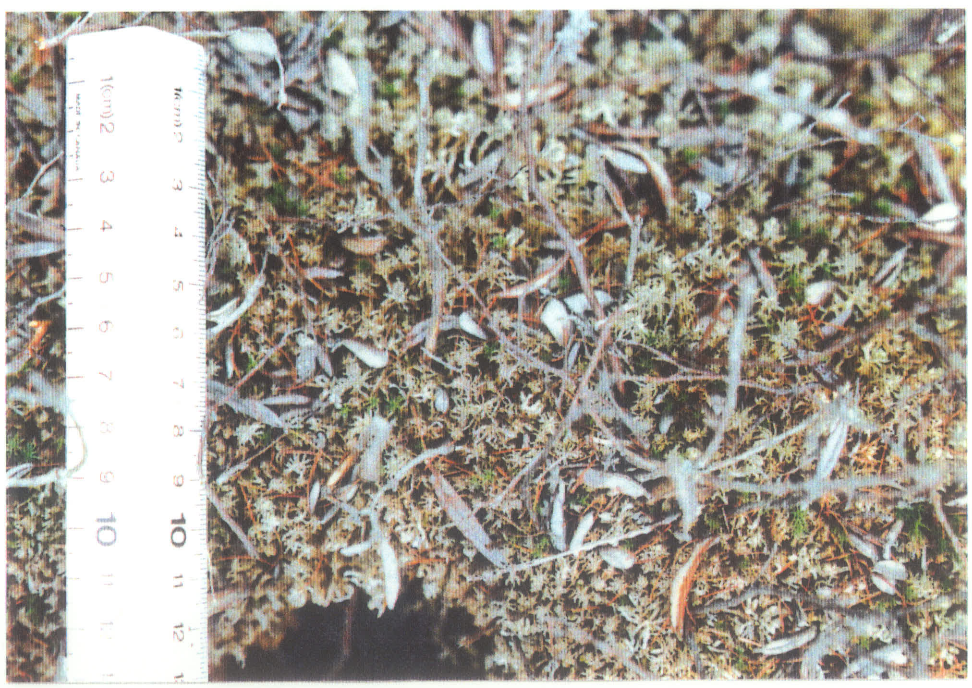
Treatment of 0.55 kg/ha of picloram (Figure 11c) showed the most erratic results of the three rates at Elma. For example, treatment in June indicated the chlorophyll values partially recovered after week 6, while application in July illustrated a continual decrease over the 6 week period sampled and application in August is variable. The general trend observed at this herbicide level indicated less chlorophyll was lost when picloram was applied later in the summer.

Although recovery of the chlorophyll content in *S.fuscum* was observed sporadically throughout the treatment , the plants remained dried and a brown yellow in colour one year after treatment (Figure 12b). The plants appeared dead and no recovery was apparent. Other bryophyte species (eg. *Polytrichum* sp.) were apparently unaffected by the application of the three treatment levels of picloram. The untreated *S. fuscum* was moist and a healthy brown green in colour (Figure 12a).

Application of Tordon 22K at the three treatment levels significantly reduced the chlorophyll content of the treated *S.fuscum* at all sampling

Figure 12 *Sphagnum fuscum* - at Elma

a) Untreated *Sphagnum* - healthy green brown in color (June, 1989).



b) Treated *Sphagnum* - one year after application with picloram at 0.46 ml/m2 (June, 1989).

Table 5.

The effect of Tordon 22K to the chlorophyll content (mg Chl g^{-1} dry weight) of *S.fuscum* (capitula) at Devil's Lake from May to August (1988) 1, 2, and 3 months after the treatment date.

	1 month				2 months				3 months			
Treatment Date	Control	0.92 ml/m2	0.46 ml/m2	0.23 ml/m2	Control	0.92 ml/m2	0.46 ml/m2	0.23 ml/m2	Control	0.92 ml/m2	0.46 ml/m2	0.23 ml/m2
May 18	2.299 (.16)	0.939* (.02)	1.076* (.03)	1.006* (.06)	1.654 (.02)	0.580* (.003)	0.612*† (.02)	0.419*† (.01)	0.971 (.01)	0.179* (.01)	0.219*† (.01)	0.423*† (.02)
June 16	1.654 (.02)	0.610* (.04)	0.482*† (.02)	0.706*† (.02)	0.971 (.01)	0.298* (.01)	0.240* (.02)	0.337* (.03)	-	-	-	-
July 16	0.971 (.01)	0.356*† (.01)	0.464*† (.02)	0.415* (.03)	-	-	-	-	-	-	-	-

Standard errors shown in brackets. Treatment means with * within a date differ significantly from the control at $p < 0.05$ (N=3). Treatments with † are significantly different from one another, determined by Scheffe's multicomparison test (Appendix 3).

times at Devil's Lake (Table 5). The overall decrease of chlorophyll observed at Devil's Lake was greater than for either Sprague or Elma. The chlorophyll content of the untreated plants decreased from May through to July , which was similar to both Sprague and Elma.

Treatment A (2.2 kg/ha) applied on May 18 reduced the chlorophyll content of the treated plants to ~41% of the chlorophyll content of the control 4 weeks after treatment (percentage calculations based on Table 5). After 8 weeks the chlorophyll content had decreased a further 6% and by 12 weeks the chlorophyll content was ~18% of the control. Similar initial trends were observed when 2.2 kg/ha was applied on June 16 and July 16 (Figure 13a). Four weeks after application, on July 16, treatment A had 0.356 mg Chl g^{-1} dry wt which differed significantly ($p<0.05$) from treatment B at 0.464 mg Chl g^{-1} dry wt (Appendix 3). The general trend indicated that application of picloram at 0.92 ml/m^2 (2.2 kg/ha) would significantly reduce the chlorophyll content of *S. fuscum* regardless of the date when treated.

Treatment B (1.1kg/ha) reduced the chlorophyll content of the treated plants from ~47 to ~30% of the untreated 4 weeks after application. After 8 weeks the chlorophyll (similar to treatment A) had been reduced a further 10%. The final collection indicated a further decrease, although the chlorophyll value 0.219 mg Chl g^{-1} dry wt was slightly higher than those plants treated with 0.92 ml/m^2 (2.2 kg/ha). *Sphagnum* treated on June 16 with 1.1 kg/ha had a chlorophyll content of 0.482 mg Chl g^{-1} dry wt, which differed significantly from *Sphagnum* treated with 0.55 kg/ha with 0.706 mg Chl g^{-1} dry wt 4 weeks following application, as well as 8 and 12 weeks after treatment on May 18 (Table 5 and Appendix 4). Unlike 2.2 kg/ha, application

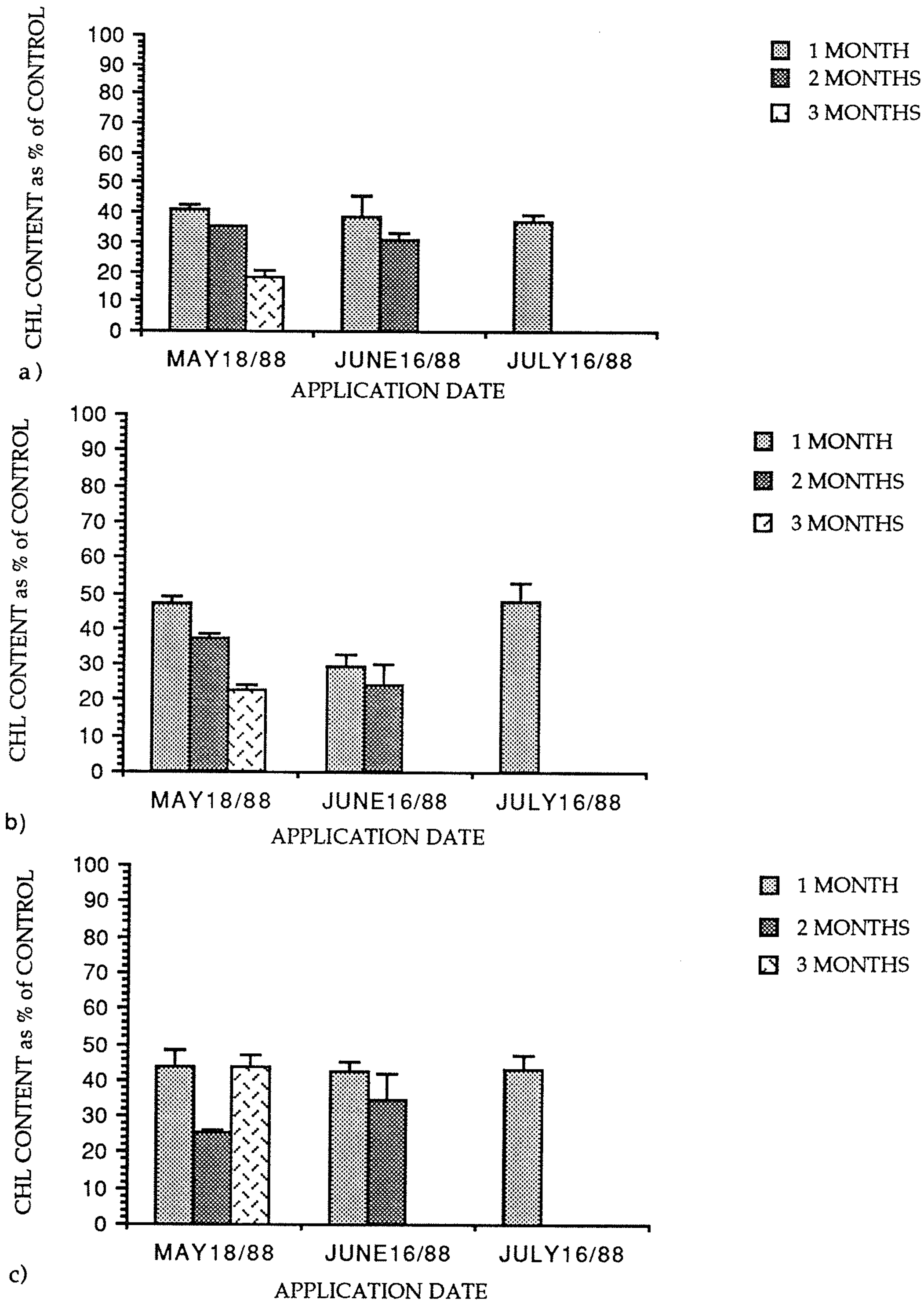


FIGURE 13

Picloram Application at Devil's Lake. Chlorophyll Content of Capitula of *Sphagnum fuscum* from plots treated at various times with a) 2.2 kg/ha b) 1.1 kg/ha and c) 0.55 kg/ha of picloram collected 1, 2, and 3 months after application. Each bar +/- Standard Error (N=3).

of 1.1 kg/ha indicated that treatment on June 16 would be more effective at reducing the chlorophyll content of *S. fuscum*.

Picloram applied at 0.55 kg/ha produced similar chlorophyll values to *Sphagnum* treated with 2.2 kg/ha after the first 8 weeks, decreasing from ~47% of the control plants to 36% of the chlorophyll content. The general trend paralleled the *Sphagnum* treated with 2.2 kg/ha, indicating application date had little effect on the reduction of the chlorophyll content. Unlike 2.2 and 1.1 kg/ha picloram applied at 0.55 kg/ha showed an increase or recovery of chlorophyll 3 months after application (Figure 13b).

<u>Elongation</u>

Piclroam decreased the elongation of *S.fuscum*. At Sprague the untreated plants elongated more that at the other two sites (Figure 14). As the season progressed the untreated *Sphagnum* elongated less than in the earlier part of the season such that there was less than 1 mm of growth between August 25 to September 22, 1988. The treated plants increased in elongation during the same period. The plots treated early in the season showed a negative elongation or "negative growth"; because the *Sphagnum* carpet had dried out and pulled away from the crankwire resulting in a negative measurement. The untreated plants at Sprague had grown or elongated over 6 mm from June 17 to September 22, while the treated plants had pulled away from the crankwire from 1 to 3 mm over the same period. The *Sphagnum* treated on July 14 and 26 (10 and 8 weeks after installation respectively) (Figure 14) showed little change in growth. Measurements observed 4 and 6 weeks after the herbicide was applied indicated that the

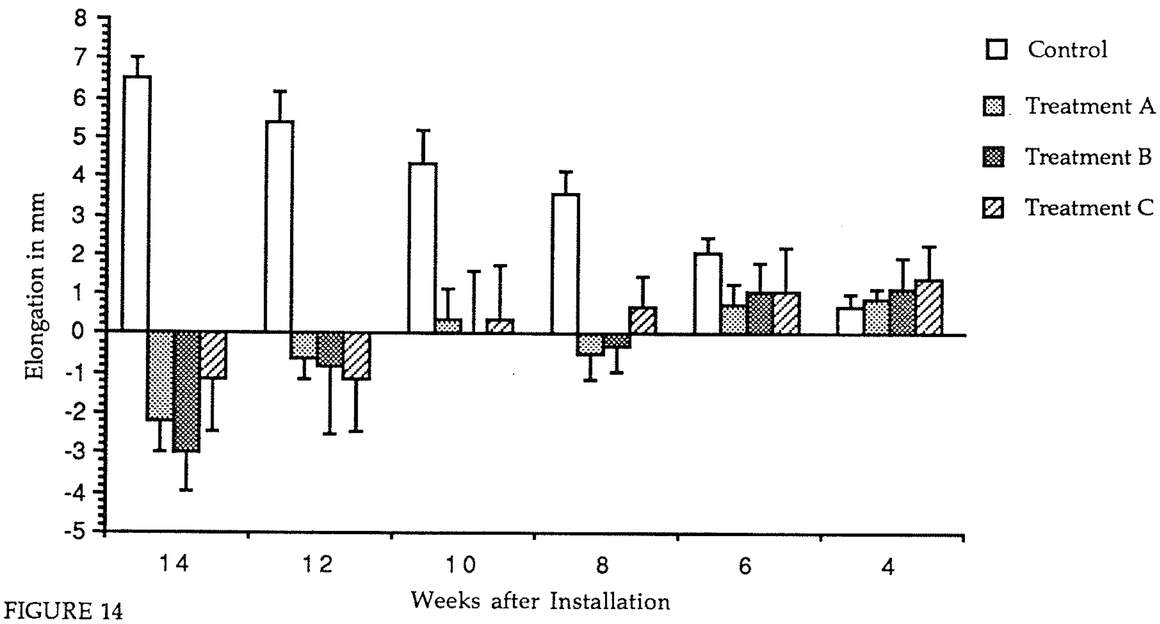


FIGURE 14

Herbicide Application at Sprague. Effect of Tordon 22K Sphagnum fuscum growth treated from June to August, 1988. Standard error of means (n=3).

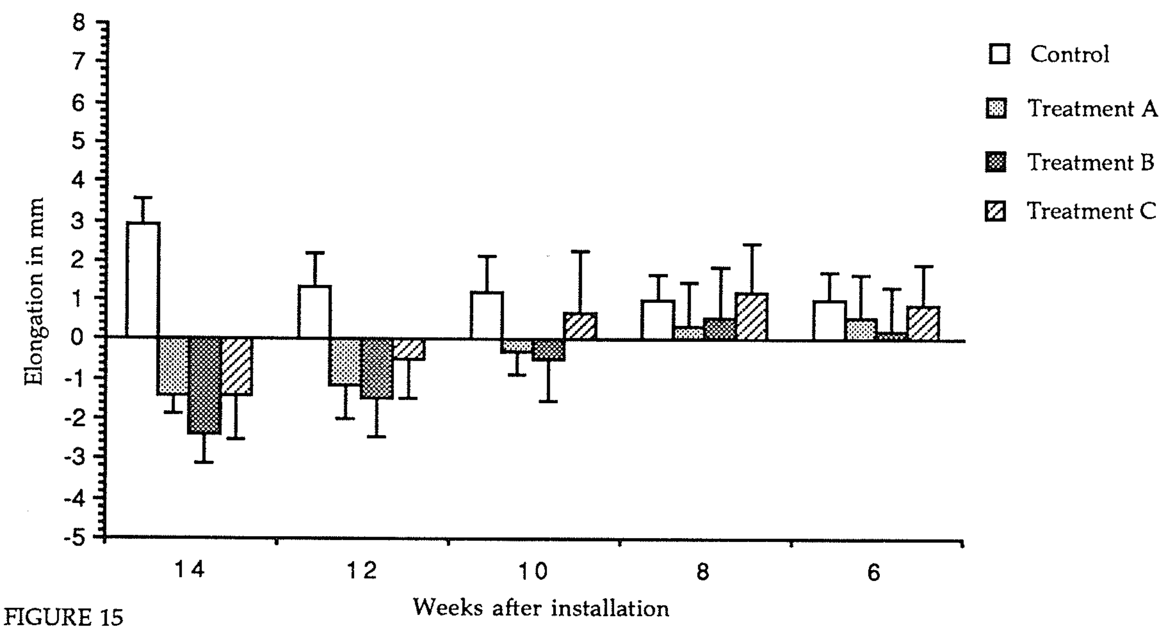


FIGURE 15

Herbicide Application at Elma. The Effect of Tordon 22K Sphagnum fuscum growth treated from June to August, 1988. Standard error of means (n=3).

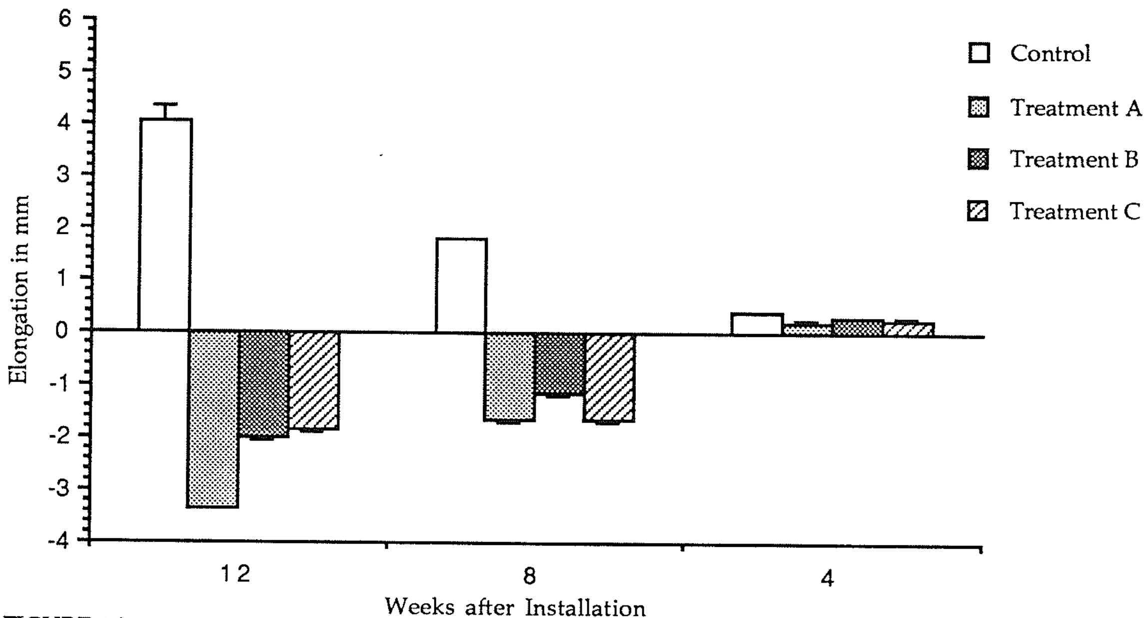


FIGURE 16

Herbicide Application at Devil's Lake. Effect of Tordon 22K Sphagnum fuscum growth treated from June to August 1988. Standard error of the means (n=3).

plants had elongated as much as or more than the control plants. It was noted that all three herbicide levels had a comparable effect on the plants.

The three levels of picloram applied at Elma produced similar results to those observed at Sprague (Figure 15). The untreated plants decreased in elongation over the study while the treated plants increased. The growth of the untreated moss at Elma was half, (~3 mm) of the untreated plants growth at Sprague. The treated *Sphagnum* at Elma showed a similar shrinkage to the treated plants at Sprague. Picloram applied at 1.1 kg/ha on June 17, 28 and on July 12 resulted in the greatest shrinkage of the three herbicide levels, whereas picloram applied at 0.55 kg/ha on July 12, 26 and on August 8 produced the most substantial elongation. However, it should be noted that there is little difference in the overall effect of the herbicide on *Sphagnum* (Figure 15).

Treated and untreated *Sphagnum* at Devil's Lake illustrated the same pattern of "negative growth" and elongation as the plants at Sprague and Elma (Figure 16). The untreated plants had grown ~4 mm from May to August and ~2 mm from June to August, which was the least growth observed at the three sites studied. The treated *Sphagnum* pulled away marginally from the crankwires. Four weeks after the crankwires were installed at Devil's Lake the *Sphagnum* had dried and only a slight elongation was observed, and the capitula were no longer in compact tufts (Figure 17). The shrinkage and loss of capitula compactness was most distinct at this site although also present to a lesser degree at Sprague and Elma.

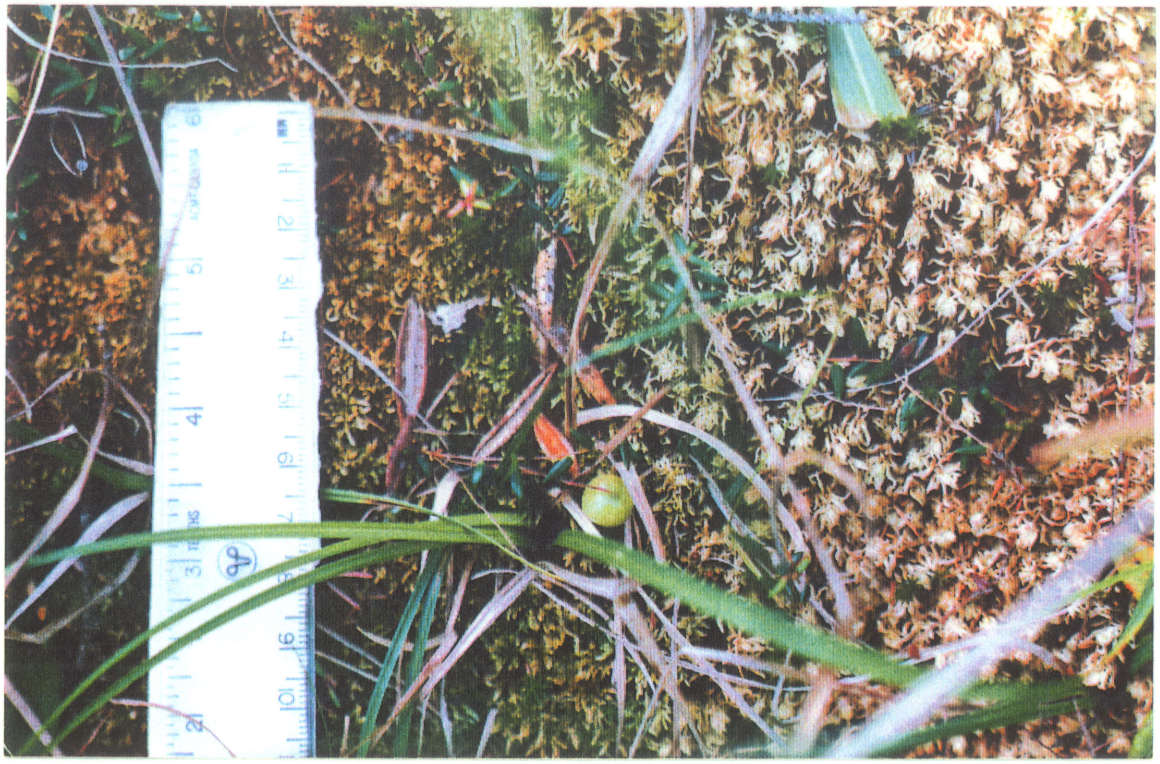


Figure 17. Comparison of untreated and treated *Sphagnum fuscum* at Devil's Lake, one month after treatment with 0.46 ml/m2, showing capitula elongation and the pale yellow-brown colour of the treated plants.

Culture

Culturing of *S. fuscum* under controlled conditions enabled closer observations to be made on the structural modifications of the capitula by picloram and helped to achieve a better understanding of what had occurred to the *Sphagnum* in the field. The capitula expanded from 0.5 to 15.0 mm in three weeks prior to transfer. The control capitula remained compact and a healthy green and the branches developed compact tips of new individuals six days after being transferred onto new plates. The capitula had grown an average of 6.3 mm (Table 6) in diameter during the six days and the agar medium was clear of algal populations. Although algal populations, such as *Nostoc* sp. were observed in close association with the control capitula, they did not invade the agar media (Figure 18). Seventeen days after being transferred the capitula had expanded by 19.7 mm and many of the expanding tips showed new capitula developing.

The treated plants at all three herbicide levels were a yellowish brown in colour and it was observed that six days after being transferred and treated with picloram, algal communities associated with *S. fuscum* migrated into the agar medium leaving the plate yellow (Figure 18 b.c.d). The three herbicide levels produced variable results in the expansion of the diameter of the capitula. The capitula treated with picloram equivalent to the field application of 0.23 ml/m^2 showed the least growth of all the cultures, expanding only 4.7 mm after six days (Figure 18b). Those capitula treated with picloram equivalent to the highest rate used in the field 0.92 ml/m^2 showed the greatest growth in diameter both at six days 8.7 mm and after 17 days 25.0 mm (Figure 18d). The capitula which were treated with picloram at

Figure 18 *Sphagnum* capitulum cultured and treated under controlled conditions. (size of the labels 4.4 cm in length).

a) Untreated *Sphagnum* showing a heathly compact capitula. The agar medium remaining relatively clear of algae after two weeks. *Nostoc* sp. is in close association with branch leaves.

b) *Sphagnum* capitulum treated with picloram at a rate equivalent to 0.23 ml/m^2 (1/2X Manitoba Hydro's Rate). Agar medium is pale yellow from algae and the capitulum, although still recognizable is no longer compact.

c) *Sphagnum* capitulum treated with picloram at a rate equivalent to 0.46 ml/m^2 (1X Manitoba Hydro's Rate). Agar medium is yellow from migrating algae and capitulum is no longer structurally identifiable.

d) *Sphagnum* capitulum treated with picloram at a rate equivalent to 0.92 ml/m^2 (2X Manitoba Hydro's Rate). Agar medium is yellow from migrating algae and the orginal capitulum is no longer recognizable.

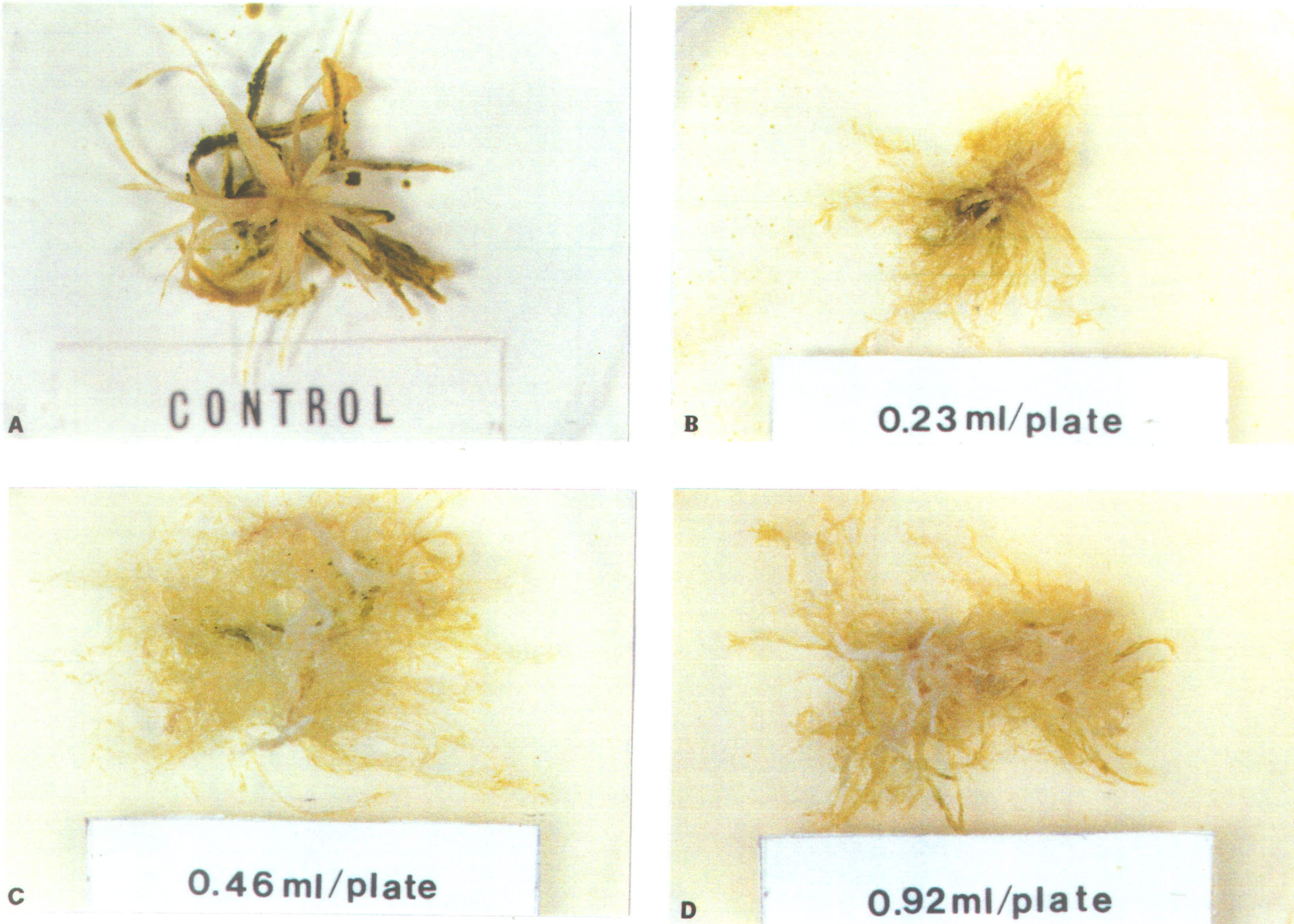

A
CONTROL
B
0.23 ml/plate
C
0.46 ml/plate
D
0.92 ml/plate

Table 6

The diameter expansion of capitula cultured under controlled conditions at 22 º C in continuous light. Standard errors shown in brackets (N=3).

	mm of diameter expansion			
Days After Application	Control	0.92 ml/m2	0.46 ml/m2	0.23 ml/m2
4	3.3 (.03)	5.7 (.06)	4.7 (.05)	2.7 (.05)
6	3.0 (.03)	3.0 (.08)	2.3 (.03)	2.0 (.05)
7	3.0 (.07)	3.0 (.05)	3.3 (.03)	5.0 (.05)
10	3.0 (.20)	3.3 (.08)	2.1 (.08)	2.7 (.03)
12	2.3 (.20)	2.37 (.16)	3.3 (.00)	1.3 (.05)
17	5.1 (.20)	7.6 (.19)	3.67 (.10)	4.0 (.08)

0.46 ml/m^2 showed greater expansion in diameter after six days than the control plant 7.0 mm (Figure 18c), although after 17 days the control plants showed a slightly greater diameter (Table 6).

The capitula of the treated plants began to deteriorate after six days, whereas the control capitula remained compact. It was also noted that the lower levels of herbicide resulted in the dichotomy of the capitula, increasing the number of branching capitula tips. Although the greatest expansion in diameter was observed from the capitula treated with the highest concentration, no new capitula tips were recorded. The petri dish lids were removed at the end of the experiment to photograph the changes. The treated capitula dried quickly and became a pale yellow in colour, whereas the control capitula remained moist and viable for two to three days after the lids were removed.

Conductivity

The conductivity of *S. fuscum* treated with picloram was used as a rapid measure of herbicide injury (Vanstone and Stobbe, 1977). All samples were treated with 1.104 ppm picloram equivalent to the field rate used by Manitoba Hydro. The active metabolizing capitula produced an overall increase in the conductivity during the experiment (Figure 19a). The stems, which are the older dying portions of the plant did not increase in conductivity (Figure 19b). The whole plant showed a greater increase in the conductivity than the combination of the conductivity of the stem and capitula individually (Figure 19c).

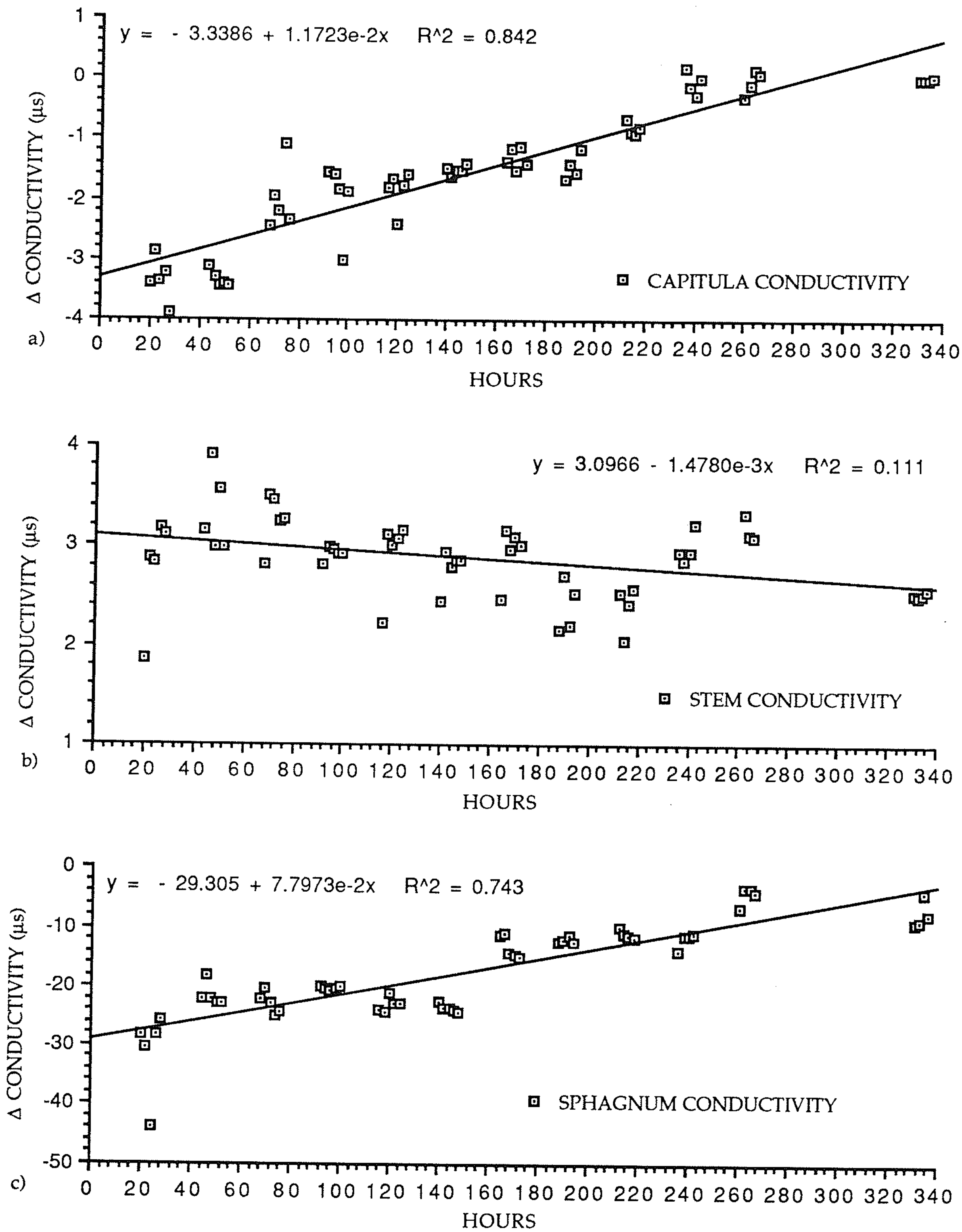


Figure 19

The Effect of Picloram at 1.104 ppm (Manitoba Hydro's Rate) to the Conductivity of a) Capitula b) Stems and c) Whole Plant of S. fuscum under Controlled Laboratory Conditions.

Both the treated capitula and whole *Sphagnum* plants had lower conductivities than the controls at the beginning of the experiment. This resulted in negative values being observed until the end of the experiment when the conductivity of the treated plants had increased to be approximately equal to that of the control plants. In this set of experiments the beakers were covered with parafilm to prevent evaporation. After two weeks the untreated control appeared bright green and the capitula remained compact, whereas the *Sphagnum* treated with 1.104 ppm picloram showed dissolution of the capitula, which had become a dull beige green in colour (Figure 20a). One stem from each beaker was extracted and photographed to illustrate the effects of the picloram on the active metabolizing portion of *S. fuscum* (Figure 20b). The control plants showed no alteration in the morphological structure after 2 weeks whereas the treated plant had no recognizable capitulum (Figure 20b). Micrographs were taken from a branch removed from the capitulum of a control plant and a branch from the tip of a treated plant (Figure 21a,b). The compact growing point of the control plant is surrounded by large uniform branch leaves, which have a relatively short internode (the length of branch stem between the branch leaves) (Figure 21a). The treated plant illustrates extensive twisting and elongation of the growing tip. Furthermore, the newly developed leaves are stunted with abnormally long internodal lengths (Figure 21b). Although, only plants from trial 1 were used in the photographs the treated and untreated plants from the trial 2 conductivity experiment showed similar morphological changes.

The second trial was run with equivalent weights measured for each particular treatment and the beakers were left exposed to allow for

Figure 20 *Sphagnum fuscum* from conductivity experiment, trial 1 (with parafilm).

a) The control and treated plants in the beakers have their bases covered with aluminium foil. The compact capitulum of the control plants (left) remained bright green throughout the two week experiment, while the treated *Sphagnum* (right) turned beige green in colour and showed dissolution of the capitula approximately three days after application.

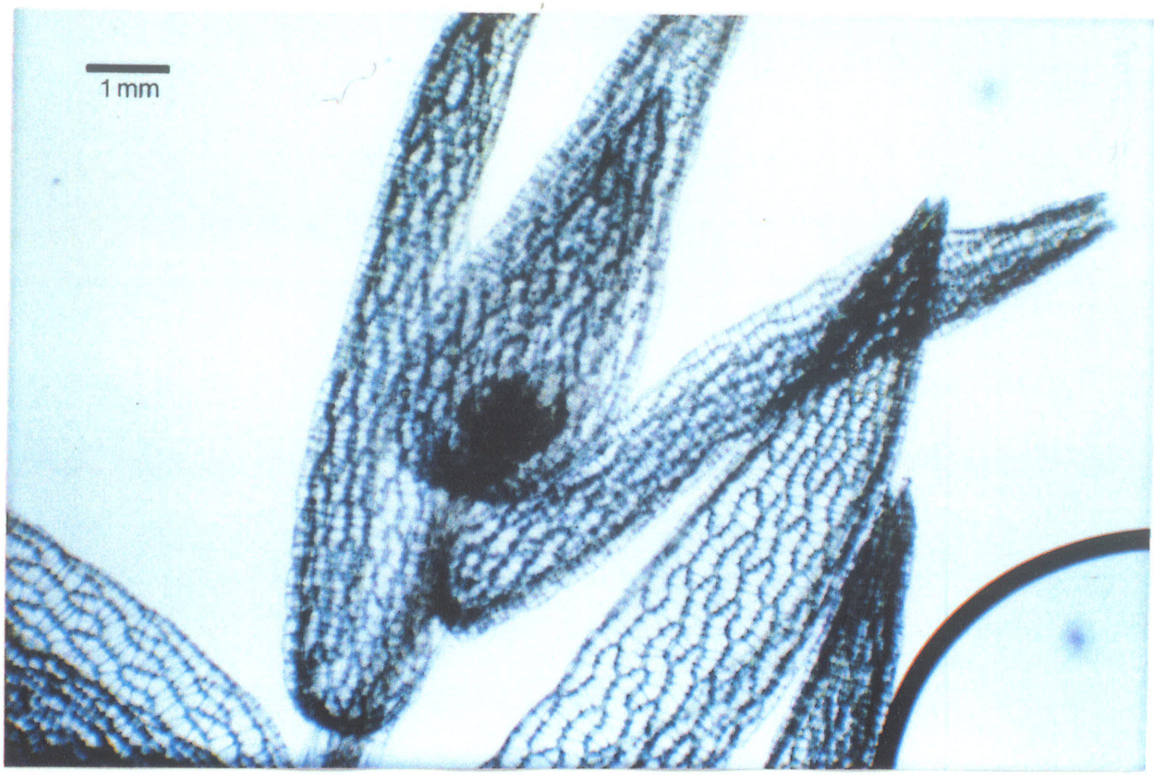
b) Treated and control plants removed from the respective beakers. The control plant (left) appeared healthy and the capitulum compact. The stem of the treated plant (right) appeared similar to the control plant, except the tip showed no recognizable capitulum.


cm
2
3
4
5
6
7
8
9

Figure 21. Micrographs of branches removed from the apex (capitulum area) of *Sphagnum fuscum* used in the conductivity experiment (trial 1).

a) The tip of a branch selected from the compact capitulum of the control *Sphagnum.* The growing tip is compact with well developed leaves having relatively short internodes.

b) A branch removed from the tip of a treated *Sphagnum* plant. The growing tip illustrates extensive twisting (epinasty) and elongation and the new leaves are small and poorly developed.


1 mm


1 mm

evaporation. The results for the stems and the capitula produced similar results to those observed in the first trial (Appendix 5). In the second trial, the *Sphagnum* showed a slight decrease in conductivity. The high evaporation rate from the treated *Sphagnum* in the beakers required 20 ml of the picloram solution to be added daily to maintain the water level. The control beaker required only a few mls of deionized water every three of four days. Similar to the first trial, the treated *Sphagnum* capitula illustrated extensive elongation and when allowed to dry became a pale yellow brown in colour.

Discussion

This study has verified that *S.fuscum* is susceptible to picloram, and that picloram may result in irreversible damage to at least one species within this genus. *Sphagnum* species are fundamental to the production and maintenance of the bog community. The reduction or elimination of this species will alter the natural plant succession in the habitat and subsequent peat accumulation by reducing the production of decay resistant material (Reader and Stewart, 1972; Suffling and Smith, 1979). The sensitivity or tolerance of specific *Sphagnum* species to picloram herbicides has also been documented by others. *S. magellanicum* (Dana, 1967), *S. capillaceum* and *S. palustre* (Suffling, 1975) are reported to be tolerant or resistant to Tordon 101 (a 2, 4-D picloram formulation), whereas *S. fuscum* and *S. nemoreum* are reported as sensitive (Magnusson, 1986). After treatment the susceptible *Sphagnum* species are replaced either successionally by picloram-tolerant moss species such as *Polytrichum strictum* which leads to a drier bog community, or to picloram-resistant sedge and grass species resulting in a wetter fen community (Magnusson, 1986). This replacement of the *Sphagnum* species under the hydro electric transmission lines is satisfactory from a management point of view in that it fulfils the management objectives of: a) producing vegetation which will not interfere with the transmission of electricity and b) producing a vegetation cover that is easily accessible to maintenance and inspection.

<u>Chlorophyll content</u>

Analysis of chlorophyll a and b content indicated that picloram decreased the chlorophyll content of *S.fuscum.* The symptoms of chlorophyll degradation occur on dying plants following picloram spraying. Bachelard and Ayling (1971) suggested that picloram disrupted the chloroplast membrane structures and the integrity of all membranes in the stem tips of certain dicotyledonous plant species. Other investigators have noted that picloram inhibited photosynthesis, decreased the chlorophyll content, disrupted the cell walls and interfered with protein and nucleic acid metabolism and synthesis in a variety of vascular plants (Chang and Foy, 1971 a; Sharma and Vanden Born, 1972; Foy, 1980). Degraded chlorophyll levels in *S.fuscum* may have been caused by similar disruptions in cellular metabolism. The chlorophyll content may be further degraded by loss of algal populations associated with *Sphagnum* sp.. Prior to determination of the chlorophyll content, the algal chlorophyll was considered to represent a small percentage of the total chlorophyll readings. Algal chlorophyll will be recorded as background noise in the chlorophyll readings. More precision in the chlorophyll determination of *Sphagnum* could be obtained by low powered sonication of the capitula to remove the epiphtyic algal populations prior to chlorophyll extraction.

The chlorophyll content of the untreated *Sphagnum* capitula ranged from 1.00 - 1.23 mg g^{-1} dwt at Sprague, 1.30 - 1.62 mg g^{-1} dwt at Elma and 0.97 - 2.29 mg g^{-1} dwt at Devil's Lake from June to August. These values are similar to the ranges (1.20 - 3.00 mg g^{-1} dwt) reported in the literature

(Parkarinen and Tolonen, 1978; Karunen and Salin, 1982; Gaberscik and Martincic, 1987). The chlorophyll content of the treated plants was generally lower than the chlorophyll content of the untreated, although the values varied between the sites; Devil's Lake showed the greatest decrease and Sprague the least.

The Sprague site is a treed bog with an Ericoid-*Sphagnum* association, where the water level was high throughout the season and highest during June. Grace (1970) observed that when *Sphagnum* grows in a saturated habitat the photosynthetic rate decreases due to the longer path of CO_2 diffusion. This indicated that the decrease of chlorophyll content in June probably has resulted from the lower photosynthetic activity of the plants. Later as the water level dropped in July and August the metabolic activity of the *Sphagnum* increased, more picloram was assimilated and greater reductions of the chlorophyll content were recorded.

The rainfall received at Sprague from the time of application in June to the collections made in July was approximately 184.2 mm. The excess of rain diluted the highly water soluble picloram, with a reduction in the subsequent damage. Samples taken 2 weeks after application with treatment on June 28 showed a higher chlorophyll content than the untreated plants. A number of investigations (Hayward and Clymo, 1983; Schofield, 1985; Crum, 1988) have noted that the chlorophyll content of *Sphagnum* growing in shaded habitats is higher than the chlorophyll content of *Sphagnum* in exposed sites. The plots treated with 0.46 ml/m^2 (1.1 kg/ha) had a greater vegetation cover than the untreated plots. Thus, *Sphagnum* in the treated plots would have an initial higher chlorophyll content and this in combination with the vegetation cover may have prevented the picloram from reaching the target species. The greatest chlorophyll reductions occurred following application in July when the temperature and humidity were highest. The higher the temperature and the humidity, the greater the effect of picloram (Sharma and Vanden Born, 1971; Ashton and Crafts, 1981). Morrison and Vanden Born (1975) indicated that initially picloram is passively taken up across leaf and root boundaries and subsequent movement in the plant is at least in part an active process. Thus more picloram will be taken up by the *Sphagnum* in June and July when they are more metabolically active.

Elma is a mature, relatively dry, treed bog with a firm substrate, and a ground cover which is dominated by Ericoid/*Sphagnum* associations. This site, unlike Sprague, was affected by drought conditions. The water level was low throughout the growing season and by August was > 1.0 m below the vegetation surface. As a result the *Sphagnum* was relatively dry and the application of picloram produced a greater decrease in the chlorophyll content than the treated plants at Sprague. A consequence of this desiccation is a reduction in the respiration, photosynthetic carbon fixation and productivity rates (Rydin, 1985; Andrus, 1986). The duration of the desiccation is of particular importance since it affects the ability of *Sphagnum* to recover. Remoistening dry *Sphagnum* will increase the respiration rate, which could limit the number of times the moss can tolerate desiccation (Rydin, 1985). During application, the *Sphagnum* was thoroughly soaked which could increase respiration and reduce cellular tolerance to picloram. This, in combination with the other effects of the herbicide and the drought conditions may have resulted in a greater decrease of the chlorophyll content observed.

As previously mentioned, picloram decreased the evapotranspiration rate of treated plants. *Sphagnum* does not have a vascular system, and following application of picloram, the drying out of the moss is thought to be caused by the herbicide possibly binding the water and breaking the water column, thus resulting in the death of the plants. This could have resulted from the picloram disrupting the hyaline cells, which form a capillary around the stem. The chlorophyll content of dying plants will continue to degrade until there is very little or no chlorophyll remaining, except in the case of *Sphagnum* collected under drought (Figure 11). The chlorophyll content decreased two weeks after the application of picloram and little change in the chlorophyll content was observed from four to six weeks. Arvik *et al* (1971) indicated that picloram at 2 ppm or less, equivalent to the dosages used in the field would not affect algal growth. This suggests that the algal populations do not migrate and that the chlorophyll content observed four and six weeks after treatment may be the chlorophyll of the algal communities associated with *S.fuscum*.

The Devil's Lake site is a mature treed bog, which like Sprague was not affected by drought conditions. The water level at this site was relatively stable throughout the growing season at approximately 30 cm below the surface vegetation level. The Ericoid/*Sphagnum* association was well shaded by numerous Black Spruce and Tamarack. The shaded conditions in combination with the high water content of the *Sphagnum* produced higher chlorophyll contents in untreated plants (Gaberscik and Martincic 1987; Crum 1988).

The untreated *Sphagnum* at Devil's Lake had the highest chlorophyll content, and the treated *Sphagnum* the lowest chlorophyll content (Figure 13). The high degree of shading results in the untreated *Sphagnum* producing a higher chlorophyll content, thus compensating for the low light levels (Crum, 1988). The large reduction reflects the higher metabolic activity of the plant. As previously mentioned the uptake of picloram is, at least in part, an active process (Morrison and Vanden Born, 1975). Therefore, one can conclude that the greater the metabolic activity, the more active is the uptake of the herbicide and the greater is the reduction in the chlorophyll content.

Elongation

The effect of the picloram on the elongation of *Sphagnum* stems can be explained by the auxin-type behavior of picloram. The herbicide produces distortions of the growing tips and leaves which parallel the effects produced by 2, 4-D (Foy, 1980; Ashton and Crafts, 1981). Picloram is toxic to dicotyledonous plants, by inhibiting photosynthesis, decreasing chlorophyll content and interfering with nucleic acid metabolism and protein synthesis (Chang and Foy, 1971a; Sharma and Vanden Born, 1972).

The use of picloram adversely affected stem elongation which resulted in the *Sphagnum* eventually drying up and pulling away from the crankwire producing a "negative growth". The first few weeks after application, the stem tips elongated covering the horizontal portion of the crankwire demonstrating a "positive growth". *Sphagnum* which was treated 8 to 10 weeks prior to the removal of the crankwires on September 22 showed no growth. The plants treated 10 weeks prior to September 22 had pulled away illustrating a "negative growth". The initial elongation observed is explained by the action of the picloram, which causes cell elongation and increased meristematic activity (Foy, 1980). As a plant dies, it loses water and nutrients and the plant structure eventually collapses, thus explaining the "negative growth" observed. Chang and Foy (1971a) indicated that picloram decreases the evapotranspiration rate by causing wilting in susceptible plants. The combination of nutrient and water loss and decreased evapotranspiration rate causes drying and results in the *Sphagnum* pulling away from the crankwires.

The pale colour and the collapsed stem and capitula of *S.fuscum* was similar at all three sites. Drought and high temperatures can cause a decrease in the metabolic activity of *Sphagnum* mosses (Rydin, 1985; Andrus, 1986). The high temperatures and drought conditions experienced at Elma during the growing season in 1988 resulted in *Sphagnum* pulling further away from the crankwires than those at the other sites. The hot dry conditions also increased evaporation, which resulted in greater capillary movement and ion exchange (Crum, 1988). It is believed that there is greater binding of the herbicide to the *Sphagnum* leaves and stems during drought, and this combination eventually produced the dried and collapsed *Sphagnum*. Healthy *Sphagnum* has a higher metabolic activity than *Sphagnum* in a desiccated state (Rydin, 1985; Andrus, 1986).*Sphagnum* at Devil's Lake and Sprague assimilated more of the picloram than *Sphagnum* at Elma as a result of a higher metabolic activity, which produces elongation and subsequent pulling away from the crankwires (Figures 14,15,16).

The stem growth of *Sphagnum* in the untreated plots at the three site showed results similar to those observed by other investigators (Magnusson, 1986; Gaberscik and Martincic, 1987). *Sphagnum* species have a high growth rate in the spring and early summer with half of the total growth being observed by the beginning of July (Karunen and Salin, 1982). The *Sphagnum* stems at Sprague elongated more than at any of the other two sites, which is believed in part to be a result of the high water table at the site. Luken (1985) reported that *Sphagnum* mosses have a higher rate of elongation at higher water table levels. The water table at Elma was the lowest of the three sites and the *Sphagnum* illustrated the least growth, which was expected, because it was the only site to be affected by drought conditions. The untreated *Sphagnum* at Devil's Lake averaged approximately 2 mm less elongation of the stems than those plants observed at Sprague even though the water table levels at the two sites were comparable. The hummocks at Devil's Lake are larger, more mature and relatively drier than those at Sprague which are smaller and located closer to the water table. The hummocks are limited in height to ~50 cm primarily because of the increased evapotranspiration rate, thereby limiting the amount of growth (Crum, 1988). Hayward and Clymo (1983) suggested that shading of the *Sphagnum* carpet will reduce the amount of elongation. Therefore shaded conditions may possibly account for the reduced growth of the stem observed at Devil's Lake. Also Clymo and Hayward (1982) observed that the greater the supply of nutrients, the greater the growth rate of *Sphagnum*. Sprague had the highest rainfall of the three sites in 1988 and since rainfall is the primary supply of nutrients in bog communities this probably explained the greater stem elongation.

Culture

Sphagnum was cultured on an agar medium (Appendix 2) and treated with picloram at the three concentrations equivalent to those used in the field. This was carried out in order to observe the specific effects of the picloram on the morphological structure of the capitulum and the amount of expansion in the capitula. The culturing of *Sphagnum* species has previously been performed in aqueous solutions (Boatman and Lark 1971; Baker and Boatman 1985). However, it was found that the growth form of the mature gametophytic plant was altered when grown in aqueous medium. As a result an agar medium was used in an attempt to prevent the alteration of the growth form caused by aqueous solutions. The culture medium used contained a similar nutrient composition to those solutions used by Boatman and Lark (1971) and Baker and Boatman (1985). It should be noted that when the media contained vitamins the *Sphagnum* was healthier and had a higher growth rate.

The algal population (eg. *Nostoc* sp.) associated with the *Sphagnum* capitula were observed colonizing the agar medium three days after picloram was applied. Wegener *et al.* (1985) indicated that soil algae covered the surface of the soil when damaged by certain herbicides (eg. chlortoluron & terbutryne) and caused a reduction in the acetylene (C_2H_2) reduction (nitrogenase) several days after application. This suggests that the associated algae are affected by picloram and are released or leach into the agar because of loss in the viability of the cell wall caused by the herbicide. The capitula elongated extensively until no recognizable compact apex remained. This is similar to the elongation observed in the conductivity experiment, and is believed to be a result of the auxin-type behavior of the picloram (Ashton and Crafts, 1981). The extensive elongation and the alteration of the normal growth habit destroyed the compact *S. fuscum* population growing on top of the hummocks. This breaking of the water column or wick would explain the extreme dryness of the *Sphagnum* on the treated hummocks in the field (Figure 17). Titus *et al.* (1983) and Andrus (1986) indicated that hummock species once dried are unable to recover as well as hollow species. As previously mentioned Dana (1967) and Suffling (1975) found certain *Sphagnum* species growing in wetter hollows were not affected by picloram. It was further noted that if the *Sphagnum* was maintained in a moist environment, the capitula elongated and expanded but did not dry out and die. The elimination or reduction of *Sphagnum* species such as *S. fuscum* will change the hummock-hollow microtopography on peatlands traversed by electrical transmission corridors.

Conductivity

Conductivity experiments were performed under controlled conditions to remove the influence of light, temperature and rainfall variations in order to observe the effects of picloram on the *Sphagnum* medium at a level equivalent to that used by Manitoba Hydro in the field (~1.104 ppm) on the conductance of the media in which *S. fuscum* was growing. Two trials produced similar results (Figure 19 and Appendix 5). The conductivity of the *Sphagnum* resulted in a slight increase in the conductivity of the solution over two weeks (Figure 19). Vanstone and Stobbe (1977) showed that certain herbicides alter the membrane structure of a plant releasing cell electrolytes into solution thus resulting in a significant increase in the conductivity within two hours of application. Bachelard and Ayling (1971) reported that a mixture of 2, 4-D and picloram altered the membrane integrity of the cell membranes of susceptible plants. However, Foy (1980) reported that picloram did not produce any membrane damage. If the cell membranes are not damaged by the picloram, then cell electrolytes will not be released readily into solution thus explaining the slow increase in the conductivity of the solution.

Sphagnum species have an exceptionally high cation exchange capacity, which enables them to bind cations that would otherwise precipitate at the low pH found in bog habitats (Clymo and Hayward, 1982; Andrus, 1986; Crum, 1988). This will influence the cations in solution and therefore affect the conductivity of the medium. Cations such as potassium (K^+) are absorbed by the living portions of the *Sphagnum* mosses (Crum, 1988). Tordon 22K is a potassium salt formulation of picloram and is assumed to be absorbed by the cation exchange sites on the plant. Hummock species such as *S.fuscum* have a greater capacity for cation exchange than do hollow species (Parkarinen and Tolonen 1978; Andrus 1986) and therefore, more of the herbicide should be bound by hummock species. It was noted during the field season that the hummock species did show greater damage after picloram use.

The first trial of the conductivity experiment (Figure 19) had an equilibrating period, which enabled the picloram to interact with the *Sphagnum*. This allowed the potassium salt of picloram to bind to the cation exchange sites on the walls and decrease the conductivity of the solution. The conductance of the treated plants slowly increased. This may have resulted from the release of cations from the exchange sites, the migration of algal cells or the release of cell electrolytes into solution. Any cation exchange should increase conductivity. The second trial (see Appendix 5) had no equilibrating period and no parafilm to prevent evaporation. Initially the conductance of the treated plants was high and a subsequent decrease was observed as the picloram bound to the exchange sites in the cell walls. Unlike the first trial, 20 to 30 ml of picloram solution was replaced daily because of the extremely high evaporation rate. This interfered with the conductance of this trial producing an unexpected decrease.

The capitulum of *Sphagnum* is the most metabolically active portion of the plant and has the greatest number of cation exchange sites (Malmer, 1988). The capacity of the cation exchange mechanism decreases with the age of the stem (Clymo and Hayward, 1982). The portion of the stem 0.5 to 1.5 cm below the capitulum has the potential to be equally as active as the capitulum (Karunen and Salin, 1982). Below 1.5 cm the stem is not as metabolically active and has fewer cation exchange sites. Therefore, when the picloram is added to the stems there is little to no change in the conductivity of the solution. The slight decrease of the conductivity observed may be produced by the picloram being bound to the few exchange sites on the stem walls thus removing some of the cations from solution and reducing the conductivity. The lower metabolism of the stems will also reduce the damage of the picloram and fewer cations would be released back into the solution. This also explains why the conductivity of the *Sphagnum* plant was slightly lower than the conductivity of the capitula by themselves.

Chapter 2

Picloram Residue Times in *Sphagnum* Peat

Introduction

Picloram (4 - amino - 3, 5, 6 - trichloropicolinic acid) is marketed by the Dow Chemical Company under the trade name Tordon. It is one of the most effective and widely used herbicides for the control of perennial weeds, woody and broadleaf plants (Ragab, 1975; Fryer, *et al.*, 1979; Wells *et al.*, 1984). It has a low mammalian toxicity, with Tordon 22K having an oral LD_{50} in rats of 10, 330 mg/kg and Tordon 101 (picloram/2, 4 - D formulation) an oral LD_{50} in rats of 3, 080 mg/kg (Dow Chemical, 1987). Picloram is classified as a restricted-use herbicide because of its persistence in soils at levels which are phytotoxic and its relatively high water solubility with the potential for leaching into ground water (Fryer *et al.*, 1979; Wells *et al.*, 1984; Lym and Messersmith, 1988).

The most important means by which many pesticides are degraded in the soil is through the action of the microbial communities (Meikle *et al.*, 1973). Also, photodegradation of picloram will occur when solutions of the herbicide are exposed directly to ultraviolet light (Neary *et al.*, 1985; Lym and Messersmith, 1988). The potassium salt of picloram degrades slowly and phytotoxic levels can persist in the soil medium for up to 5 years after application depending on dosage and soil type (Herr *et al.*, 1966; Lym and Messersmith, 1988). The long persistence and the mobility of picloram could cause unacceptable environmental impact such as ground water contamination and/or the elimination or reduction of susceptible non-targeted plant species.

The persistence and degradation of picloram in the soil is influenced by a number of factors including soil type, rainfall, temperature, rate of application and microbial activity (Moffat 1968; Meikle *et al* 1973). The moisture conditions and the amounts of organic matter radically affect the persistence of the herbicide. Increased moisture enhances the microbial community whose higher metabolism often stimulates the degradation of a herbicide. The most active fraction of organic matter in soils is humic acid which enhances the adsorption of herbicides such as picloram. This increases the contact with microorganisms and in turn stimulates degradation of the pesticide (Khan, 1973; Que Hee *et al.*, 1981). Adsorption also increases with decreasing pH and as a result soil leaching of the herbicide decreases in acidic peat soils (Suffling *et al.*, 1974; Neary *et al.*, 1985).

Peatlands have soils with greater than 65% organic matter originating from the incomplete decomposition of litter from the surface vegetation (Damman and French 1987; Crum 1988). Peat in its natural state is 85 to 95 % water by mass (Shotyk, 1989), and the average pH of a *Sphagnum* bog varies between 4.2 and 3.7 (Crum, 1988). It should be noted that the parent acid of picloram is stable at a pH of 3.0 (Lym and Messersmith, 1988). The combination of the high organic matter (upwards of 95%) and the low pH produce conditions which are conducive for the adsorption of picloram. The binding of the picloram by the organic matter influences the conductivity, behavior , bio-availability, and degradation of the herbicide in soils of high organic matter (Khan, 1973). An attempt is made in this study to:

a) determine a procedure for measuring recoverable residue of picloram ; and
b) measure the persistence of picloram in a short- term monitoring experiment on recoverable picloram residues.

Residue Experimental Design

A laboratory experiment was designed to determine the residue time of picloram activity in peat soils. Commercial peat was dried and weighed then mixed with the appropriate amount of deionized water necessary to give the peat an 80% water content. The peat was treated with 1.104 ppm (wt/wt) picloram and thoroughly mixed. This is approximately equivalent to 1.1 kg/ha which is the rate used by Manitoba Hydro in the field. One hundred grams of the treated peat was weighed and then transferred into a 12.70 cm diameter pot. Sixteen pots were prepared with treated peat and 4 were prepared with untreated peat to be used as controls. The pots were placed in a closed container within a growth chamber and subjected to 16 hr/8 hr day-night photoperiod at 25ºC day and 15ºC night temperature plus a relative humidity of 100% over 24 hours.

The 20 pots were divided into four groups and labeled 1, 2, 3, 4 and control, one of each group was placed randomly in a line producing a random block design. Every two weeks one of each of the labeled pots was randomly selected from each of the five lines. The peat in the selected pots was then analyzed for picloram residue. A set of standards was prepared at each two week interval by the same method as the unknowns. The standards were made with commercial peat and were mixed with a given amount of picloram then immediately extracted. The experiment was designed to determine the degradation of picloram herbicide under standardized conditions in peat soils. A series of field samples treated in 1988 were analyzed for residue and were compared to the results observed in the laboratory.

Methods

The methods used in the residue analysis were based on procedures of Wells *et al.* (1984) and Lym and Messersmith (1988). The five samples (four replicate treatments and one control) were each transferred to a 600 ml beaker at each of the two week time intervals. Three standards were prepared at 2 week intervals using the same extraction method. Then approximately 250 ml of deionized water was added to each beaker and the solution was acidified to pH 3 with 6N sulfuric acid (H_2SO_4). The peat solution was then placed in a blender and mixed until the solution was a smooth paste. The mixture was poured into 50 ml stainless steel centrifuge tubes and centrifuged for 10 minutes at 3000 rmp on a GLC - 1 (Sorvall). The supernatant was filtered through a porcelain Buchner funnel with # 1 Whatman filter paper into 10 ml of H_2SO_4, which caused the humic acid to precipitate out of solution. The filtrate was centrifuged again for 5 min to remove as much of the humic acid as possible.

Approximately 200 ml of the supernatant was collected and poured into a 250 ml beaker to which 1.5 ml of potassium permanganate was added. The beaker was stirred on a plate for 5 minutes at room temperature to oxidize the organic matter in the solution. The solution was then clarified by adding 5M sodium bisulfite ($NaHSO_3$) dropwise. The clear solution was placed into a separatory and extracted three times with 40 ml, 20 ml, and 20 ml of methylene chloride. The extract was decanted into a 500 ml round bottom flask and placed in a water bath ~100 º C to be rotary evaporated until dryness. The remaining concentrate was dissolved with 1.5 ml of acetonitrile and water (60:40 v/v). The extract was stored in a vial and placed in the dark for 12 hours after which a precipitate (possibly remaining humic acids) formed at the bottom of the vial. The clear extract was removed from the solution and stored in a new vial to be analyzed for picloram residue.

Five µl of the eluate was injected into a Shimadzu High Pressure Liquid Chromatograph with a 150 mm long PRP - 1 Column (Hamilton) to quantify the residue. The flow rate of the solvent system was 1.0 ml/minute and consisted of Eluent 'A', 1% acetic acid in water (v/v) and Eluent 'B' 1% acetic acid in acetonitrile (v/v). The detector was a variable wavelength spectrophotometer which was operated at 254 nm. The retention time of the picloram extract was approximately 9 minutes. The data was then quantified by comparing the areas of the standard peaks with the areas of the unknown peaks of the samples on a Shimadzu CR4A data collector and a SCL - 6A system control computer, thus determining the amount of residue extracted.

Results

The degradation experiment was designed to determined the short term viability of picloram in peat soils. The extraction process after 2 weeks of incubation resulted in a mean of approximately 16 ppb (Figure 22) picloram residue being recovered, which is ~1.5 % of the orginally applied concentration (Table 7). There was slightly less residue recovered four weeks after incubation, where approximately 13 ppb or ~1.2% of the initial picloram was recovered (Figure 22 and Table 7). Six weeks after the picloram was mixed into the peat the extraction process resulted in a mean of ~20 ppb of picloram residue or 1.8 % of the original concentration, which is a 7 ppb increase in the recovered picloram residue from 4 weeks of incubation (Figure 22). After 8 weeks of incubation the greatest amount of residue was recovered with a mean of approximately 58 ppb or around 5 % of the initial picloram added to the peat, which is approximatley three times the amount of residue extracted at 6 weeks (Figure 22). There is little change in concentration of the residue recovered during the 8 weeks (Figure 22). There were four replicate samples examined at each interval time and after 2 months of incubation 223.8 ppb of picloram residue was extracted from one the the four replicates. The remaining three replicates had a mean extraction recovery of 3.0 ppb of residue. The average of the four samples resulted in the large mean observed and the extremely large standard error calculated, as a result the outlier was removed (Figure 22). This may have resulted from the peat in the one pot not having had the picloram throughly mixed.

Table 7

The detectable amounts of picloram residues recovered after the extraction process from replicates of commericial peat and peat treated during the field season of 1988, at Elma. Standard errors in brackets N= 4 at 14, 28, and 42 days, N=3 at 56 days and N=2 at 365 days.

	The Picloram Residues Recovered									
	14 Days		28 Days		42 Days		56 Days		365 Days	
Applied concentration	Mean (ppb)	% of Applied	Mean (ppb)	% of Applied	Mean (ppb)	% of Applied	Mean (ppb)	% of Applied	Mean (ppb)	% of Applied
0.552 ppm	-	-	-	-	-	-	-	-	4.074	0.738
1.104 ppm	16.118 (5.639)	1.459	13.063 (4.083)	1.183	19.885 (4.915)	1.801	2.970 (0.575)	0.269	4.728	0.428
2.208 ppm	-	-	-	-	-	-	-	-	2.396	0.109

The standards used to calculate the amount of residue extracted were prepared and extracted the same day. A comparison was made between the peat standards and water standards which were exposed to the same extraction process. The water standards were used to reference the peat standards because there is no interference of humic substance in deionized water and the comparison can determine the accuracy of the peat standards. Immediate extraction removed ~ 80 to 90 % of the added picloram, which was calculated by the HPLC computer as the standards were run.

Several samples from the plots treated at the Elma site during 1988 were collected for analysis of picloram residue one year after the herbicide had been applied. There were three herbicide rates used in the field 0.92 ml/m^2, (2.2 kg/ha) 0.46 ml/m^2 (1.1 kg/ha) and 0.23 ml/m^2 (0.55 kg/ha). Two samples from each treatment level were analyzed for residue. There was 2.4 ppb of picloram residue recovered from the field plots treated with 0.92 ml/m^2 Tordon 22K during 1988. When calculated as a percentage of the applied rate (2.208 ppm), 0.11 % was recovered which was the lowest recovery of the field samples. A picloram residue of 4.7 ppb was recovered from the plots treated with 0.46 ml/m^2. This value is similar to 3 of the replicates of the commericial peat which had been incubated for 56 days (Table 7). The lowest field rate 0.23 ml/m^2 showed a large variation in the two samples extracted, 1.6 ppb or 0.287 % of applied and 6.6 ppb or 1.189 % of the applied with a mean of 4.07 ppb (Table 7). The lowest field application on average shows a greater recovery of picloram residue than the plots treated with the highest field rate of picloram.

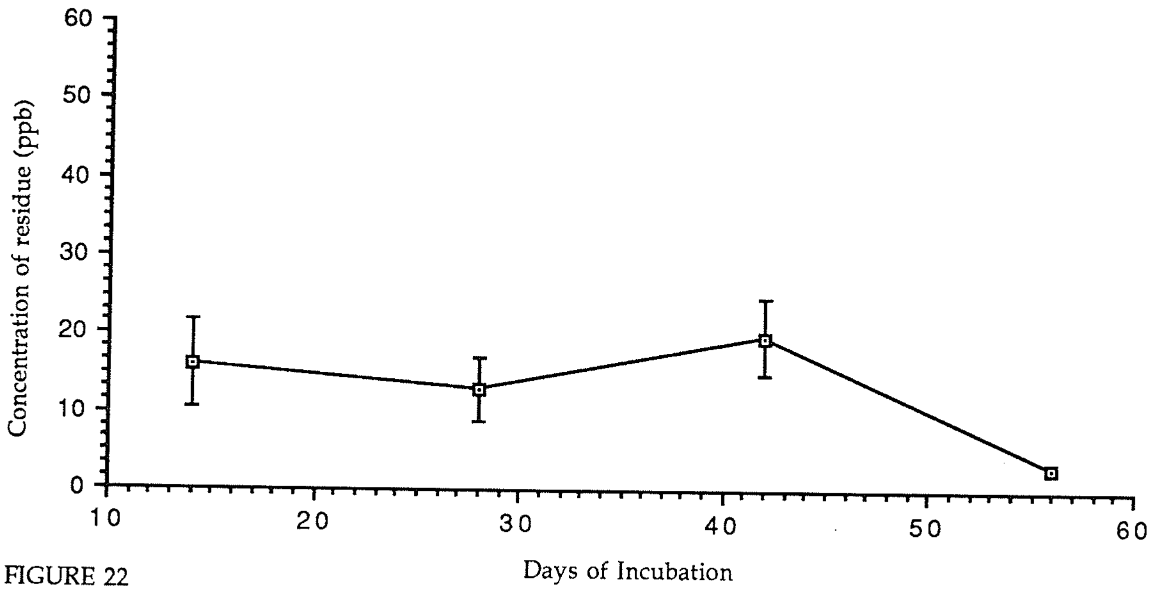


FIGURE 22

The amount of Picloram residue recovered from commericial peat treated with 1.104 ppm 2, 4, 6, and 8 weeks after herbicide mixed into the peat. Standard error bars at 2, 4, and 6 weeks based on N=4, and N=3 at 8 weeks.

Discussion

The major component of peat soils is humic substances, which are divided into three major fractions, humic acid, humin, and fulvic acid (Landva *et al.*, 1983; Aiken *et al.*, 1985). The humic substances are the most active fraction of organic soils and actively adsorb a wide variety of herbicides (Khan, 1973). There are several mechanisms or combination of mechanisms which have been suggested for the adsorption of herbicides by humic substances, aside from the cation exchange mechanism. These include hydrogen bonding, charge transfer, coordination through an attached metal (ligand exchange), van der Waals forces and hydrophobic bonding (Khan, 1973; Stevenson, 1985). Adsorption by ion (cation) exchange is restricted to those organic chemicals that either exist as cations or become positively charged through protenation (Stevenson, 1985).

Khan (1973) concluded that initial rapid uptake of picloram (potassium salt) by humic substances was a product of diffusion of the herbicide molecule across a water film to the surface of the humic acid and the subsequent slower adsorption was a product of the humic acid structure. Humic substances are believed to have voids or holes of different molecular dimension and therefore the longer times of adsorption are believed to be governed by the diffusion of the herbicide into the interior of the humic substances and possibily bound by van der Waals forces and hydrophobic bonds (Khan, 1973). There is substantial evidence indicating that pesticides can form stable linkages with humic substances and therefore greatly increase their persistence in the soil (Mathur and Farnham, 1985). Picloram is a persistant herbicide and chemical attachment or incorporation of the herbicide into a newly formed humic and fulvic acid during humification may further prolong the phytoxicity of the picloram in the peat soil. Since humic substances can degrade, albeit slowly, the bound herbicide will in time be released from the humic substance into the soil by microbes (Khan 1982; Mathur and Farnham 1985; Mishra and Srivastava 1986). The retardation in decomposition may result from the unavailability of nitrogen to microorganisms from the complex humic substance molecules (Mishra and Srivastava, 1986). The presence of these slowly released herbicides may lead to undesirable uptake by non-target plant species.

Highly organic soils such as peat soils are predominantly associated with humic acids, charge neutralizing cations, and other organic humic compounds (Hayes, 1985). Therefore to extract picloram from peat soils the humic substances must be extracted and then the picloram must be separated from the chemically complex humic substances. The effectiveness of the extraction of the humic substances from the soil is dependant on the formation of the humic molecules. Water is an excellent solvent for humic substances when the acid groups on the macromolecules are dissociated, however, when the charges on the humic molecules are neutralized by cations dissolution by water is inhibited and neutral salt solutions should be used (Hayes, 1985). The extraction procedure used in this experiment was probably limited by the high content of humic substances in peat soils.

Wells *et al* (1984) developed a method of extraction to remove picloram from soils. From this method Lym and Messersmith (1988) developed a procedure for surveying picloram in ground water. A combination of these two methods was used to develop the extraction process in this experiment. The extraction method resulted in recovery of approximately the same amount of picloram residue at each incubation time (within standard error) and similar recovery values were obtained from the samples taken from the field one year after treatment. Although the extraction process did not successfully extract all the picloram bound to the humic substances, it demonstrated that the picloram applied in the field during 1988 had not degraded further than the picloram applied to the pots incubated in a growth chamber for 56 days.

There are other factors aside from the complicating effects of humic substances which influence the rate of degradation of picloram in the soil matrix. Meikle *et al.*, (1973) illustrated a positive correlation between moisture content and degradation and the soil temperature and herbicide decompostion. Other factors affecting the disappearance of picloram include rainfall rate of application, the soil type, and microbial communities (Moffat, 1968). The microbial communities have the greatest effect on degrading herbicides and eventually removing them from a habitat (Foy, 1980). The high temperatures experienced at the three sites during 1988 should have increased the decomposition of the picloram. The field samples analyzed were taken only from the Elma site, which was affected by drought conditions. The high temperatures and dry conditions will decrease the activity of the microbial populations and in turn slow the rate of degradation. The Sprague and the Devil's Lake site were not analyzed for picloram residues, because it was assumed there would be a higher degradation rate resulting from the greater water availability, thus the residue would not be present in a high enough concentration to detect by the extraction process used in the experiment.

The greatest abundance of microoganisms, such as fungi and bacteria are located on the upper aerobic horizons of bogs and the presence of any viable microorganisms at depths greater than 1 meter has been disputed (Clymo, 1965). Applications of picloram reportedly have no drastic effect on the life processes of soil microorganisms (Foy, 1980), although applications have been shown to adversely affect certain soil algal species (Arvik *et al,* 1971). Peat soils have fewer microbes than most soils and in combination with the complex humic substances and persistance of the herbicide will further reduce the rate of decomposition. *Apergillus niger* is one of the few microorganisms which is known to degrade picloram (Foy, 1980). There are also other methods of decomposition reported for picloram such as oxidation and reduction (non-biological processes). The methods of picloram decomposition are not well understood.

Summary and Conclusions

Picloram damaged the elongation of the stem tips and induced a reduction of the chlorophyll content of *S.fuscum* at all three study sites. The three herbicide rates used 0.92 ml/m^2, 0.46 ml/m^2 and 0.23 ml/m^2 in the field generally did not significantly decrease the chlorophyll content of the *Sphagnum* at each site. Differences between the herbicide dosages were observed periodically at Devil's Lake and Sprague.

Picloram applied at Sprague on July 14th was the most effective at decreasing the chlorophyll content by 50 to 60 % of the untreated *Sphagnum,* while application in June resulted in the lowest reduction 20 % of the untreated plants. Unlike Sprague, application date had little or no effect at Elma and Devil's Lake. The treatments at Elma showed an insignificant difference with treatment C (0.23 ml/m2) reducing the chlorophyll from 50 to 80 % and treatment A (0.92ml/m2) by 50 - 60 % of the untreated. Picloram applied at Devil's Lake decreased the chlorophyll content to 40 -50 % of the untreated *Sphagnum* for all treatment levels at all treatment times.

The amount of light exposure inversely influenced the reduction of the chlorophyll content of *S. fuscum* (high light exposure low chlorophyll reduction). The Sprague site had been cleared of Black spruce and Tamarack resulting in high light exposure at the site and the decrease of chlorophyll was the lowest of the three sites. The Elma site, which is partially shaded, showed a greater reduction in chlorophyll than the plants at Sprague. At the Devil's

Lake site there was the least exposure to direct sunlight and the greatest reduction in the chlorophyll content.

Initially the picloram produced an elongation in the *Sphagnum* tip, but as the plants dried up they pulled away from the crankwires and a "negative growth" was observed. Elongation of *S. fuscum* shoots during a four month period at Sprague was 6.3 mm for untreated shoots and a mean of -2.0 mm for the shoots treated with picloram, with little variation between the three herbicide rates. Elongation of the untreated plants was approximately 3.0 mm and around -2.9 mm of the treated plants. The drought conditions at Elma reduced the growth of the untreated *Sphagnum*. The untreated *Sphagnum* at Devil's Lake elongated approximately 4.2 mm. The treated plants pulled away from the crankwire a mean of -3.3 mm for the three treatment levels.

The culturing techniques developed illustrated the effect of picloram on the metabolically active capitula of *Sphagnum*. It was established that cleaning the capitula with deionized water was more successful than other sterilization methods in successful growth of the capitula on agar plates. Capitula growth was more rapid when vitamins were added to the medium and CO_2 was readily available. The capitula treated with ~2.2 ppm and ~1.1 ppm picloram illustrated greater expansion in diameter than the capitula treated with ~0.55 ppm. The agar medium in the three treated plates turned yellow three days after application of the herbicide, belieced to be from associated algal populations migrating into the agar. The control plate remained clear, although *Nostoc* sp. were found closely associated with the new developing branches of the control plants.

Conductivity of liquid from *Sphagnum* treated with picloram was used as a measure of herbicide injury. The capitula produced an increase in the conductivity of the solution medium, whether or not evaporation occurred. The stems are not metabolically active and the addition of picloram resulted in little change in the conductivity either with or without evaporation. The treated *Sphagnum*, when covered with parafilm to prevent evaporation, showed an increase in the conductivity, however when not covered evaporation was extremely rapid and picloram solution had to be replaced daily, resulting in a decreased conductivity. Micrographs of the treated *Sphagnum* were used to observe how the picloram affected the stems and to gain a better understanding of why the plants were drying. The micrographs showed the tips of the branches in the capitula extensively elongated after treatment, thus producing a larger surface area allowing for an increase of the evaporation and drying of the *Sphagnum*.

The technique developed to extract picloram residues from peat soils detected the presence of the residue in the peat samples. Exact amounts remaining in the peat were not determined by this method, because an extensive clean-up of the humic substances was not performed. This method extracted approximately ~ 3.0 ppb of picloram (excluding the outlier 223.8. Table 7) after 56 days of incubation which compared with the amount of residue recovered from the field one year after application. This indicates that the amount of picloram remaining in the peat in the field site is similar to that in the commericial peat. This technique of picloram determination is a quick and easy method of confirming the presence of picloram in peat soils although, a more extensive method of clean-up of the humic substances would be required to determine exact amounts of residue remaining in the soil.

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Appendix 1

Vegetation Frequencies

(Nomenclature of vascular plants follows Scoggan (1978, 1979) and Bryophytes follows Ireland *et al* (1980)).

Species	Abbreviation
Betulaceae	
Alnus rugosa (Duroi) Sprengel	Betula
Betula glandulosa Michx	
Cupressaceae	
Juniper horizontalis Moench.	Junp
Cyperaceae	
Carex sp.	Car
Eriophorum viridi-carinatum L.	Eriop
Droseraceae	
Drosera rotundifolia L.	Dros
Ericeaceae	
Ledum groenlandicum Oeder	Ledu
Kalmia polifera Wang.	Kalm
Chamdaedaphne calyculata (L.) Moench.	Cham
Andromeda glaucophylla Link.	Andro
Vaccinium oxycoccus L.	Vacco
V. vitis-ideae L.	Vacci
Gentianaceae	
Menyanthes trifoliata L.	BogB
Gramineae	
unidentified Grasses	Carex
Lilaceae	
Smilacina trifolia (L.) Desf.	Smila
Myricaceae	
Myrica gale L.	Mgale
Orchidaceae	
Cypripedium acaule Ait.	Cyp A
C. calceolus L.	Cyp C
Pinaceae	
Larix laricina (Du Roi) Koch	Larix
Picea mariana (Mill.) BSP.	Blspr
Rosaceae	
Potentilla palustris (L.) Scop.	Pot
Salicaeae	
Salix sp.	Salix

Species	Abbreviation
Typhaceae	
Typha latifolia L.	Typha
Aulacomniaceae	
Aulacomnium palustre (Hedw.) Schwaegr.	Aulac
Endodontaceae	
Pleurozium schreberi (Brid.) Mitt.	Plur
Sphagnaceae	
Sphagnum fuscum (Schimp.) Kliggr.	Sphag
Polytrichaceae	
Polytrichum strictum Brid.	Polyt
Sarraceniaceae	
Sarracenia purpurea L.	Sarac

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	SITE	LINE	INTERV	SPHAG	LEDUM	CHAME	POLYT	VACCO	VACCI	KALMI	ANDRO	LARIX	AULAC	ERIOP	BLSPR	SEDGE	BETUL	POPUL	BOGB	ALDER	SMILA	SALIX	POT	PLUR	TYPHA	SARAC	MGALE	DROSE
2	ELMA	1	0->1	89	66	50	32	47	6	14	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	ELMA	1	2->3	71	30	23	38	27	2	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	ELMA	1	4->5	100	71	36	10	35	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	ELMA	1	6->7	100	37	21	69	52	0	17	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	ELMA	1	8->9	65	44	57	22	36	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	ELMA	1	10->11	90	36	32	10	37	40	13	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	ELMA	1	12->13	29	67	29	7	57	14	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	ELMA	1	14->15	100	50	82	6	22	31	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	ELMA	2	0->1	100	83	52	26	5	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	ELMA	2	2->3	100	38	63	27	24	26	20	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	ELMA	2	4->5	79	51	40	27	57	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	ELMA	2	6->7	40	59	29	82	37	14	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	ELMA	2	8->9	42	40	35	57	66	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	ELMA	2	10->11	66	42	31	41	23	35	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	ELMA	2	12->13	69	34	42	15	65	19	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	ELMA	2	14->15	100	26	31	36	47	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	ELMA	2	16->17	100	45	27	11	44	23	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	ELMA	3	0->1	100	16	49	28	24	1	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	ELMA	3	2->3	100	19	57	21	9	8	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	ELMA	3	4->5	100	59	37	57	1	5	4	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	ELMA	3	6->7	100	42	41	9	0	15	6	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	ELMA	3	8->9	100	6	19	11	7	4	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	ELMA	3	10->11	100	17	54	12	34	10	9	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	ELMA	3	12->13	81	21	29	25	32	9	15	19	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	ELMA	4	0->1	100	30	100	9	0	11	12	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	ELMA	4	2->3	100	79	95	4	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	ELMA	4	4->5	100	64	48	0	3	0	11	0	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	ELMA	4	6->7	98	27	94	11	57	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	ELMA	4	8->9	95	7	35	13	0	3	7	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	ELMA	4	10->11	87	38	73	18	25	12	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	ELMA	4	12->13	100	23	47	18	21	6	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	ELMA	4	14->15	100	20	38	60	0	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	ELMA	4	16->17	100	15	68	25	30	0	18	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	ELMA	5	0->1	100	35	87	8	0	2	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	ELMA	5	2->3	100	33	52	2	4	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	ELMA	5	4->5	100	51	41	14	22	8	17	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	ELMA	5	6->7	100	35	57	28	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	ELMA	5	8->9	100	35	43	60	14	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	ELMA	5	10->11	94	19	56	33	2	0	10	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	ELMA	5	12->13	100	20	72	25	0	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42	ELMA	5	14->15	86	29	42	64	0	2	15	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	ELMA	6	0->1	100	32	71	18	2	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	ELMA	6	2->3	65	45	87	83	0	0	14	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
45	ELMA	6	4->5	34	47	86	76	0	2	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	ELMA	6	6->7	83	94	68	28	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
47	ELMA	6	8->9	100	32	25	70	0	2	25	30	12	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	ELMA	6	10->11	100	55	38	87	0	0	2	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
49	ELMA	6	12->13	90	52	19	80	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	ELMA	6	14->15	90	27	34	70	0	0	9	8	0	0	0	20	0	2	0	0	0	0	0	0	0	0	0	0	0
51	ELMA	6	16->17	100	0	37	70	5	0	15	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	ELMA	7	0->1	100	31	32	15	0	0	11	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
53	ELMA	7	2->3	100	48	22	20	25	20	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	ELMA	7	4->5	100	45	12	30	10	0	7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	ELMA	7	6->7	100	35	10	20	22	0	6	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
56	ELMA	7	8->9	90	44	16	10	20	0	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	ELMA	7	10->11	100	30	37	7	12	0	7	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
58	ELMA	7	12->13	100	42	15	20	0	0	6	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
59	ELMA	7	14->15	100	43	28	20	20	0	16	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	ELMA	7	16->17	100	57	12	5	50	0	8	12	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
61	ELMA	8	0->1	100	36	25	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
62	ELMA	8	2->3	100	31	26	10	1	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
63	ELMA	8	4->5	100	28	20	20	0	0	12	11	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64	ELMA	8	6->7	100	63	21	7	0	0	11	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	ELMA	8	8->9	100	47	23	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
66	ELMA	8	10->11	100	26	36	25	10	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	ELMA	9	0->1	100	23	22	6	0	0	1	11	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
68	ELMA	9	2->3	100	21	28	15	0	0	8	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	ELMA	9	4->5	100	11	13	20	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	ELMA	9	6->7	100	38	37	20	0	0	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
71	ELMA	9	8->9	100	17	32	15	0	0	5	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
72	ELMA	10	0->1	100	24	26	10	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
73	ELMA	10	2->3	100	37	31	4	18	10	7	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
74	ELMA	10	4->5	100	26	34	5	2	10	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
75	ELMA	10	6->7	90	8	26	15	0	1	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	ELMA	10	8->9	100	42	22	8	1	11	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77	ELMA	10	10->11	100	52	30	5	15	8	16	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
78	ELMA	10	12->13	100	45	28	5	10	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
79	ELMA	10	14->15	100	38	35	5	0	0	7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80	ELMA	11	0->1	100	25	20	25	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
81	ELMA	11	2->3	65	28	33	30	10	15	6	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
82	ELMA	11	4->5	90	36	35	15	10	30	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
83	ELMA	11	6->7	100	19	24	5	0	16	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
84	ELMA	11	8->9	30	40	18	40	8	10	6	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	ELMA	11	10->11	100	29	20	5	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
86	ELMA	12	0->1	100	36	12	15	20	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
87	ELMA	12	2->3	75	13	43	5	15	8	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
88	ELMA	12	4->5	100	24	24	5	25	12	1	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0
89	ELMA	12	6->7	100	27	25	10	10	0	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	ELMA	12	8->9	100	23	19	20	15	0	3	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91	ELMA	12	10->11	90	24	24	10	12	0	5	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
92	ELMA	12	12->13	90	23	28	10	10	0	2	0	0	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
93	ELMA	13	0->1	81	47	64	29	15	27	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
94	ELMA	13	2->3	89	47	50	18	16	51	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95	ELMA	13	4->5	86	20	13	32	23	40	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
96	ELMA	13	6->7	89	29	21	14	90	63	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
97	ELMA	13	8->9	52	74	19	4	5	38	11	7	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
98	ELMA	14	0->1	100	44	72	11	44	23	4	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
99	ELMA	14	2->3	100	53	37	36	51	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100	ELMA	14	4->5	69	34	41	15	65	19	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
101	ELMA	14	6->7	66	42	31	41	23	35	18	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
102	ELMA	14	8->9	42	40	62	39	39	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
103	ELMA	14	10->11	40	59	29	82	37	14	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
104	ELMA	14	12->13	79	15	49	27	57	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
105	ELMA	14	14->15	100	38	45	0	51	63	20	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
106	ELMA	14	16->17	100	83	52	44	23	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
107	ELMA	15	0->1	100	25	43	6	10	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
108	ELMA	15	2->3	100	43	42	15	0	12	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
109	ELMA	15	4->5	100	35	12	3	0	20	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
110	ELMA	15	6->7	100	13	34	15	0	12	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
111	ELMA	15	8->9	100	37	21	15	2	5	8	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
112	ELMA	15	10->11	100	18	36	5	20	5	11	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
113	ELMA	15	12->13	100	40	35	15	10	10	12	1	52	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
114	ELMA	15	14->15	100	33	35	8	5	5	11	9	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
115	ELMA	16	0->1	100	19	26	10	0	15	3	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
116	ELMA	16	2->3	100	33	5	15	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
117	ELMA	16	4->5	100	21	35	10	0	15	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
118	ELMA	16	6->7	100	34	18	5	1	15	2	2	0	0	2	20	0	0	0	0	0	0	0	0	0	0	0	0	0
119	ELMA	16	8->9	100	27	37	15	5	15	8	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
120	ELMA	16	10->11	100	29	12	7	5	8	16	0	10	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
121	ELMA	16	12->13	100	12	20	20	5	8	12	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
122	ELMA	17	0->1	100	36	27	20	0	8	10	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
123	ELMA	17	2->3	100	23	8	10	0	5	0	0	5	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0
124	ELMA	17	4->5	100	41	17	15	0	5	5	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
125	ELMA	17	6->7	100	28	25	10	4	18	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
126	ELMA	17	8->9	100	35	37	10	0	15	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
127	ELMA	17	10->11	100	38	30	20	0	30	3	7	65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
128	ELMA	17	12->13	100	14	18	1	20	5	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
129	ELMA	17	14->15	100	40	23	3	4	20	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
130	ELMA	18	0->1	89	66	50	32	47	6	14	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
131	ELMA	18	2->3	71	30	23	38	27	2	2	4	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
132	ELMA	18	4->5	100	71	36	10	35	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
133	ELMA	18	6->7	100	37	21	69	50	0	17	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
134	ELMA	18	8->9	65	44	57	22	36	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
135	ELMA	18	10->11	90	36	32	10	37	95	9	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
136	ELMA	18	12->13	29	67	29	7	57	14	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
137	ELMA	18	14->15	100	0	82	6	22	29	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
138	ELMA	18	16->17	23	61	0	54	35	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
139	ELMA	19	0->1	100	42	32	1	20	3	23	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
140	ELMA	19	2->3	100	18	15	2	3	5	0	26	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
141	ELMA	19	4->5	100	19	27	5	15	0	9	6	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
142	ELMA	19	6->7	100	18	20	8	25	0	6	14	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
143	ELMA	19	8->9	100	33	29	0	0	0	14	8	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
144	ELMA	19	10->11	100	20	12	15	22	0	8	5	0	0	0	0	12	5	0	0	0	0	0	0	0	0	0	0	0
145	ELMA	19	12->13	100	35	32	4	8	2	4	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
146	ELMA	19	14->15	100	4	48	5	5	0	0	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
147	ELMA	20	0->1	100	22	19	8	15	0	5	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
148	ELMA	20	2->3	100	31	30	10	10	0	2	15	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
149	ELMA	20	4->5	100	25	18	10	12	0	5	5	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
150	ELMA	20	6->7	70	30	16	0	10	5	6	8	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0
151	ELMA	20	8->9	100	38	6	5	5	8	0	6	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
152	ELMA	21	0->1	100	29	23	2	5	0	2	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
153	ELMA	21	2->3	100	26	13	20	15	5	2	10	40	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
154	ELMA	21	4->5	100	13	13	5	15	0	5	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
155	ELMA	21	6->7	100	26	22	2	20	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
156	ELMA	21	8->9	100	38	4	10	16	0	6	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
157	ELMA	21	10->11	100	19	30	4	2	0	4	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
158	ELMA	21	12->13	100	18	24	1	13	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
159	ELMA	22	0->1	100	25	22	10	30	10	10	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
160	ELMA	22	2->3	100	16	35	5	20	10	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
161	ELMA	22	4->5	100	37	16	10	5	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
162	ELMA	22	6->7	100	39	31	10	7	5	4	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
163	ELMA	22	8->9	100	28	30	15	5	12	10	4	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
164	ELMA	22	10->11	100	17	32	5	15	8	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
165	ELMA	23	0->1	60	35	27	20	10	22	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
166	ELMA	23	2->3	100	30	17	5	5	33	8	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
167	ELMA	23	4->5	100	13	39	10	12	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
168	ELMA	23	6->7	100	13	14	5	30	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
169	ELMA	23	8->9	100	21	24	4	5	18	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
170	ELMA	23	10->11	80	8	33	20	5	5	6	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
171	ELMA	24	0->1	74	18	42	20	10	10	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
172	ELMA	24	2->3	25	0	45	25	0	10	18	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
173	ELMA	24	4->5	75	33	44	3	0	15	5	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
174	ELMA	24	6->7	100	31	38	10	25	15	11	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
175	ELMA	24	8->9	100	21	26	15	15	12	17	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
176	ELMA	24	10->11	100	36	38	10	10	12	8	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
177	ELMA	24	12->13	25	28	31	65	0	8	0	18	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
178																												
179				SPHAG	LEDUM	CHAME	POLYT	VACCO	VACCI	KALMI	ANDRO	LARIX	AULAC	ERIOP	BLSPR	SEDGE	BETUL	POPUL	BOGB	ALDER	SMILA	SALIX	POT	PLUR	TYPHA	SARAC	MGALE	DROSE
180		TOTAL		####	4493	4256	2566	1800	1348	913	560	502	88	79	57	43	25	2	0	0	0	0	0	0	0	0	0	0
181		% total possi		72.8	25.5	24.2	14.6	10.23	7.659	5.19	3.18	2.85	0.5	0.45	0.324	0.24	0.14	0.01	0	0	0	0	0	0	0	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	SITE	LINE	INTERV	SPHAG	BETUL	CHAME	ANDRO	VACCO	SEDGE	SMILA	LEDUM	POLYT	ERIOP	KALMI	PLUR	AULAC	BOGB	SARAC	BLSPR	SALIX	LARIX	TYPHA	ALDER	MGALE	POT	DROSE
2	SPRAGUE	1	0->1	100	38	55	0	20	34	18	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	SPRAGUE	1	2->3	100	8	52	0	35	32	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	SPRAGUE	1	4->5	100	0	25	12	18	50	30	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	SPRAGUE	1	6->7	14	0	13	14	17	50	8	12	34	0	0	0	0	0	0	0	5	0	0	0	0	0	5
6	SPRAGUE	1	8->9	80	70	13	25	45	25	0	0	20	0	5	0	0	0	0	0	0	0	0	0	0	0	0
7	SPRAGUE	1	10->11	80	4	4	28	0	50	7	7	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0
8	SPRAGUE	2	0->1	49	16	38	21	6	0	0	0	12	12	6	0	40	0	0	0	0	0	6	0	0	0	0
9	SPRAGUE	2	2->3	39	27	37	28	0	0	6	0	5	25	0	0	2	5	0	0	0	0	0	0	0	0	0
10	SPRAGUE	2	4->5	100	12	23	22	19	0	6	0	5	7	18	0	0	5	4	0	0	0	0	0	0	0	0
11	SPRAGUE	2	6->7	0	0	20	22	0	0	5	10	40	60	7	0	0	0	0	0	0	0	0	0	0	0	0
12	SPRAGUE	2	8->9	100	33	0	7	10	0	10	27	5	0	8	0	0	2	0	0	0	0	0	0	0	0	0
13	SPRAGUE	2	10->11	100	15	31	23	15	0	13	0	2	5	6	0	0	0	0	0	0	0	0	0	0	0	0
14	SPRAGUE	2	12->13	100	12	27	13	10	0	8	13	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0
15	SPRAGUE	2	14->15	100	0	36	0	10	0	13	8	5	10	7	0	0	0	1	0	0	0	0	0	0	0	0
16	SPRAGUE	2	16->17	55	45	20	10	15	0	10	0	45	12	10	0	0	17	0	0	5	0	0	0	0	0	0
17	SPRAGUE	2	18->19	100	70	18	8	20	0	15	7	5	30	15	0	0	0	0	0	0	0	0	0	0	0	0
18	SPRAGUE	2	20->21	100	22	26	21	10	0	15	0	2	10	1	0	0	5	0	0	0	0	0	0	0	0	0
19	SPRAGUE	3	0->1	100	0	37	11	15	0	0	6	5	10	6	0	0	2	5	0	0	0	0	0	0	0	0
20	SPRAGUE	3	2->3	100	50	18	42	5	0	12	10	3	10	13	0	0	0	0	0	0	0	0	0	0	0	0
21	SPRAGUE	3	4->5	30	10	10	18	5	0	15	0	30	30	0	0	0	10	0	0	0	0	0	0	0	0	0
22	SPRAGUE	3	6->7	100	0	19	40	10	0	15	10	2	15	10	0	0	0	5	0	0	0	0	0	0	0	0
23	SPRAGUE	3	8->9	100	40	31	19	15	0	10	6	1	25	8	0	0	0	0	0	0	0	0	0	0	0	0
24	SPRAGUE	3	10->11	100	5	39	0	12	0	4	0	2	10	0	0	0	0	0	0	0	0	0	0	0	0	0
25	SPRAGUE	3	12->13	100	25	39	10	15	0	1	7	1	20	5	0	0	0	0	0	0	0	0	0	0	0	0
26	SPRAGUE	3	14->15	80	35	30	15	10	10	10	0	2	10	8	0	0	0	0	0	0	0	0	0	0	0	0
27	SPRAGUE	3	16->17	100	0	16	15	10	5	10	2	5	5	2	0	0	0	2	4	0	0	0	0	0	0	0
28	SPRAGUE	4	0->1	100	3	30	20	6	0	10	11	2	15	7	0	0	0	0	0	0	0	0	0	0	0	0
29	SPRAGUE	4	2->3	100	0	10	24	0	0	10	24	2	25	0	0	0	30	0	0	0	0	0	0	0	0	0
30	SPRAGUE	4	4->5	20	0	27	3	10	0	8	5	0	15	0	0	0	0	0	0	5	0	0	0	0	0	0
31	SPRAGUE	4	6->7	100	40	0	6	15	0	6	12	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	SPRAGUE	4	8->9	100	50	0	27	15	0	8	7	2	2	5	0	0	0	0	0	0	0	0	0	0	0	0
33	SPRAGUE	4	10->11	100	0	16	11	0	0	12	2	10	5	4	0	0	0	0	0	0	0	0	0	0	0	0
34	SPRAGUE	4	12->13	100	9	5	8	10	0	12	12	5	3	9	0	0	0	0	85	0	0	0	0	0	0	0
35	SPRAGUE	4	14->15	100	25	21	16	15	0	10	10	5	5	3	0	0	0	0	0	5	0	0	0	0	0	0
36	SPRAGUE	5	0->1	100	18	27	22	10	0	12	0	3	10	6	0	0	0	5	0	0	0	0	0	0	0	0
37	SPRAGUE	5	2->3	100	5	30	18	15	0	10	8	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0
38	SPRAGUE	5	4->5	100	0	30	32	10	0	6	6	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0
39	SPRAGUE	5	6->7	100	14	10	15	10	0	8	4	5	2	0	0	0	0	3	1	0	0	0	0	0	0	0
40	SPRAGUE	5	8->9	100	8	13	22	15	0	8	0	0	0	6	0	0	12	0	0	0	0	0	0	0	0	0
41	SPRAGUE	5	10->11	100	5	15	18	10	0	2	6	5	5	7	0	0	0	5	0	0	0	0	0	0	0	0
42	SPRAGUE	5	12->13	25	5	11	0	5	0	6	0	0	35	0	0	0	0	0	0	0	0	0	0	0	2	0
43	SPRAGUE	6	0->1	60	10	9	56	2	0	2	6	5	30	0	0	0	0	15	0	4	0	6	0	0	0	0
44	SPRAGUE	6	2->3	100	0	27	32	10	0	10	8	0	10	4	0	0	0	0	0	0	0	0	0	0	0	0
45	SPRAGUE	6	4->5	100	22	20	29	5	0	8	0	1	2	2	0	0	0	12	0	0	0	0	0	0	0	0
46	SPRAGUE	6	6->7	100	12	4	27	10	0	4	4	0	1	0	0	0	0	0	0	3	0	0	0	0	0	0
47	SPRAGUE	6	8->9	100	25	6	28	15	0	6	0	5	1	8	0	0	0	0	0	0	0	0	0	0	0	0
48	SPRAGUE	6	10->11	80	12	16	16	15	0	12	0	2	20	6	0	0	0	0	0	0	0	0	0	0	0	0
49	SPRAGUE	6	12->13	100	80	4	22	5	0	10	0	0	25	4	0	2	0	12	0	4	0	0	0	0	0	0
50	SPRAGUE	6	14->15	100	30	17	24	10	0	8	0	5	10	0	0	0	0	0	0	0	0	0	0	0	0	0
51	SPRAGUE	7	0->1	90	6	35	21	10	30	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0
52	SPRAGUE	7	2->3	100	65	23	25	26	10	15	0	16	0	13	0	0	0	0	0	0	0	0	35	0	0	0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
53	SPRAGUE	7	4->5	90	80	11	23	26	15	10	7	0	0	7	0	5	4	0	2	0	0	0	0	0	0	0
54	SPRAGUE	7	6->7	100	35	19	15	15	5	1	0	0	0	0	0	25	5	0	0	2	0	0	0	0	0	0
55	SPRAGUE	7	8->9	100	10	31	13	15	3	7	10	10	0	0	0	5	0	0	0	0	0	0	0	0	0	0
56	SPRAGUE	7	10->11	10	15	26	37	2	20	8	0	5	0	0	0	70	0	0	0	9	0	0	0	0	2	0
57	SPRAGUE	7	12->13	55	7	8	22	15	30	10	8	15	0	0	28	0	2	0	0	0	0	0	0	0	0	0
58	SPRAGUE	7	14->15	9	25	26	11	30	2	6	16	5	0	3	0	10	0	0	0	0	0	0	0	0	0	0
59	SPRAGUE	7	16->17	100	20	24	36	15	2	5	9	2	0	3	0	0	4	0	0	5	0	8	0	0	0	0
60	SPRAGUE	8	0->1	100	80	34	20	15	5	3	5	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
61	SPRAGUE	8	2->3	100	25	12	21	10	2	6	17	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
62	SPRAGUE	8	4->5	100	44	9	26	15	20	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
63	SPRAGUE	8	6->7	90	40	4	12	15	20	4	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
64	SPRAGUE	8	8->9	100	38	0	15	15	0	12	6	5	0	2	0	1	5	12	15	0	0	0	0	0	0	0
65	SPRAGUE	8	10->11	65	20	0	27	5	30	4	2	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0
66	SPRAGUE	8	12->13	75	22	7	22	10	25	0	0	0	0	3	12	0	0	0	0	0	0	0	0	0	0	0
67	SPRAGUE	8	14->15	65	10	14	14	15	35	2	7	7	0	3	0	0	0	0	0	0	0	0	0	0	0	0
68	SPRAGUE	9	0->1	100	0	45	16	11	2	2	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
69	SPRAGUE	9	2->3	45	5	12	6	15	25	1	13	0	0	6	0	2	0	0	0	0	0	0	0	0	0	0
70	SPRAGUE	9	4->5	65	5	8	11	15	20	8	8	20	0	0	40	0	0	0	0	5	0	0	0	0	0	0
71	SPRAGUE	9	6->7	10	15	0	14	21	10	4	4	5	0	3	0	20	0	0	0	0	0	0	0	0	0	0
72	SPRAGUE	9	8->9	10	0	37	6	10	5	10	0	0	0	5	0	15	0	0	0	0	0	0	0	0	0	0
73	SPRAGUE	9	10->11	70	0	16	11	15	15	4	0	10	0	4	10	0	8	0	0	0	0	0	0	0	0	0
74	SPRAGUE	9	12->13	100	30	15	16	25	2	5	12	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0
75	SPRAGUE	9	14->15	100	30	17	0	12	1	5	4	2	0	2	0	0	2	0	0	0	0	0	0	0	0	0
76	SPRAGUE	10	0->1	65	0	8	0	15	35	2	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
77	SPRAGUE	10	2->3	50	15	25	5	5	35	8	0	10	0	0	30	10	0	0	0	0	0	0	0	0	0	0
78	SPRAGUE	10	4->5	70	45	12	2	15	10	8	4	2	0	6	8	10	0	8	0	0	0	0	0	0	0	0
79	SPRAGUE	10	6->7	15	0	35	6	8	40	3	5	10	0	0	50	0	0	0	0	0	0	0	0	0	0	0
80	SPRAGUE	10	8->9	100	35	29	10	20	5	5	7	5	0	5	0	0	0	15	0	0	0	0	0	0	0	0
81	SPRAGUE	10	10->11	100	25	43	9	5	2	6	0	0	0	0	0	5	5	24	0	0	0	9	0	0	0	0
82	SPRAGUE	10	12->13	100	55	0	25	15	2	5	4	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0
83	SPRAGUE	10	14->15	100	40	21	21	6	4	6	3	5	0	6	0	5	0	0	0	0	0	2	0	0	0	0
84	SPRAGUE	11	0->1	100	0	39	0	15	1	6	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
85	SPRAGUE	11	2->3	80	5	23	16	15	1	3	17	5	0	6	0	0	0	0	0	0	0	0	0	0	0	0
86	SPRAGUE	11	4->5	100	10	4	20	10	5	4	12	5	0	9	0	0	0	2	0	0	0	0	0	0	0	0
87	SPRAGUE	11	6->7	100	8	0	8	12	5	3	30	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
88	SPRAGUE	11	8->9	100	0	32	3	25	2	2	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
89	SPRAGUE	11	10->11	0	7	11	4	0	80	0	0	0	0	0	60	0	0	0	0	0	0	0	0	0	0	0
90	SPRAGUE	11	12->13	65	3	10	30	10	30	0	0	15	0	2	5	0	0	0	0	8	0	0	0	0	0	0
91	SPRAGUE	12	0->1	10	85	17	23	4	15	2	4	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0
92	SPRAGUE	12	2->3	100	100	0	0	30	10	6	5	5	0	3	0	0	0	0	0	0	0	0	0	0	0	0
93	SPRAGUE	12	4->5	100	55	26	8	20	1	5	6	6	0	5	0	0	0	0	0	0	0	0	0	0	0	0
94	SPRAGUE	12	6->7	100	100	14	25	20	2	5	16	3	0	0	0	5	0	0	0	0	0	0	0	0	0	0
95	SPRAGUE	12	8->9	100	2	27	7	15	5	1	7	6	0	7	0	1	0	0	0	3	0	0	0	0	0	0
96	SPRAGUE	12	10->11	20	6	4	2	3	40	0	0	0	0	8	35	5	0	0	0	0	0	0	0	0	0	0
97	SPRAGUE	12	12->13	70	15	18	28	10	0	2	8	3	0	4	0	10	0	2	2	0	0	2	0	0	0	0
98	SPRAGUE	12	14->15	80	60	20	12	9	2	2	8	12	0	10	0	10	4	0	2	0	0	0	0	0	0	0
99	SPRAGUE	13	0->1	90	15	37	9	20	1	2	9	5	0	3	0	0	0	0	25	0	0	0	0	0	0	0
100	SPRAGUE	13	2->3	90	2	8	22	12	10	0	4	5	0	4	0	5	0	30	0	1	0	0	0	0	0	0
101	SPRAGUE	13	4->5	90	25	15	22	5	5	5	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
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103	SPRAGUE	13	8->9	70	9	14	14	8	40	0	11	0	0	6	20	2	0	0	0	0	0	0	0	0	0	0
104	SPRAGUE	13	10->11	90	0	23	23	8	15	1	12	5	0	2	0	0	0	0	0	0	0	0	0	0	0	0

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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
105	SPRAGUE	14	0->1	100	100	35	6	40	3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
106	SPRAGUE	14	2->3	100	0	9	31	20	2	1	9	10	0	8	0	0	0	0	8	0	0	0	0	0	0	0
107	SPRAGUE	14	4->5	90	0	15	15	20	10	4	0	5	0	4	15	0	0	12	2	0	0	0	0	0	0	0
108	SPRAGUE	14	6->7	100	5	2	14	25	45	0	0	0	0	10	0	0	0	6	0	5	0	0	0	0	7	0
109	SPRAGUE	14	8->9	90	0	8	16	12	5	2	4	5	0	6	0	10	0	0	0	0	0	0	0	0	0	0
110	SPRAGUE	14	10->11	100	13	31	4	30	4	8	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
111	SPRAGUE	14	12->13	85	8	4	32	15	1	3	18	5	0	3	0	10	0	0	0	0	0	0	0	0	0	0
112	SPRAGUE	14	14->15	100	12	0	23	22	1	0	11	3	0	0	0	8	0	0	0	0	0	4	0	0	0	0
113	SPRAGUE	15	0->1	90	40	15	26	15	1	2	0	5	0	2	5	0	0	0	0	0	0	0	0	25	0	0
114	SPRAGUE	15	2->3	100	14	15	7	4	1	2	7	5	0	0	0	20	0	0	0	0	0	0	0	0	0	0
115	SPRAGUE	15	4->5	70	25	14	18	15	10	4	5	5	0	0	10	6	0	0	0	0	0	0	0	0	0	0
116	SPRAGUE	15	6->7	70	35	0	16	18	1	0	0	2	0	0	30	1	2	0	0	0	25	0	0	0	5	0
117	SPRAGUE	15	8->9	100	0	30	8	7	1	3	4	0	0	2	0	0	6	0	0	8	0	0	0	0	0	0
118	SPRAGUE	15	10->11	80	0	18	0	3	3	0	0	3	0	0	10	5	7	0	0	2	0	0	0	0	0	0
119	SPRAGUE	15	12->13	100	16	0	8	25	4	0	0	10	0	12	0	0	0	0	0	6	0	0	0	0	0	0
120	SPRAGUE	16	0->1	35	0	0	0	5	60	2	2	0	0	5	0	0	0	10	0	0	0	10	0	0	0	0
121	SPRAGUE	16	2->3	80	35	0	15	4	5	0	10	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
122	SPRAGUE	16	4->5	40	0	25	5	2	25	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
123	SPRAGUE	16	6->7	100	0	9	6	5	6	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
124	SPRAGUE	16	8->9	100	0	20	15	5	5	2	10	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
125	SPRAGUE	16	10->11	80	30	25	4	8	5	2	4	1	0	0	0	0	0	15	0	0	0	0	0	0	0	0
126	SPRAGUE	17	0->1	85	37	4	14	15	40	0	0	0	0	0	0	0	22	0	0	0	0	0	0	0	4	0
127	SPRAGUE	17	2->3	100	6	26	10	25	10	2	0	0	0	0	0	0	2	6	0	0	0	0	0	0	0	0
128	SPRAGUE	17	4->5	34	0	17	21	0	50	0	0	0	0	0	0	0	7	0	20	14	0	0	0	0	0	0
129	SPRAGUE	17	6->7	100	10	48	10	7	5	4	11	2	0	0	0	12	0	0	0	3	0	0	0	0	0	0
130	SPRAGUE	17	8->9	70	0	15	40	10	30	6	10	10	0	0	0	0	8	0	0	0	0	0	0	0	0	0
131	SPRAGUE	17	10->11	57	0	29	18	15	30	0	0	0	0	0	0	0	15	5	0	0	0	0	0	0	0	0
132	SPRAGUE	17	12->13	70	75	0	13	10	35	0	0	5	0	0	0	0	19	0	0	0	0	0	0	0	0	0
133	SPRAGUE	18	0->1	80	12	18	15	20	20	0	0	0	0	0	0	0	23	0	5	12	0	0	0	0	0	0
134	SPRAGUE	18	2->3	100	75	18	16	25	15	14	2	0	0	0	0	2	0	0	0	10	0	0	0	0	0	0
135	SPRAGUE	18	4->5	20	0	20	4	0	80	0	0	0	0	0	0	0	2	0	0	4	0	5	0	0	0	0
136	SPRAGUE	18	6->7	100	24	8	14	20	0	0	1	0	0	0	0	0	12	4	0	4	0	0	0	0	0	0
137	SPRAGUE	18	8->9	75	25	28	20	10	25	5	5	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
138	SPRAGUE	18	10->11	100	53	43	12	15	0	7	23	7	0	3	0	0	0	0	0	0	0	0	0	0	0	0
139	SPRAGUE	18	12->13	100	29	18	12	20	0	14	13	4	0	7	0	0	0	7	0	11	0	0	0	0	0	0
140	SPRAGUE	18	14->15	100	54	11	30	15	10	11	2	10	0	0	0	0	8	0	6	0	0	0	0	0	0	0
141																										
142																										
143				SPHAG	BETUL	CHAME	ANDRO	VACCO	SEDGE	SMILA	LEDUM	POLYT	ERIOP	KALMI	PLUR	AULAC	BOGB	SARAC	BLSPR	SALIX	LARIX	TYPHA	ALDER	MGALE	POT	DROSE
144		TOTAL		11317	3007	2571	2218	1793	1546	765	752	644	531	432	373	344	280	247	177	157	55	52	35	25	20	5
145		% total possib		81.42	21.63	18.5	15.96	12.9	11.12	5.504	5.41	4.633	3.82	3.108	2.683	2.475	2.014	1.777	1.273	1.129	0.396	0.374	0.252	0.18	0.144	0.036

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	SITE	SPHA(	ERIOF	LEDUI	PLUR	POLYT	BLSPR	SMILA	VACCC	VACC	JUNIP	BETUI	DROSI	CARE:	CHAM
2	Devil's Lake	0	70	0	0	0	10	2	3	2	24	0	0	0	0
3	Devil's Lake	76	75	3	30	32	0	2	0	0	0	0	0	3	0
4	Devil's Lake	74	87	20	37	13	4	5	0	0	7	24	0	0	0
5	Devil's Lake	67	46	0	5	11	0	4	0	3	5	0	9	2	1
6	Devil's Lake	92	36	18	0	0	0	4	0	5	7	0	2	0	0
7	Devil's Lake	90	30	0	0	0	0	7	0	0	0	43	1	0	0
8	Devil's Lake	100	15	82	10	0	55	5	8	7	0	0	0	0	0
9	Devil's Lake	87	22	28	0	3	0	0	33	0	4	0	1	0	2
10	Devil's Lake	100	9	53	13	45	2	3	0	36	0	0	2	1	0
11	Devil's Lake	100	8	56	0	22	0	11	0	3	0	0	0	0	5
12	Devil's Lake	100	6	23	0	0	0	0	12	17	0	0	0	2	0
13	Devil's Lake	100	45	46	42	4	11	11	27	5	0	0	1	0	0
14	Devil's Lake	100	61	43	0	17	0	23	23	8	6	0	1	0	0
15	Devil's Lake	58	0	41	0	11	0	16	2	0	0	0	2	0	2
16	Devil's Lake	100	24	17	46	0	2	16	0	0	31	0	0	3	0
17	Devil's Lake	50	8	67	0	0	50	0	0	0	0	0	0	0	0
18															
19	SITE	SPHA(	ERIOF	LEDUI	PLUR	POLYT	BLSPR	SMILA	VACCC	VACC	JUNIP	BETUI	DROSI	CARE:	CHAM
20	TOTAL	1294	542	497	183	158	134	109	108	86	84	67	19	11	10
21	% total pos	80.9	33.9	31.1	11.4	9.88	8.375	6.81	6.75	5.38	5.25	4.19	1.19	0.69	0.63

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	CYP A	CYP C	KALM	SARA	TAMA	ANDR(	LARIX	AULA(	SEDGI	BOGB	ALDEI	SALIX	POT	TYPH/	MGAL
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0
4	5	3	0	2	2	0	0	0	0	0	0	0	0	0	0
5	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
14	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
15	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18															
19	CYPEF	CYPEF	KALM	SARA	TAMA	ANDR(	LARIX	AULA(	SEDGI	BOGB	ALDEI	SALIX	POT	TYPH/	MGAL
20	10	10	7	7	5	0	0	0	0	0	0	0	0	0	0
21	0.63	0.63	0.44	0.44	0.31	0	0	0	0	0	0	0	0	0	0

Appendix 2

Culture Medium.

Culture medium used*:

Compound	Stock ($g \cdot L^{-1}$)	ml stock$\cdot L^{-1}$ final
dionized H_2O	987ml	
K_2HPO_4	40.00	1.00
$Ca(NO_3)_2 \cdot 4H_2O$	26.00	1.00
$MgSO_4 \cdot 7H_2O$	25.00	2.00
NH_4NO_3	20.00	1.00
$FeSO_4 \cdot 7H_2O$	0.50	----> 5.00 (with NaEDTA 0.80)
NaEDTA	0.80	
NaEDTA	0.046	Add dry
H_3BO_3	0.550	
$CuSO_4 \cdot 5H_2O$	0.010	
$ZnSO_4 \cdot 7H_2O$	0.022	-----> 1.00 (H_3BO_3 through $NaMoO_4 \cdot 2H_2O$)
$CoCL_2 \cdot 6H_2O$	0.010	
$MnCL_2 \cdot 4H_2O$	0.180	
$NaMoO_4 \cdot 2H_2O$	0.170	

Vitamins :	Stock ($mg \cdot 2L^{-1}$)	
D-Ca pantothenate	20.0	
Pyridoxine HCl (B_6)	20.0	
Riboflavin (B_2)	20.0	
Folic Acid	20.0	
Thiamine HCl	20.0	
Biotin	1.0	-----> 2.00 (all vitamins)
Nicotinamide	20.0	
p-aminobenzoic Acid	20.0	
i-inositol	40.0	
Choline chloride	20.0	
Vitamin B_{12}	1.0	
Agar	12.50g	Added dry

Stocks were refrigerated in darkness.

All stocks are added before autoclaving, except vitamin stock. This is added aseptically to medium afterwards while it is warm. Vitamin stock was filter sterilized prior to addition to other stocks.

Final pH is about 6.0 when no buffer is added.

*Macronutrients concentrations followed Landolt (1975), micronutrients were after Nichols' Woods Hole MBL (1973) and vitamins followed Bowker *et al.* (1980).

Appendix 3

Chlorophyll Data of the 3 Study Sites.

	A	B	C	D	E	F	G	H	I
1	TREATMENT	COLL. DATE	DRY WT	A650	A665	A750	mgChl/g d	REPLI	WK
2	CONTROL	28/06/88	0.173	.	0.204	0.017	1.029	1	2
3	A	28/06/88	0.205	.	0.230	0.026	0.945	1	2
4	B	28/06/88	0.103	.	0.105	0.021	0.774	1	2
5	C	28/06/88	0.102	.	0.097	0.025	0.667	1	2
6	CONTROL	28/06/88	0.122	.	0.151	0.018	1.039	2	2
7	A	28/06/88	0.213	.	0.160	0.025	0.602	2	2
8	B	28/06/88	0.166	.	0.140	0.044	0.551	2	2
9	C	28/06/88	0.155	.	0.205	0.037	1.032	2	2
10	CONTROL	28/06/88	0.166	.	0.190	0.028	0.931	3	2
11	A	28/06/88	0.165	.	0.118	0.031	0.498	3	2
12	B	28/06/88	0.116	.	0.089	0.031	0.470	3	2
13	C	28/06/88	0.179	.	0.200	0.044	0.826	3	2
14	CONTROL	14/07/88	0.150	0.119	0.182	0.026	0.983	3	2
15	A	14/07/88	0.130	0.118	0.216	0.047	1.237	1	4
16	B	14/07/88	0.190	0.134	0.204	0.035	0.845	1	4
17	C	14/07/88	0.110	0.110	0.107	0.022	0.737	1	4
18	CONTROL	14/07/88	0.150	0.136	0.226	0.021	1.300	2	4
19	A	14/07/88	0.090	0.075	0.112	0.023	0.936	2	4
20	B	14/07/88	0.173	0.122	0.192	0.025	0.915	2	4
21	C	14/07/88	0.122	0.057	0.092	0.023	0.542	2	4
22	CONTROL	14/07/88	0.100	0.097	0.157	0.019	1.314	3	4
23	A	14/07/88	0.160	0.088	0.139	0.023	0.690	3	4
24	B	14/07/88	0.100	0.074	0.105	0.020	1.000	3	4
25	C	14/07/88	0.120	0.073	0.113	0.019	0.739	3	4
26	CONTROL	14/07/88	0.140	0.087	0.114	0.005	0.739	1	6
27	A	14/07/88	0.160	0.087	0.152	0.007	0.863	1	6
28	B	14/07/88	0.100	0.075	0.120	0.005	1.098	1	6
29	C	14/07/88	0.110	0.066	0.111	0.005	0.921	1	6
30	CONTROL	14/07/88	0.120	0.068	0.103	0.002	0.799	2	6
31	A	14/07/88	0.120	0.053	0.082	0.004	0.620	2	6
32	B	14/07/88	0.140	0.090	0.106	0.003	0.699	2	6
33	C	14/07/88	0.150	0.067	0.125	0.002	0.779	2	6
34	CONTROL	14/07/88	0.073	0.040	0.065	0.004	0.789	3	6
35	A	14/07/88	0.120	0.053	0.091	0.003	0.696	3	6
36	B	14/07/88	0.053	0.042	0.079	0.004	1.356	3	6
37	C	14/07/88	0.090	0.067	0.110	0.006	1.104	3	6
38	CONTROL	26/07/88	0.100	0.073	0.119	0.004	1.089	1	2
39	A	26/07/88	0.177	0.087	0.149	0.004	0.782	1	2
40	B	26/07/88	0.116	0.047	0.075	0.004	0.586	1	2
41	C	26/07/88	0.185	0.101	0.174	0.008	0.854	1	2
42	CONTROL	26/07/88	0.095	0.065	0.108	0.005	1.025	2	2
43	A	26/07/88	0.304	0.130	0.227	0.004	0.698	2	2
44	B	26/07/88	0.161	0.063	0.106	0.005	0.598	2	2
45	C	26/07/88	0.168	0.073	0.123	0.004	0.670	2	2
46	CONTROL	26/07/88	0.103	0.066	0.108	0.004	0.962	3	2
47	A	26/07/88	0.338	0.181	0.306	0.008	0.836	3	2
48	B	26/07/88	0.228	0.138	0.232	0.005	0.946	3	2
49	C	26/07/88	0.199	0.114	0.192	0.005	0.892	3	2
50	CONTROL	26/07/88	0.121	0.079	0.131	0.005	0.989	1	4
51	A	26/07/88	0.210	0.075	0.117	0.005	0.509	1	4
52	B	26/07/88	0.174	0.063	0.102	0.002	0.542	1	4
53	C	26/07/88	0.302	0.183	0.311	0.005	0.961	1	4
54	CONTROL	26/07/88	0.100	0.067	0.114	0.003	1.051	2	4
55	A	26/07/88	0.142	0.066	0.106	0.005	0.673	2	4
56	B	26/07/88	0.226	0.095	0.162	0.005	0.660	2	4
57	C	26/07/88	0.240	0.095	0.157	0.004	0.605	2	4
58	CONTROL	26/07/88	0.083	0.045	0.075	0.003	0.827	3	4
59	A	26/07/88	0.087	0.030	0.048	0.003	0.485	3	4
60	B	26/07/88	0.129	0.073	0.122	0.004	0.869	3	4
61	C	26/07/88	0.104	0.053	0.088	0.005	0.755	3	4
62	CONTROL	26/07/88	0.112	0.068	0.110	0.006	0.879	1	6
63	A	26/07/88	0.173	0.072	0.114	0.006	0.589	1	6
64	B	26/07/88	0.120	0.038	0.061	0.004	0.451	1	6
65	C	26/07/88	0.173	0.089	0.144	0.005	0.761	1	6
66	CONTROL	26/07/88	0.080	0.041	0.069	0.002	0.793	2	6
67	A	26/07/88	0.247	0.079	0.132	0.006	0.483	2	6
68	B	26/07/88	0.217	0.083	0.140	0.003	0.600	2	6

	A	B	C	D	E	F	G	H	I
69	C	26/07/88	0.095	0.042	0.067	0.005	0.626	2	6
70	CONTROL	26/07/88	0.105	0.057	0.094	0.005	0.808	3	6
71	A	26/07/88	0.156	0.040	0.064	0.003	0.369	3	6
72	B	26/07/88	0.084	0.033	0.052	0.004	0.539	3	6
73	C	26/07/88	0.092	0.025	0.040	0.004	0.378	3	6
74	CONTROL	08/08/88	0.117	0.082	0.119	0.005	0.928	1	2
75	A	08/08/88	0.177	0.037	0.129	0.007	0.653	1	2
76	B	08/08/88	0.220	0.070	0.105	0.005	0.435	1	2
77	C	08/08/88	0.155	0.055	0.078	0.005	0.448	1	2
78	CONTROL	08/08/88	0.123	0.088	0.110	0.003	0.829	2	2
79	A	08/08/88	0.186	0.047	0.070	0.003	0.344	2	2
80	B	08/08/88	0.190	0.096	0.155	0.001	0.769	2	2
81	C	08/08/88	0.194	0.100	0.174	0.001	0.845	2	2
82	CONTROL	08/08/88	0.143	0.078	0.104	0.004	0.661	3	2
83	A	08/08/88	0.083	0.048	0.084	0.004	0.917	3	2
84	B	08/08/88	0.119	0.036	0.245	0.004	1.934	3	2
85	C	08/08/88	0.176	0.131	0.214	0.003	1.132	3	2
86	CONTROL	08/08/88	0.091	0.069	0.100	0.005	0.996	1	4
87	A	08/08/88	0.121	0.048	0.072	0.007	0.517	1	4
88	B	08/08/88	0.137	0.051	0.067	0.006	0.424	1	4
89	C	08/08/88	0.178	0.048	0.069	0.005	0.344	1	4
90	CONTROL	08/08/88	0.120	0.072	0.095	0.004	0.720	2	4
91	A	08/08/88	0.119	0.041	0.072	0.005	0.537	2	4
92	B	08/08/88	0.153	0.045	0.066	0.006	0.370	2	4
93	C	08/08/88	0.101	0.036	0.051	0.007	0.412	2	4
94	CONTROL	08/08/88	0.127	0.070	0.115	0.004	0.831	3	4
95	A	08/08/88	0.109	0.028	0.045	0.002	0.372	3	4
96	B	08/08/88	0.175	0.050	0.079	0.006	0.396	3	4
97	C	08/08/88	0.176	0.034	0.050	0.007	0.235	3	4
98	CONTROL	08/08/88	0.134	0.126	0.184	0.016	1.188	1	6
99	A	08/08/88	0.119	0.026	0.042	0.002	0.314	1	6
100	B	08/08/88	0.171	0.073	0.114	0.004	0.610	1	6
101	C	08/08/88	0.055	0.100	0.047	0.004	0.741	1	6
102	CONTROL	08/08/88	0.117	0.100	0.159	0.004	1.263	2	6
103	A	08/08/88	0.134	0.049	0.072	0.005	0.475	2	6
104	B	08/08/88	0.101	0.043	0.067	0.003	0.596	2	6
105	C	08/08/88	0.110	0.061	0.099	0.003	0.829	2	6
106	CONTROL	08/08/88	0.114	0.079	0.125	0.003	1.017	3	6
107	A	08/08/88	0.159	0.036	0.062	0.003	0.350	3	6
108	B	08/08/88	0.140	0.060	0.112	0.002	0.748	3	6
109	C	08/08/88	0.115	0.060	0.099	0.002	0.793	3	6
110	CONTROL	25/08/88	0.107	0.112	0.174	0.003	1.528	1	2
111	A	25/08/88	0.104	0.039	0.059	0.005	0.495	1	2
112	B	25/08/88	0.091	0.039	0.060	0.004	0.575	1	2
113	C	25/08/88	0.092	0.044	0.072	0.003	0.711	1	2
114	CONTROL	25/08/88	0.090	0.088	0.135	0.002	1.399	2	2
115	A	25/08/88	0.143	0.045	0.079	0.005	0.489	2	2
116	B	25/08/88	0.126	0.041	0.067	0.003	0.478	2	2
117	C	25/08/88	0.094	0.026	0.039	0.003	0.364	2	2
118	CONTROL	25/08/88	0.091	0.067	0.101	0.002	1.032	3	2
119	A	25/08/88	0.139	0.077	0.126	0.003	0.838	3	2
120	B	25/08/88	0.176	0.045	0.066	0.005	0.329	3	2
121	C	25/08/88	0.151	0.033	0.032	0.002	0.187	3	2
122	CONTROL	25/08/88	0.090	0.060	0.091	0.002	0.929	1	4
123	A	25/08/88	0.108	0.056	0.101	0.002	0.875	1	4
124	CONTROL	25/08/88	0.091	0.048	0.082	0.002	0.830	2	4
125	C	25/08/88	0.102	0.054	0.095	0.003	0.856	2	4
126	CONTROL	25/08/88	0.086	0.080	0.119	0.002	1.299	3	4
127	A	25/08/88	0.102	0.037	0.056	0.004	0.483	3	4
128	C	25/08/88	0.132	0.043	0.068	0.004	0.460	3	4
129	CONTROL	25/08/88	0.101	0.070	0.104	0.004	0.937	1	6
130	A	25/08/88	0.095	0.039	0.065	0.003	0.620	1	6
131	B	25/08/88	0.090	0.045	0.076	0.003	0.774	1	6
132	C	25/08/88	0.088	0.038	0.057	0.002	0.593	1	6
133	CONTROL	25/08/88	0.121	0.090	0.130	0.003	0.994	2	6
134	A	25/08/88	0.089	0.036	0.052	0.004	0.511	2	6
135	B	25/08/88	0.094	0.037	0.062	0.003	0.595	2	6
136	C	25/08/88	0.091	0.030	0.048	0.002	0.482	2	6

	A	B	C	D	E	F	G	H	I
137	CONTROL	25/08/88	0.133	0.089	0.122	0.008	0.812	3	6
138	A	25/08/88	0.115	0.048	0.072	0.004	0.556	3	6
139	B	25/08/88	0.118	0.030	0.044	0.002	0.337	3	6
140	C	25/08/88	0.110	0.057	0.092	0.003	0.768	3	6
141	CONTROL	25/08/88	0.109	0.092	0.166	0.004	1.413	1	2
142	A	25/08/88	0.166	0.064	0.096	0.003	0.528	1	2
143	B	25/08/88	0.147	0.070	0.105	0.005	0.647	1	2
144	C	25/08/88	0.132	0.078	0.116	0.005	0.806	1	2
145	CONTROL	08/09/88	0.129	0.087	0.125	0.003	0.896	2	2
146	A	08/09/88	0.178	0.082	0.140	0.003	0.727	2	2
147	CONTROL	08/09/88	0.138	0.130	0.226	0.004	1.528	3	2
148	C	08/09/88	0.100	0.058	0.108	0.002	1.011	3	2
149	CONTROL	08/09/88	0.104	0.073	0.110	0.003	0.979	1	4
150	A	08/09/88	0.141	0.037	0.056	0.003	0.358	1	4
151	B	08/09/88	0.103	0.047	0.078	0.004	0.684	1	4
152	C	08/09/88	0.084	0.031	0.048	0.003	0.507	1	4
153	CONTROL	08/09/88	0.111	0.064	0.092	0.004	0.753	2	4
154	A	08/09/88	0.166	0.037	0.058	0.004	0.305	2	4
155	B	08/09/88	0.100	0.059	0.103	0.004	0.940	2	4
156	C	08/09/88	0.112	0.045	0.069	0.004	0.555	2	4
157	CONTROL	08/09/88	0.126	0.098	0.150	0.003	1.106	3	4
158	A	08/09/88	0.144	0.049	0.073	0.003	0.463	3	4
159	C	08/09/88	0.091	0.020	0.071	0.001	0.734	3	4
160	CONTROL	08/09/88	0.116	0.102	0.150	0.001	1.222	1	6
161	A	08/09/88	0.132	0.067	0.101	0.001	0.722	1	6
162	B	08/09/88	0.140	0.049	0.071	0.002	0.472	1	6
163	C	08/09/88	0.116	0.061	0.103	0.001	0.837	1	6
164	CONTROL	08/09/88	0.124	0.079	0.112	0.003	0.839	2	6
165	A	08/09/88	0.131	0.039	0.065	0.004	0.442	2	6
166	B	08/09/88	0.097	0.040	0.061	0.003	0.576	2	6
167	C	08/09/88	0.125	0.051	0.076	0.003	0.560	2	6
168	CONTROL	08/09/88	0.103	0.078	0.116	0.005	1.030	3	6
169	A	08/09/88	0.111	0.023	0.031	0.005	0.222	3	6
170	B	08/09/88	0.142	0.069	0.104	0.003	0.671	3	6
171	C	08/09/88	0.130	0.048	0.072	0.004	0.498	3	6
172	CONTROL	08/09/88	0.098	0.050	0.076	0.003	0.701	1	2
173	A	08/09/88	0.106	0.045	0.068	0.004	0.577	1	2
174	B	08/09/88	0.159	0.071	0.122	0.002	0.715	1	2
175	C	08/09/88	0.146	0.093	0.160	0.002	1.027	1	2
176	CONTROL	08/09/88	0.101	0.084	0.136	0.002	1.265	2	2
177	A	08/09/88	0.124	0.051	0.085	0.002	0.631	2	2
178	B	08/09/88	0.114	0.082	0.126	0.003	1.022	2	2
179	C	08/09/88	0.092	0.053	0.076	0.004	0.744	2	2
180	CONTROL	22/09/88	0.138	0.085	0.155	0.002	1.051	3	2
181	A	22/09/88	0.117	0.056	0.094	0.005	0.720	3	2
182	B	22/09/88	0.122	0.038	0.064	0.003	0.474	3	2
183	C	22/09/88	0.119	0.054	0.098	0.003	0.764	3	2
184	CONTROL	22/09/88	0.115	0.131	0.208	0.003	1.702	1	4
185	A	22/09/88	0.121	0.055	0.084	0.003	0.629	1	4
186	B	22/09/88	0.125	0.076	0.133	0.002	0.994	1	4
187	C	22/09/88	0.115	0.059	0.108	0.002	0.883	1	4
188	CONTROL	22/09/88	0.113	0.083	0.124	0.003	1.018	2	4
189	A	22/09/88	0.151	0.061	0.099	0.001	0.619	2	4
190	B	22/09/88	0.121	0.005	0.077	0.002	0.590	2	4
191	C	22/09/88	0.118	0.035	0.050	0.002	0.380	2	4
192	CONTROL	22/09/88	0.108	0.064	0.086	0.003	0.728	3	4
193	A	22/09/88	0.090	0.035	0.054	0.002	0.554	3	4
194	B	22/09/88	0.089	0.035	0.047	0.003	0.476	3	4
195	C	22/09/88	0.102	0.029	0.041	0.001	0.374	3	4
196	CONTROL	22/09/88	0.128	0.060	0.080	0.002	0.581	1	6
197	A	22/09/88	0.103	0.041	0.057	0.003	0.498	1	6
198	B	22/09/88	0.115	0.037	0.050	0.004	0.385	1	6
199	C	22/09/88	0.105	0.053	0.078	0.006	0.650	1	6
200	CONTROL	22/09/88	0.115	0.119	0.200	0.004	1.626	2	6
201	A	22/09/88	0.108	99.122	0.090	0.003	0.766	2	6
202	B	22/09/88	0.110	0.067	0.113	0.004	0.935	2	6
203	C	22/09/88	0.087	0.021	0.028	0.004	0.268	2	6

	A	B	C	D	E	F	G	H	I
1	TREATMENT	COLL. DATE	DRY WT	A650	A665	A750	mgChl/g dw	REPLICATE	WEEKS
2	CONTROL	6/17/88	0.1125	.	0.145	0.036	0.923	1	2
3	A	6/17/88	0.1475	.	0.087	0.023	0.412	1	2
4	B	6/17/88	0.147	.	0.154	0.029	0.808	1	2
5	C	6/17/88	0.124	.	0.106	0.027	0.610	1	2
6	CONTROL	6/17/88	0.098	.	0.114	0.029	0.824	2	2
7	A	6/17/88	0.148	.	0.094	0.042	0.334	2	2
8	B	6/17/88	0.13	.	0.131	0.035	0.699	2	2
9	C	6/17/88	0.1381	.	0.096	0.027	0.477	2	2
10	CONTROL	6/17/88	0.1626	.	0.210	0.046	0.958	3	2
11	A	6/17/88	0.134	.	0.096	0.039	0.404	3	2
12	B	6/17/88	0.15	.	0.106	0.036	0.433	3	2
13	C	6/17/88	0.144	.	0.158	0.030	0.843	3	2
14	CONTROL	6/17/88	0.15	.	0.255	0.032	1.410	1	4
15	A	6/17/88	0.1617	.	0.193	0.034	0.934	1	4
16	B	6/17/88	0.16	.	0.163	0.031	0.782	1	4
17	C	6/17/88	0.1356	.	0.174	0.031	1.001	1	4
18	CONTROL	6/17/88	0.142	.	0.191	0.030	1.072	2	4
19	A	6/17/88	0.148	.	0.139	0.032	0.684	2	4
20	B	6/17/88	0.16	.	0.177	0.028	0.886	2	4
21	C	6/17/88	0.148	.	0.206	0.040	1.068	2	4
22	CONTROL	6/17/88	0.117	.	0.151	0.037	0.928	3	4
23	A	6/17/88	0.13	.	0.128	0.043	0.626	3	4
24	B	6/17/88	0.13	.	0.088	0.028	0.436	3	4
25	C	6/17/88	0.14	.	0.133	0.035	0.667	3	4
26	CONTROL	6/17/88	0.14	.	0.286	0.028	1.755	1	6
27	A	6/17/88	0.15	.	0.149	0.023	0.800	1	6
28	B	6/17/88	0.167	.	0.185	0.028	0.895	1	6
29	C	6/17/88	0.13	.	0.105	0.029	0.552	1	6
30	CONTROL	6/17/88	0.112	.	0.121	0.026	0.806	2	6
31	A	6/17/88	0.14	.	0.108	0.031	0.522	2	6
32	B	6/17/88	162	.	0.217	0.045	0.001	2	6
33	C	6/17/88	0.13	.	0.119	0.041	0.567	2	6
34	CONTROL	6/17/88	0.123	.	0.150	0.026	0.957	3	6
35	A	6/17/88	0.187	.	0.277	0.036	1.222	3	6
36	B	6/17/88	0.135	.	0.168	0.047	0.851	3	6
37	C	6/17/88	0.14	.	0.191	0.040	1.022	3	6
38	CONTROL	6/28/88	0.163	.	0.179	0.021	0.919	1	2
39	A	6/28/88	0.1587	.	0.173	0.036	0.818	1	2
40	B	6/28/88	0.15	.	0.194	0.046	0.937	1	2
41	C	6/28/88	0.13	.	0.133	0.037	0.706	1	2
42	CONTROL	6/28/88	0.13	.	0.242	0.026	1.578	2	2
43	A	6/28/88	0.13	.	0.140	0.041	0.726	2	2
44	B	6/28/88	0.14	.	0.188	0.056	0.898	2	2
45	C	6/28/88	0.15	.	0.221	0.038	1.161	2	2
46	CONTROL	6/28/88	0.13	.	0.191	0.022	1.237	3	2
47	A	6/28/88	0.13	.	0.111	0.036	0.553	3	2
48	B	6/28/88	0.12	.	0.151	0.048	0.818	3	2
49	C	6/28/88	0.13	.	0.139	0.038	0.735	3	2
50	CONTROL	6/28/88	0.146	.	0.377	0.019	2.326	1	4
51	A	6/28/88	0.148	.	0.210	0.041	1.082	1	4
52	B	6/28/88	0.1368	.	0.213	0.025	1.303	1	4
53	C	6/28/88	0.1318	.	0.150	0.042	0.776	1	4
54	CONTROL	6/28/88	0.14	.	0.195	0.042	1.038	2	4
55	A	6/28/88	0.154	.	0.189	0.039	0.925	2	4
56	B	6/28/88	0.153	.	0.159	0.052	0.662	2	4
57	C	6/28/88	0.1463	.	0.224	0.053	1.110	2	4
58	CONTROL	6/28/88	0.13	.	0.172	0.030	1.037	3	4
59	A	6/28/88	0.158	.	0.207	0.046	0.964	3	4
60	B	6/28/88	0.12	.	0.151	0.041	0.876	3	4
61	C	6/28/88	0.13	.	0.163	0.040	0.896	3	4
62	CONTROL	6/28/88	0.1	.	0.204	0.038	1.570	1	6
63	A	6/28/88	0.1	.	0.114	0.034	0.753	1	6
64	B	6/28/88	0.1401	.	0.191	0.036	1.048	1	6
65	C	6/28/88	0.12	.	0.118	0.035	0.652	1	6
66	CONTROL	6/28/88	0.13	.	0.270	0.023	1.800	2	6
67	A	6/28/88	0.14	.	0.134	0.047	0.586	2	6

	A	B	C	D	E	F	G	H	I
68	B	6/28/88	0.11		0.123	0.038	0.731	2	6
69	C	6/28/88	0.15		0.141	0.045	0.610	2	6
70	CONTROL	6/28/88	0.16	0.155	0.276	0.020	1.402	3	6
71	A	6/28/88	0.1606	0.150	0.238	0.033	1.184	3	6
72	B	6/28/88	0.15	0.149	0.225	0.041	1.157	3	6
73	C	6/28/88	0.14	0.122	0.167	0.043	0.901	3	6
74	CONTROL	7/12/88	0.14	0.119	0.191	0.007	1.286	1	2
75	A	7/12/88	0.181	0.041	0.064	0.006	0.306	1	2
76	B	7/12/88	0.14	0.058	0.101	0.005	0.613	1	2
77	C	7/12/88	0.134	0.079	0.132	0.006	0.886	1	2
78	CONTROL	7/12/88	0.17	0.245	0.441	0.006	2.302	2	2
79	A	7/12/88	0.1468	0.116	0.191	0.008	1.191	2	2
80	B	7/12/88	0.125	0.103	0.181	0.004	1.292	2	2
81	C	7/12/88	0.11	0.080	0.130	0.006	1.083	2	2
82	CONTROL	7/12/88	0.113	0.155	0.279	0.004	2.190	3	2
83	A	7/12/88	0.1986	0.161	0.270	0.006	1.261	3	2
84	B	7/12/88	0.164	0.099	0.169	0.004	0.940	3	2
85	C	7/12/88	0.2	0.166	0.290	0.005	1.309	3	2
86	CONTROL	7/12/88	0.134	0.155	0.225	0.006	1.752	1	4
87	A	7/12/88	0.151	0.095	0.153	0.007	0.936	1	4
88	B	7/12/88	0.077	0.058	0.090	0.006	1.090	1	4
89	C	7/12/88	0.075	0.048	0.072	0.006	0.897	1	4
90	CONTROL	7/12/88	0.147	0.134	0.211	0.010	1.343	2	4
91	A	7/12/88	0.188	0.083	0.129	0.008	0.635	2	4
92	B	7/12/88	0.185	0.078	0.129	0.006	0.631	2	4
93	C	7/12/88	0.159	0.078	0.118	0.010	0.684	2	4
94	CONTROL	7/12/88	0.125	0.122	0.179	0.007	1.448	3	4
95	A	7/12/88	0.095	0.039	0.055	0.008	0.519	3	4
96	B	7/12/88	0.116	0.086	0.148	0.005	1.137	3	4
97	C	7/12/88	0.129	0.064	0.103	0.007	0.716	3	4
98	CONTROL	7/12/88	0.162	0.139	0.233	0.010	1.293	1	6
99	A	7/12/88	0.152	0.061	0.092	0.010	0.538	1	6
100	B	7/12/88	0.135	0.061	0.090	0.012	0.578	1	6
101	C	7/12/88	0.132	0.059	0.090	0.008	0.613	1	6
102	CONTROL	7/12/88	0.11	0.093	0.153	0.009	1.227	2	6
103	A	7/12/88	0.135	0.066	0.108	0.007	0.703	2	6
104	B	7/12/88	0.122	0.066	0.103	0.008	0.761	2	6
105	C	7/12/88	0.175	0.113	0.182	0.007	0.969	2	6
106	CONTROL	7/12/88	0.132	0.120	0.203	0.007	1.388	3	6
107	A	7/12/88	0.16	0.090	0.146	0.008	0.829	3	6
108	B	7/12/88	0.134	0.054	0.086	0.005	0.587	3	6
109	C	7/12/88	0.135	0.076	0.118	0.008	0.798	3	6
110	CONTROL	7/26/88	0.1352	0.158	0.252	0.005	1.808	1	2
111	A	7/26/88	0.1373	0.040	0.068	0.002	0.445	1	2
112	B	7/26/88	0.1143	0.083	0.148	0.004	1.134	1	2
113	C	7/26/88	0.1296	0.058	0.104	0.002	0.706	1	2
114	CONTROL	7/26/88	0.1446	0.136	0.203	0.005	1.428	2	2
115	A	7/26/88	0.1489	0.071	0.111	0.004	0.715	2	2
116	B	7/26/88	0.1185	0.046	0.078	0.002	0.597	2	2
117	C	7/26/88	0.1586	0.055	0.082	0.007	0.477	2	2
118	CONTROL	7/26/88	0.141	0.114	0.168	0.006	1.206	3	2
119	A	7/26/88	0.389	0.074	0.122	0.008	0.275	3	2
120	B	7/26/88	0.1205	0.084	0.140	0.008	1.019	3	2
121	C	7/26/88	0.1334	0.083	0.143	0.005	0.946	3	2
122	CONTROL	7/26/88	0.1297	0.129	0.191	0.007	1.483	1	4
123	A	7/26/88	0.1429	0.067	0.105	0.005	0.690	1	4
124	B	7/26/88	0.1129	0.056	0.083	0.004	0.718	1	4
125	C	7/26/88	0.0933	0.043	0.061	0.003	0.676	1	4
126	CONTROL	7/26/88	0.1643	0.117	0.163	0.003	1.082	2	4
127	A	7/26/88	0.1355	0.061	0.093	0.004	0.665	2	4
128	B	7/26/88	0.1351	0.046	0.066	0.003	0.499	2	4
129	C	7/26/88	0.1499	0.121	0.182	0.001	1.262	2	4
130	CONTROL	7/26/88	0.1357	0.112	0.158	0.009	1.191	3	4
131	A	7/26/88	0.1178	0.044	0.066	0.006	0.512	3	4
132	B	7/26/88	0.1055	0.065	0.095	0.006	0.886	3	4
133	C	7/26/88	0.094	0.043	0.061	0.006	0.619	3	4
134	CONTROL	7/26/88	0.0937	0.117	0.203	0.005	1.955	1	6

	A	B	C	D	E	F	G	H	I
135	A	7/26/88	0.0825	0.039	0.059	0.003	0.681	1	6
136	B	7/26/88	0.1176	0.064	0.107	0.008	0.783	1	6
137	C	7/26/88	0.116	0.054	0.100	0.004	0.710	1	6
138	CONTROL	7/26/88	0.1075	0.064	0.094	0.005	0.874	2	6
139	A	7/26/88	0.0926	0.038	0.061	0.006	0.565	2	6
140	B	7/26/88	0.0755	0.052	0.081	0.006	0.975	2	6
141	C	7/26/88	0.1309	0.077	0.137	0.007	0.880	2	6
142	CONTROL	7/26/88	0.1089	0.093	0.171	0.002	1.380	3	6
143	A	7/26/88	0.1244	0.083	0.151	0.002	1.073	3	6
144	B	7/26/88	0.0927	0.044	0.070	0.004	0.696	3	6
145	C	7/26/88	0.0767	0.055	0.096	0.004	1.082	3	6
146	CONTROL	8/8/88	0.082	0.109	0.183	0.004	2.074	1	2
147	A	8/8/88	0.1125	0.058	0.097	0.003	0.794	1	2
148	B	8/8/88	0.0901	0.086	0.146	0.004	1.480	1	2
149	C	8/8/88	0.1185	0.085	0.142	0.006	1.080	1	2
150	CONTROL	8/8/88	0.0689	0.066	0.098	0.003	1.455	2	2
151	A	8/8/88	0.132	0.091	0.159	0.002	1.098	2	2
152	B	8/8/88	0.1197	0.062	0.101	0.005	0.765	2	2
153	C	8/8/88	0.1299	0.130	0.212	0.007	1.519	2	2
154	CONTROL	8/8/88	0.1315	0.155	0.266	0.003	1.874	3	2
155	A	8/8/88	0.1006	0.061	0.102	0.004	0.912	3	2
156	B	8/8/88	0.1098	0.054	0.090	0.005	0.723	3	2
157	C	8/8/88	0.1009	0.087	0.150	0.003	1.357	3	2
158	CONTROL	8/8/88	0.0874	0.077	0.118	0.005	1.314	1	4
159	A	8/8/88	0.0929	0.048	0.083	0.004	0.778	1	4
160	B	8/8/88	0.0957	0.035	0.054	0.004	0.523	1	4
161	C	8/8/88	0.1197	0.088	0.147	0.002	1.165	1	4
162	CONTROL	8/8/88	0.0703	0.067	0.095	0.002	1.442	2	4
163	A	8/8/88	0.0888	0.044	0.067	0.003	0.729	2	4
164	B	8/8/88	0.0785	0.035	0.051	0.003	0.637	2	4
165	C	8/8/88	0.1082	0.056	0.094	0.004	0.771	2	4
166	CONTROL	8/8/88	0.0857	0.109	0.163	0.004	1.934	3	4
167	A	8/8/88	0.1058	0.047	0.068	0.004	0.643	3	4
168	C	8/8/88	0.0808	0.051	0.075	0.005	0.899	3	4
169	CONTROL	8/8/88	0.0746	0.070	0.099	0.002	1.428	1	6
170	A	8/8/88	0.0905	0.037	0.055	0.002	0.609	1	6
171	B	8/8/88	0.0792	0.045	0.069	0.002	0.868	1	6
172	C	8/8/88	0.0784	0.050	0.074	0.003	0.935	1	6
173	CONTROL	8/8/88	0.0851	0.078	0.117	0.003	1.397	2	6
174	A	8/8/88	0.0628	0.029	0.041	0.004	0.620	2	6
175	B	8/8/88	0.1325	0.091	0.153	0.003	1.069	2	6
176	C	8/8/88	0.0913	0.073	0.132	0.003	1.271	2	6
177	CONTROL	8/8/88	0.0709	0.075	0.115	0.002	1.620	3	6
178	A	8/8/88	0.1197	0.069	0.118	0.002	0.908	3	6
179	B	8/8/88	0.1003	0.084	0.152	0.004	1.318	3	6
180	C	8/8/88	0.1151	0.090	0.161	0.003	1.237	3	6
181	CONTROL	8/24/88	0.0937	0.065	0.096	0.003	1.041	1	2
182	A	8/24/88	0.0935	0.034	0.051	0.005	0.498	1	2
183	B	8/24/88	0.0875	0.048	0.076	0.005	0.790	1	2
184	C	8/24/88	0.1161	0.041	0.069	0.003	0.531	1	2
185	CONTROL	8/24/88	0.1053	0.105	0.187	0.004	1.571	2	2
186	A	8/24/88	0.0981	0.034	0.052	0.006	0.463	2	2
187	B	8/24/88	0.0703	0.033	0.050	0.005	0.636	2	2
188	C	8/24/88	0.1081	0.061	0.099	0.003	0.858	2	2
189	CONTROL	8/24/88	0.0856	0.086	0.131	0.003	1.546	3	2
190	A	8/24/88	0.0811	0.040	0.063	0.006	0.681	3	2
191	B	8/24/88	0.081	0.040	0.059	0.006	0.662	3	2
192	C	8/24/88	0.0783	0.038	0.051	0.008	0.598	3	2
193	CONTROL	8/24/88	0.0877	0.103	0.157	0.005	1.761	1	4
194	A	8/24/88	0.1013	0.046	0.075	0.005	0.663	1	4
195	B	8/24/88	0.0847	0.030	0.046	0.004	0.501	1	4
196	C	8/24/88	0.0861	0.050	0.078	0.004	0.864	1	4
197	CONTROL	8/24/88	0.0948	0.082	0.117	0.003	1.304	2	4
198	A	8/24/88	0.0917	0.025	0.035	0.002	0.381	2	4
199	B	8/24/88	0.096	0.057	0.087	0.005	0.861	2	4
200	C	8/24/88	0.1022	0.064	0.103	0.004	0.937	2	4
201	CONTROL	8/24/88	0.0749	0.057	0.085	0.002	1.159	3	4

	A	B	C	D	E	F	G	H	I
202	A	8/24/88	0.121	0.047	0.079	0.004	0.577	3	4
203	B	8/24/88	0.0932	0.065	0.100	0.004	1.046	3	4
204	C	8/24/88	0.0903	0.067	0.100	0.004	1.092	3	4
205	CONTROL	8/24/88	0.0981	0.106	0.158	0.004	1.631	1	6
206	A	8/24/88	0.0974	0.067	0.118	0.004	1.058	1	6
207	B	8/24/88	0.0918	0.067	0.103	0.006	1.053	1	6
208	C	8/24/88	0.0896	0.063	0.094	0.006	1.003	1	6
209	CONTROL	8/24/88	0.0899	0.110	0.161	0.004	1.853	2	6
210	A	8/24/88	0.1077	0.059	0.090	0.005	0.798	2	6
211	B	8/24/88	0.1049	0.074	0.111	0.004	1.046	2	6
212	C	8/24/88	0.0891	0.067	0.106	0.006	1.086	2	6
213	CONTROL	8/24/88	0.0923	0.084	0.122	0.005	1.346	3	6
214	A	8/24/88	0.1014	0.066	0.114	0.004	1.001	3	6
215	B	8/24/88	0.0984	0.075	0.123	0.005	1.142	3	6
216	C	8/24/88	0.1147	0.103	0.183	0.006	1.386	3	6
217	CONTROL	9/8/88	0.0963	0.113	0.196	0.005	1.827	1	2
218	A	9/8/88	0.0792	0.047	0.081	0.004	0.891	1	2
219	B	9/8/88	0.0774	0.043	0.072	0.004	0.819	1	2
220	C	9/8/88	0.0961	0.069	0.120	0.003	1.120	1	2
221	CONTROL	9/8/88	0.0858	0.095	0.164	0.003	1.748	2	2
222	A	9/8/88	0.0851	0.044	0.075	0.005	0.754	2	2
223	B	9/8/88	0.0843	0.060	0.101	0.005	1.064	2	2
224	C	9/8/88	0.0957	0.052	0.089	0.004	0.822	2	2
225	CONTROL	9/8/88	0.091	0.168	0.291	0.004	2.929	3	2
226	A	9/8/88	0.1303	0.081	0.140	0.003	0.971	3	2
227	B	9/8/88	0.0804	0.054	0.081	0.010	0.874	3	2
228	C	9/8/88	0.1018	0.079	0.127	0.003	1.186	3	2
229	CONTROL	9/8/88	0.0909	0.136	0.240	0.002	2.399	1	4
230	A	9/8/88	0.0896	0.053	0.087	0.004	0.882	1	4
231	B	9/8/88	0.0908	0.078	0.130	0.003	1.329	1	4
232	C	9/8/88	0.0853	0.038	0.058	0.002	0.664	1	4
233	CONTROL	9/8/88	0.099	0.155	0.283	0.002	2.539	2	4
234	A	9/8/88	0.1058	0.051	0.082	0.004	0.714	2	4
235	B	9/8/88	0.1387	0.100	0.166	0.004	1.119	2	4
236	C	9/8/88	0.1279	0.078	0.137	0.003	0.961	2	4
237	CONTROL	9/8/88	0.0921	0.114	0.196	0.002	1.970	3	4
238	A	9/8/88	0.0923	0.057	0.090	0.006	0.882	3	4
239	B	9/8/88	0.0917	0.049	0.076	0.003	0.799	3	4
240	C	9/8/88	0.083	0.052	0.088	0.004	0.945	3	4
241	CONTROL	9/22/88	0.0801	0.101	0.174	0.003	1.985	1	6
242	A	9/22/88	0.0825	0.057	0.100	0.003	1.064	1	6
243	B	9/22/88	0.0849	0.091	0.161	0.003	1.704	1	6
244	C	9/22/88	0.0709	0.071	0.121	0.002	1.571	1	6
245	CONTROL	9/22/88	0.0993	0.126	0.223	0.002	2.042	2	6
246	A	9/22/88	0.0772	0.041	0.069	0.003	0.794	2	6
247	B	9/22/88	0.0862	0.055	0.092	0.006	0.936	2	6
248	C	9/22/88	0.1198	0.087	0.154	0.003	1.147	2	6
249	CONTROL	9/22/88	0.0861	0.118	0.210	0.003	2.189	3	6
250	A	9/22/88	0.1006	0.064	0.111	0.005	0.967	3	6
251	B	9/22/88	0.0976	0.063	0.107	0.005	0.967	3	6
252	C	9/22/88	0.0858	0.072	0.126	0.005	1.283	3	6

	A	B	C	D	E	F	G	H
1	TREAMENT	COLL.DATE	DRY WT	A650	A665	A750	mgCHL/g DF	MONTH
2	CONTROL	JUNE 16/88	0.08	.	0.222	0.012	2.493	1
3	CONTROL	JUNE 16/88	0.08	.	0.239	0.016	2.647	1
4	CONTROL	JUNE 16/88	0.08	.	0.189	0.02	2.006	1
5	CONTROL	JUNE 16/88	0.08	.	0.194	0.021	2.054	1
6	A	JUNE 16/88	0.113	.	0.18	0.064	0.975	1
7	A	JUNE 16/88	0.113	.	0.133	0.024	0.916	1
8	A	JUNE 16/88	0.113	.	0.14	0.03	0.924	1
9	B	JUNE 16/88	0.09	.	0.129	0.029	1.055	1
10	B	JUNE 16/88	0.09	.	0.136	0.029	1.129	1
11	B	JUNE 16/88	0.09	.	0.12	0.021	1.045	1
12	C	JUNE 16/88	0.113	.	0.147	0.023	1.042	1
13	C	JUNE 16/88	0.113	.	0.135	0.03	0.882	1
14	C	JUNE 16/88	0.113	.	0.164	0.034	1.093	1
15	CONTROL	JULY 16/88	0.081	0.087	0.127	0.003	1.628	2
16	CONTROL	JULY 16/88	0.081	0.088	0.128	0.003	1.647	2
17	CONTROL	JULY 16/88	0.081	0.088	0.13	0.001	1.688	2
18	A	JULY 16/88	0.14	0.053	0.088	0.003	0.577	2
19	A	JULY 16/88	0.14	0.055	0.09	0.004	0.587	2
20	A	JULY 16/88	0.14	0.054	0.089	0.004	0.577	2
21	B	JULY 16/88	0.133	0.055	0.091	0.006	0.598	2
22	B	JULY 16/88	0.133	0.058	0.093	0.009	0.596	2
23	B	JULY 16/88	0.133	0.059	0.096	0.006	0.643	2
24	C	JULY 16/88	0.14	0.041	0.064	0.003	0.433	2
25	C	JULY 16/88	0.14	0.041	0.063	0.006	0.400	2
26	C	JULY 16/88	0.14	0.042	0.066	0.005	0.424	2
27	A1	JULY 16/88	0.14	0.054	0.08	0.005	0.553	1
28	A1	JULY 16/88	0.14	0.062	0.095	0.005	0.648	1
29	A1	JULY 16/88	0.14	0.051	0.076	0.004	0.531	1
30	A2	JULY 16/88	0.13	0.07	0.111	0.005	0.801	1
31	A2	JULY 16/88	0.13	0.058	0.087	0.005	0.646	1
32	A2	JULY 16/88	0.13	0.072	0.122	0.003	0.860	1
33	A3	JULY 16/88	0.13	0.057	0.086	0.004	0.646	1
34	A3	JULY 16/88	0.13	0.048	0.072	0.005	0.525	1
35	A3	JULY 16/88	0.13	0.047	0.067	0.006	0.496	1
36	B1	JULY 16/88	0.11	0.044	0.066	0.006	0.550	1
37	B1	JULY 16/88	0.11	0.046	0.069	0.006	0.578	1
38	B1	JULY 16/88	0.11	0.041	0.069	0.005	0.534	1
39	B2	JULY 16/88	0.13	0.044	0.065	0.006	0.463	1
40	B2	JULY 16/88	0.13	0.043	0.062	0.007	0.438	1
41	B3	JULY 16/88	0.13	0.045	0.063	0.006	0.470	1
42	B3	JULY 16/88	0.13	0.043	0.06	0.008	0.423	1
43	B3	JULY 16/88	0.13	0.04	0.055	0.007	0.398	1
44	C1	JULY 16/88	0.11	0.053	0.086	0.005	0.704	1
45	C1	JULY 16/88	0.11	0.054	0.087	0.005	0.717	1
46	C1	JULY 16/88	0.11	0.055	0.088	0.003	0.757	1
47	C2	JULY 16/88	0.12	0.056	0.089	0.002	0.719	1
48	C2	JULY 16/88	0.12	0.057	0.091	0.005	0.696	1
49	C2	JULY 16/88	0.12	0.052	0.083	0.004	0.642	1
50	A	AUG 18/88	0.1493	0.022	0.032	0.007	0.162	3
51	A	AUG 18/88	0.1493	0.019	0.03	0.003	0.173	3
52	A	AUG 18/88	0.1493	0.022	0.033	0.003	0.202	3
53	B	AUG 18/88	0.1683	0.024	0.037	0.002	0.208	3
54	B	AUG 18/88	0.1683	0.027	0.041	0.005	0.209	3
55	B	AUG 18/88	0.1683	0.029	0.046	0.004	0.239	3

	A	B	C	D	E	F	G	H
56	C	AUG 18/88	0.1692	0.061	0.091	0.014	0.445	3
57	C	AUG 18/88	0.1692	0.048	0.076	0.007	0.391	3
58	C	AUG 18/88	0.1692	0.054	0.087	0.008	0.440	3
59	CONTROL	AUG 18/88	0.126	0.08	0.126	0.001	0.998	2
60	CONTROL	AUG 18/88	0.126	0.074	0.109	0.002	0.898	2
61	CONTROL	AUG 18/88	0.126	0.077	0.115	0.002	0.938	2
62	CONTROL	AUG 18/88	0.126	0.083	0.122	0.003	0.998	2
63	CONTROL	AUG 18/88	0.126	0.082	0.122	0.0003	1.020	2
64	A1	AUG 18/88	0.13	0.027	0.038	0.003	0.289	2
65	A1	AUG 18/88	0.13	0.031	0.043	0.005	0.313	2
66	A1	AUG 18/88	0.13	0.034	0.048	0.007	0.328	2
67	A2	AUG 18/88	0.1421	0.027	0.042	0.002	0.281	2
68	A2	AUG 18/88	0.1421	0.034	0.046	0.008	0.287	2
69	A3	AUG 18/88	0.1443	0.026	0.039	0.002	0.263	2
70	A3	AUG 18/88	0.1443	0.033	0.048	0.004	0.317	2
71	A3	AUG 18/88	0.1443	0.04	0.055	0.011	0.317	2
72	B1	AUG 18/88	0.14	0.02	0.031	0.001	0.216	2
73	B1	AUG 18/88	0.14	0.018	0.027	0.001	0.192	2
74	B2	AUG 18/88	0.1156	0.024	0.032	0.009	0.205	2
75	B2	AUG 18/88	0.1156	0.02	0.028	0.005	0.205	2
76	B2	AUG 18/88	0.1156	0.016	0.025	0.002	0.194	2
77	B3	AUG 18/88	0.1444	0.036	0.053	0.008	0.310	2
78	B3	AUG 18/88	0.1444	0.036	0.054	0.007	0.321	2
79	C1	AUG 18/88	0.1256	0.022	0.039	0.005	0.227	2
80	C1	AUG 18/88	0.1256	0.026	0.039	0.004	0.279	2
81	C2	AUG 18/88	0.1145	0.032	0.049	0.003	0.403	2
82	C2	AUG 18/88	0.1145	0.028	0.042	0.002	0.359	2
83	C3	AUG 18/88	0.124	0.034	0.056	0.003	0.404	2
84	C3	AUG 18/88	0.124	0.032	0.051	0.005	0.352	2
85	A1	AUG 18/88	0.1236	0.036	0.049	0.005	0.391	1
86	A1	AUG 18/88	0.1236	0.029	0.039	0.003	0.326	1
87	A2	AUG 18/88	0.1456	0.038	0.052	0.005	0.354	1
88	A2	AUG 18/88	0.1456	0.035	0.049	0.004	0.333	1
89	A2	AUG 18/88	0.1456	0.039	0.054	0.004	0.375	1
90	B1	AUG 18/88	0.1495	0.053	0.077	0.002	0.535	1
91	B1	AUG 18/88	0.1495	0.05	0.071	0.005	0.472	1
92	B1	AUG 18/88	0.1495	0.046	0.066	0.003	0.451	1
93	B2	AUG 18/88	0.135	0.044	0.06	0.006	0.439	1
94	B2	AUG 18/88	0.135	0.039	0.053	0.005	0.392	1
95	B2	AUG 18/88	0.135	0.049	0.067	0.006	0.496	1
96	C1	AUG 18/88	0.1425	0.04	0.054	0.005	0.382	1
97	C1	AUG 18/88	0.1425	0.046	0.063	0.004	0.459	1
98	C1	AUG 18/88	0.1425	0.042	0.058	0.003	0.426	1
99	C2	AUG 18/88	0.1642	0.077	0.095	0.03	0.444	1
100	C2	AUG 18/88	0.1642	0.047	0.064	0.008	0.371	1
101	A1	AUG 18/88	0.1493	0.022	0.032	0.007	0.162	1
102	A2	AUG 18/88	0.1493	0.019	0.03	0.003	0.173	1
103	A3	AUG 18/88	0.1493	0.022	0.033	0.003	0.202	1
104	B1	AUG 18/88	0.1683	0.024	0.037	0.002	0.208	1
105	B2	AUG 18/88	0.1683	0.027	0.041	0.005	0.209	1
106	B3	AUG 18/88	0.1683	0.029	0.046	0.004	0.239	1
107	C1	AUG 18/88	0.1692	0.061	0.091	0.014	0.445	1
108	C2	AUG 18/88	0.1692	0.048	0.076	0.007	0.391	1
109	C3	AUG 18/88	0.1692	0.054	0.087	0.008	0.440	1

Appendix 4

One - Way Analysis of Variance of the Chlorophyll.

Ho: Treatment differences not Significant

Reject Ho if F> 3.0.

Sprague ANOVA values

	F values (Reject Ho if F>3.0)		
Treatment Date	2 weeks	4 weeks	6 weeks
June 17	3.255	2.083	3.482
June 28	1.186	7.402	5.236
July 14	15.606	27.446	14.159
July 26	17.669	9.514	8.784
Aug 8	11.942	9.949	2.979
Aug 25	6.125	4.182	-

Elma ANOVA values

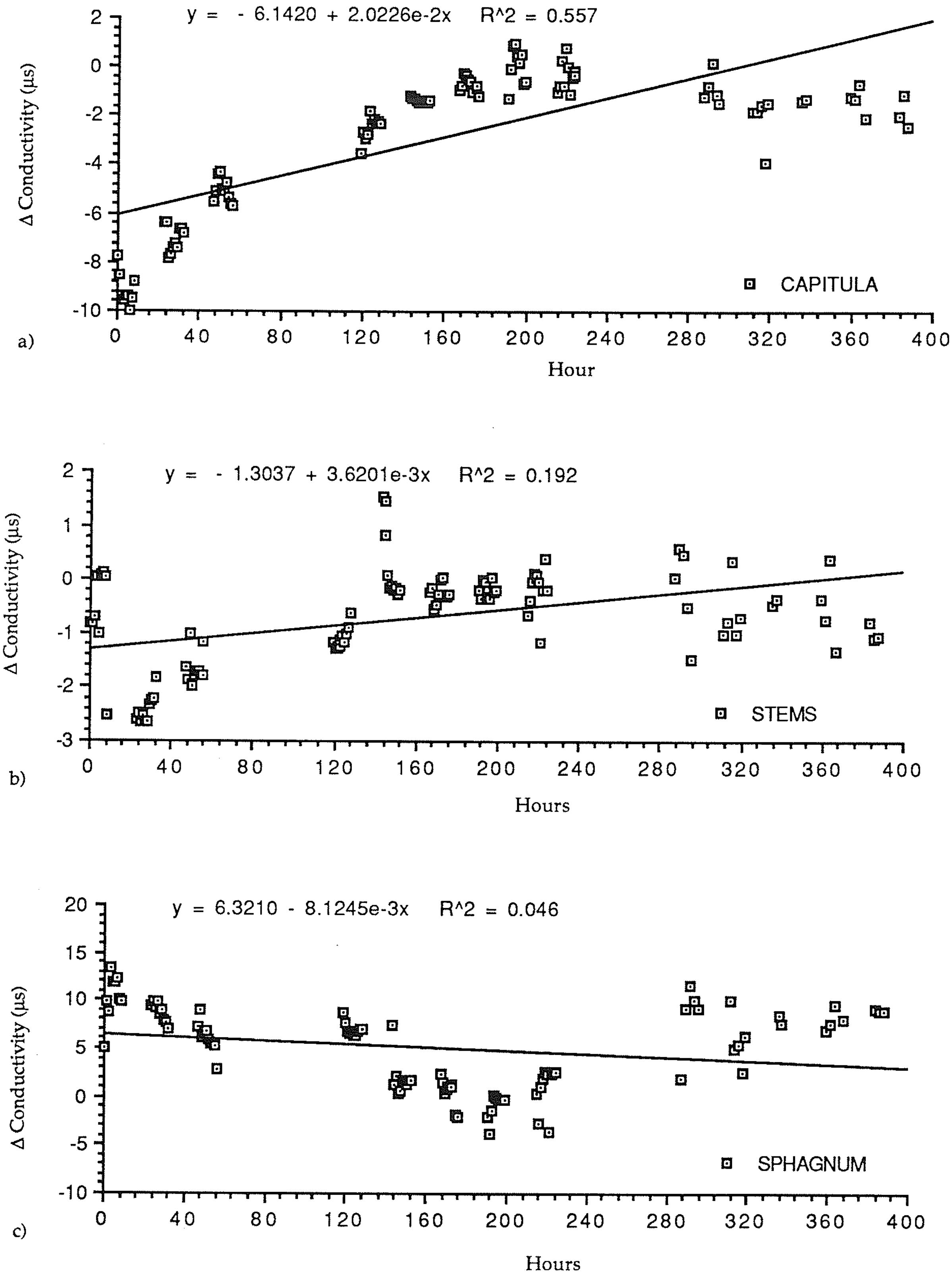
	F values (Reject Ho if F>3.0)		
Treatment Date	2 weeks	4 weeks	6 weeks
June 17	8.890	11.666	8.400
June 28	22.782	7.272	6.459
July 12	5.445	23.780	21.152
July 26	11.936	14.095	18.364
Aug 8	5.188	17.966	10.608

Devil's Lake ANOVA values

	F values (Reject Ho if F>3.0)		
Treatment Date	1 month	2 months	3 months
May 18	47.717	1943.527	409.519
June 16	257.832	167.113	-
July 16	218.162	-	-

Appendix 5

Conductvity Graph Trial 2.

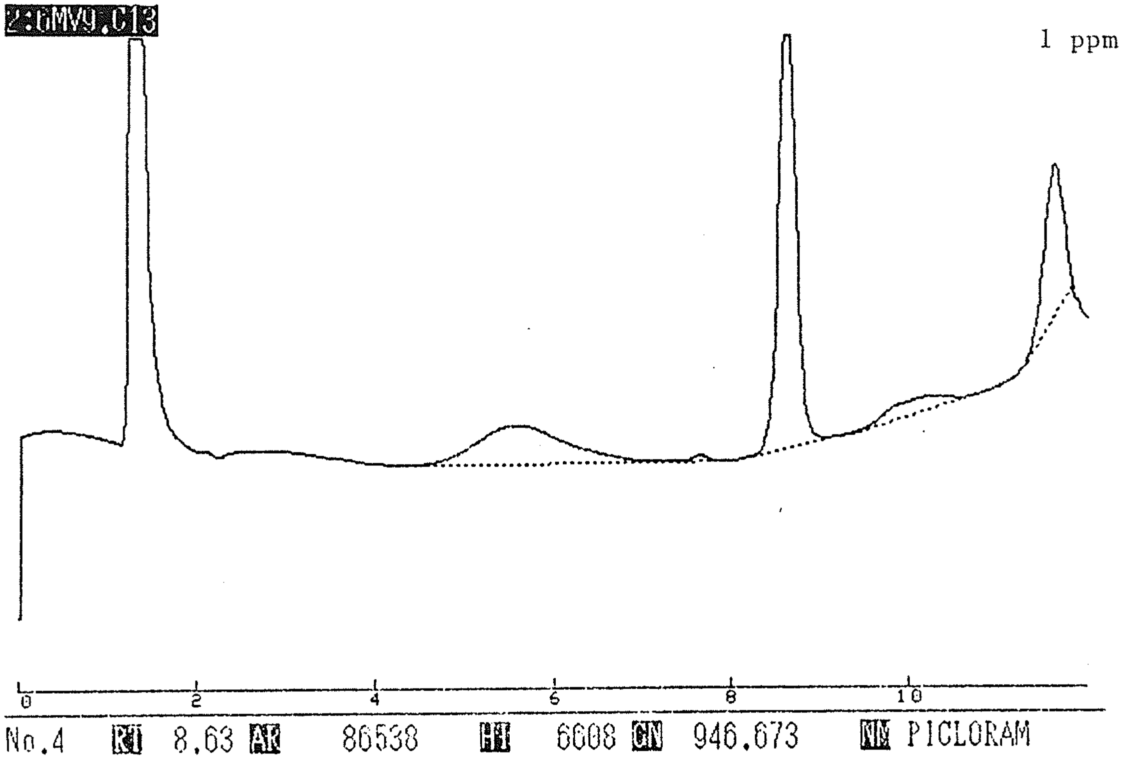


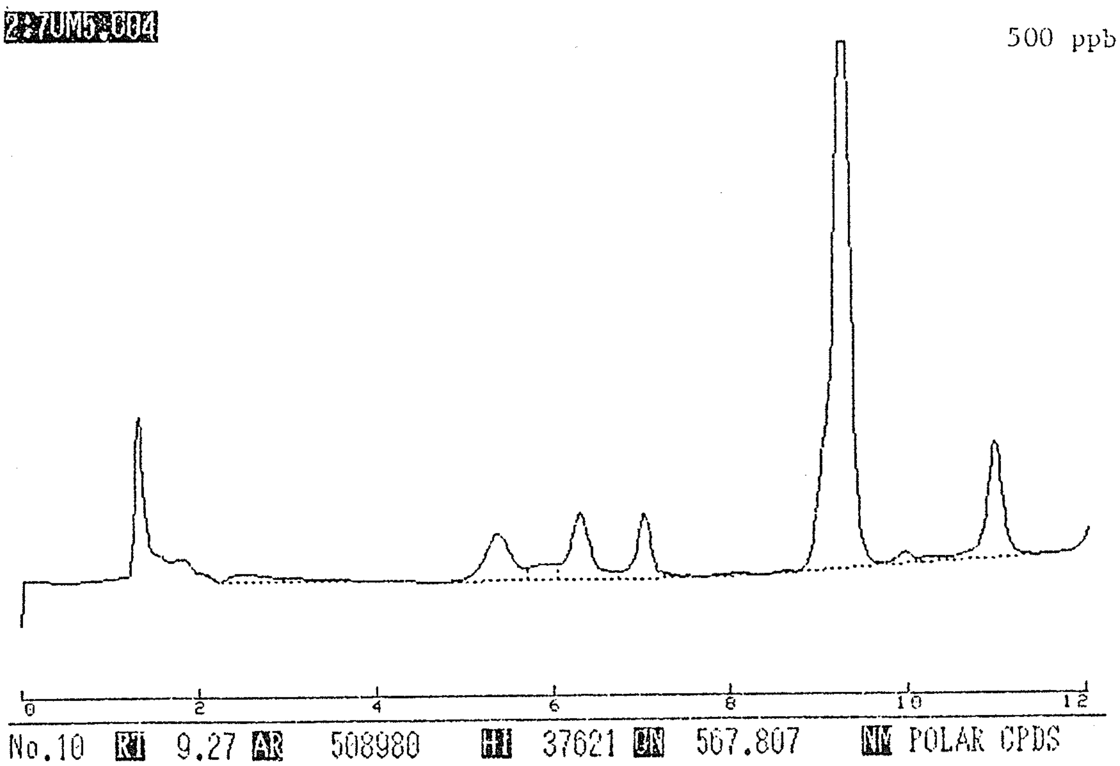
The Effect of Picloram at 1.104 ppm (Manitoba Hydro's Rate) to the Conductivity of a) Capitula B) Stems and c) Whole Plant of S. fuscum under controled Laboratory Conditions.

Appendix 6

Chromatographs - Picloram Residues.

Picloram Residue Peaks at ~ 9 minutes.


2:6MV9.C13
1 ppm
0 2 4 6 8 10
No.4 RT 8.63 AR 86538 HT 6608 CN 946.673 NM PICLORAM


2:7UM5.C04
500 ppb
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No.10 RT 9.27 AR 508980 HT 37621 CN 567.807 NM POLAR CPDS

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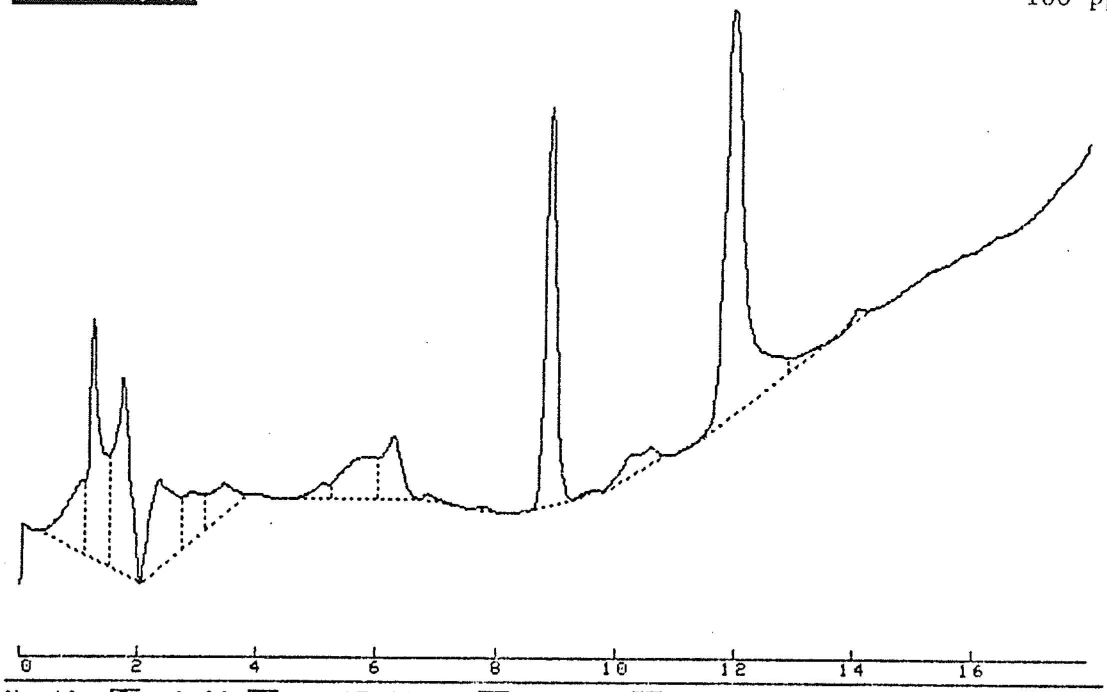

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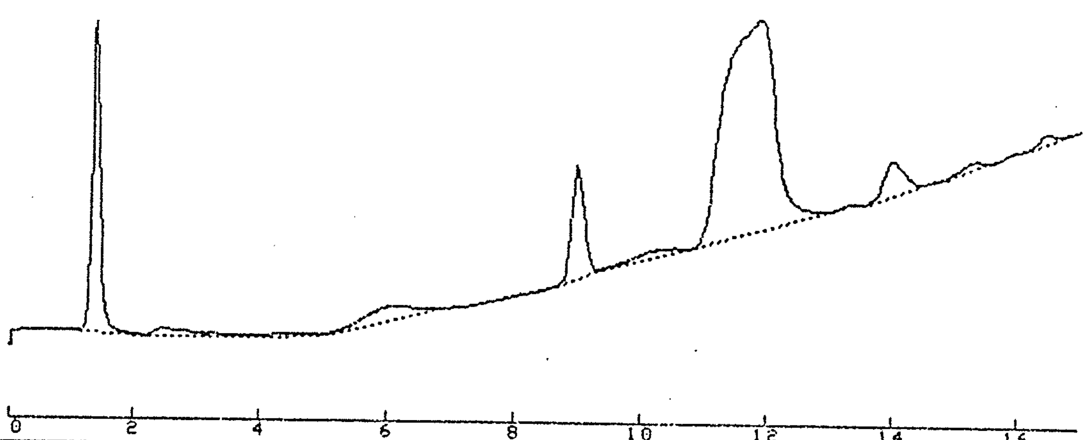

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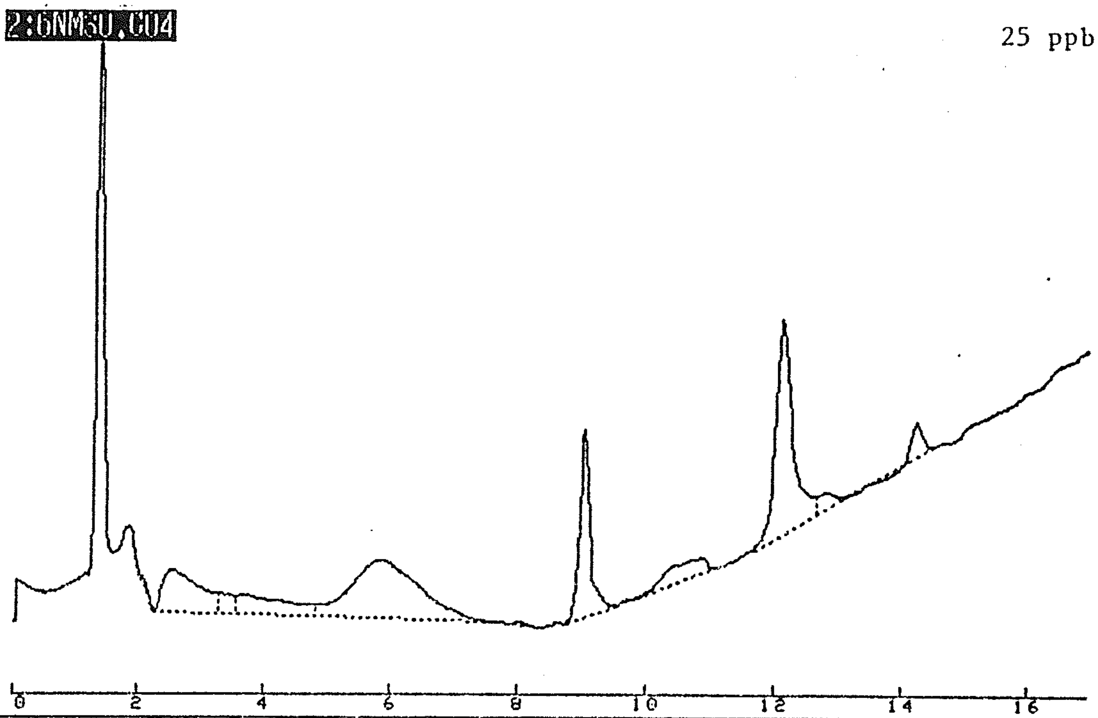

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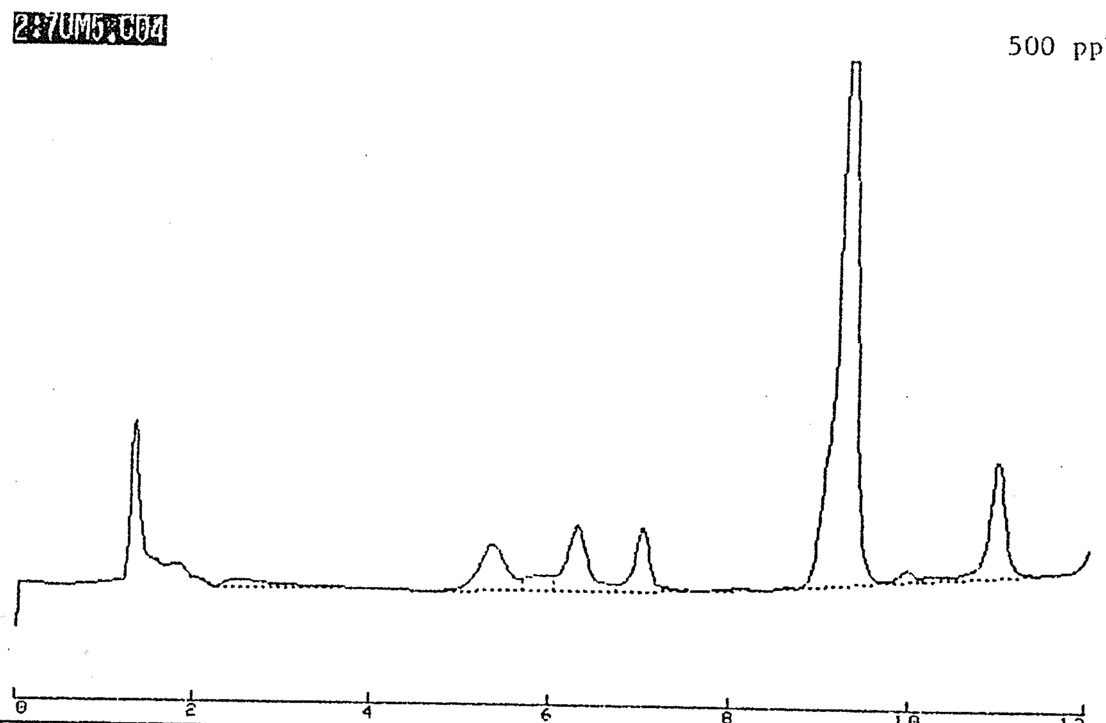

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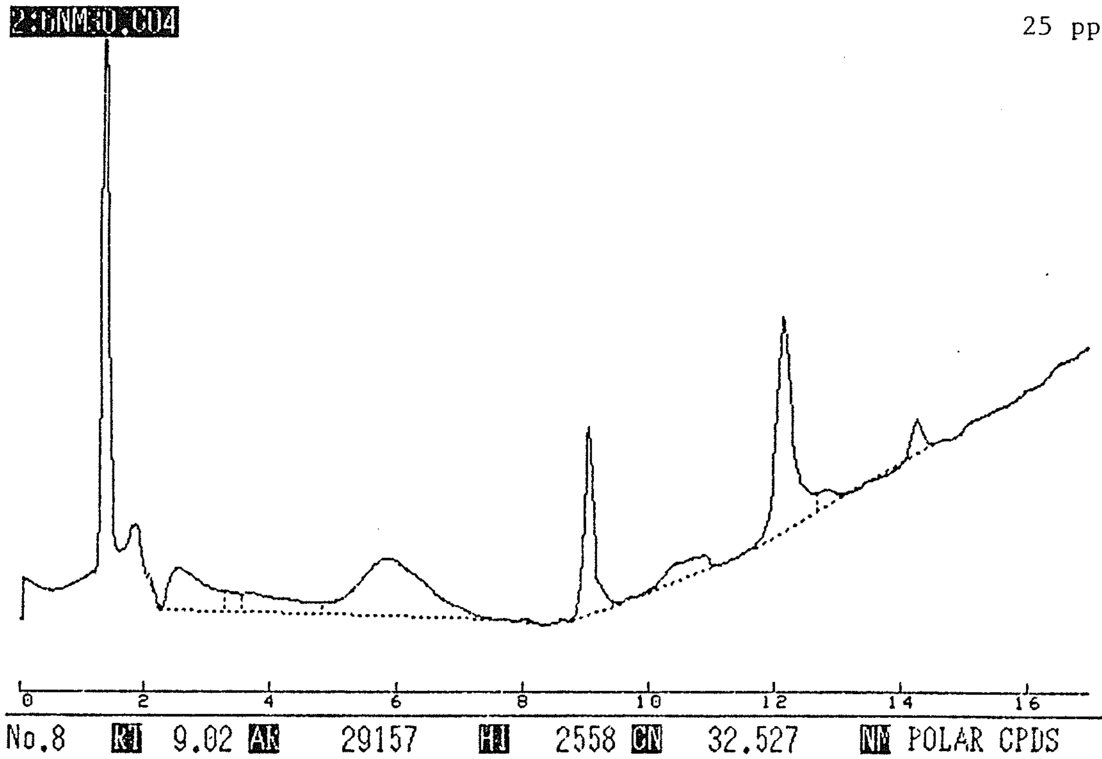
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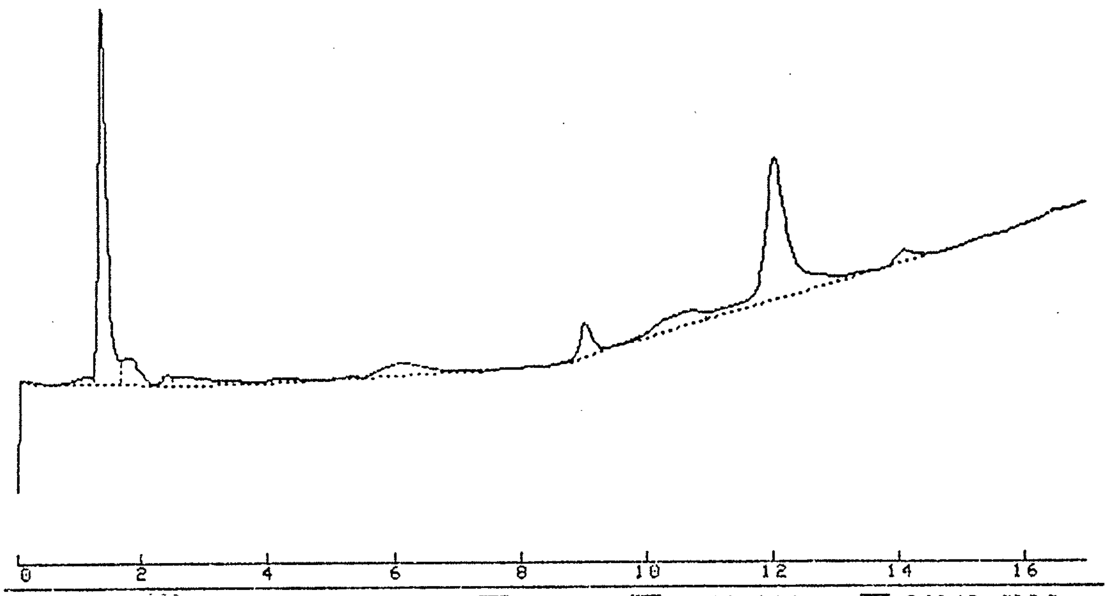

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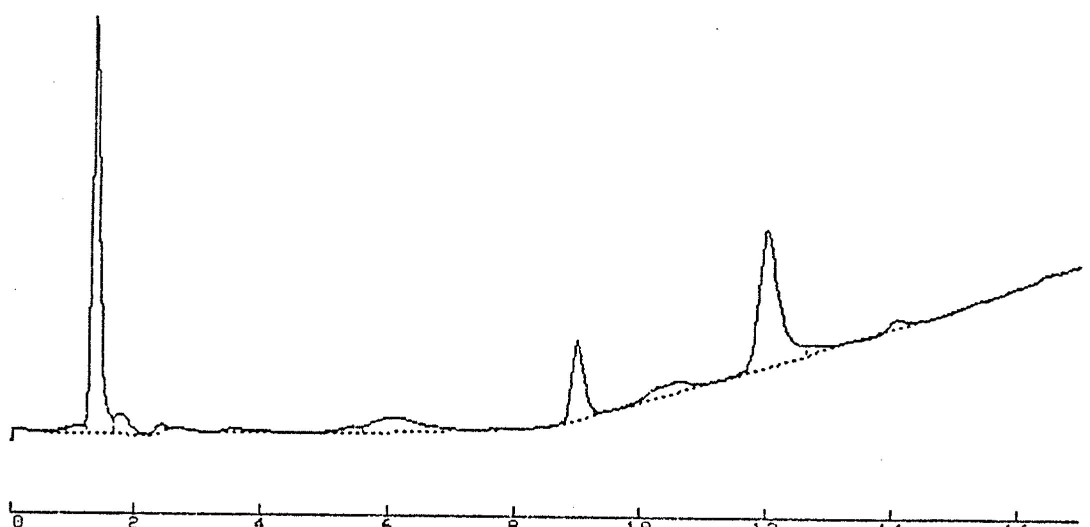

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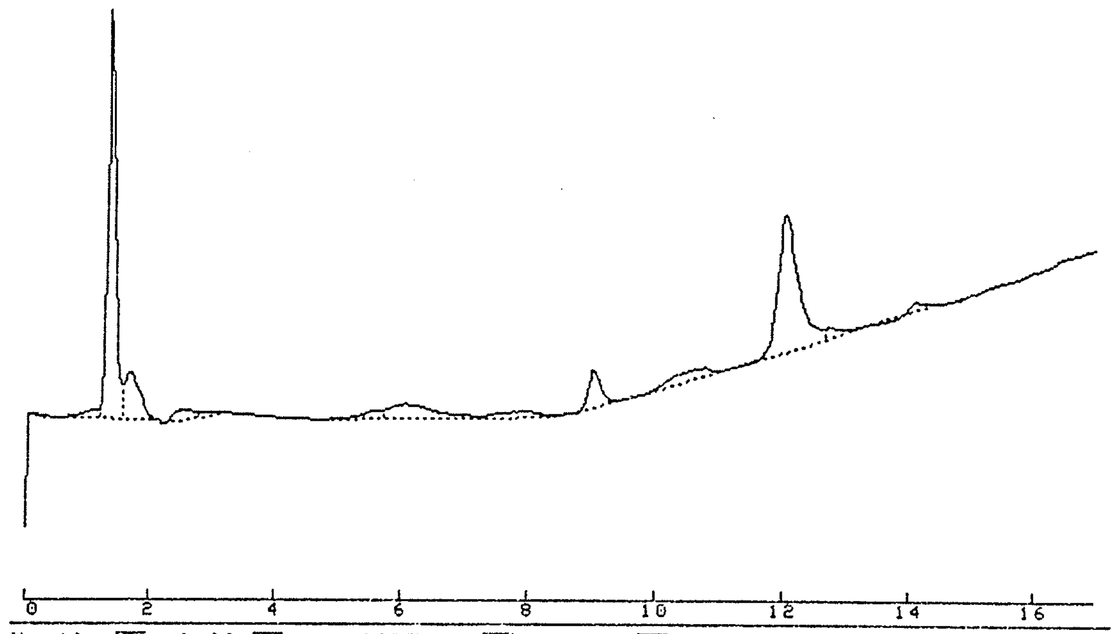

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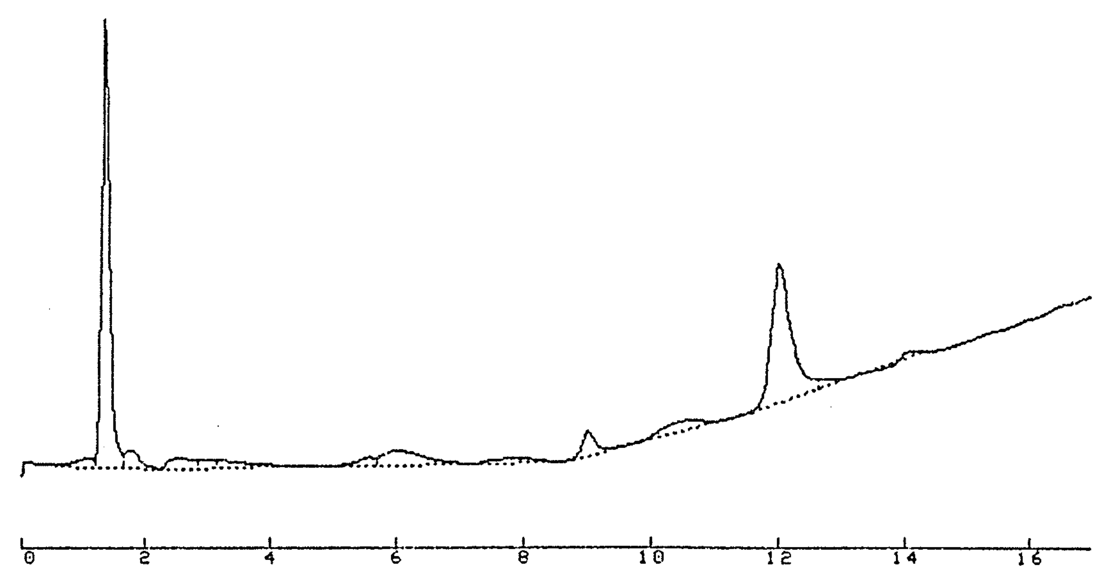

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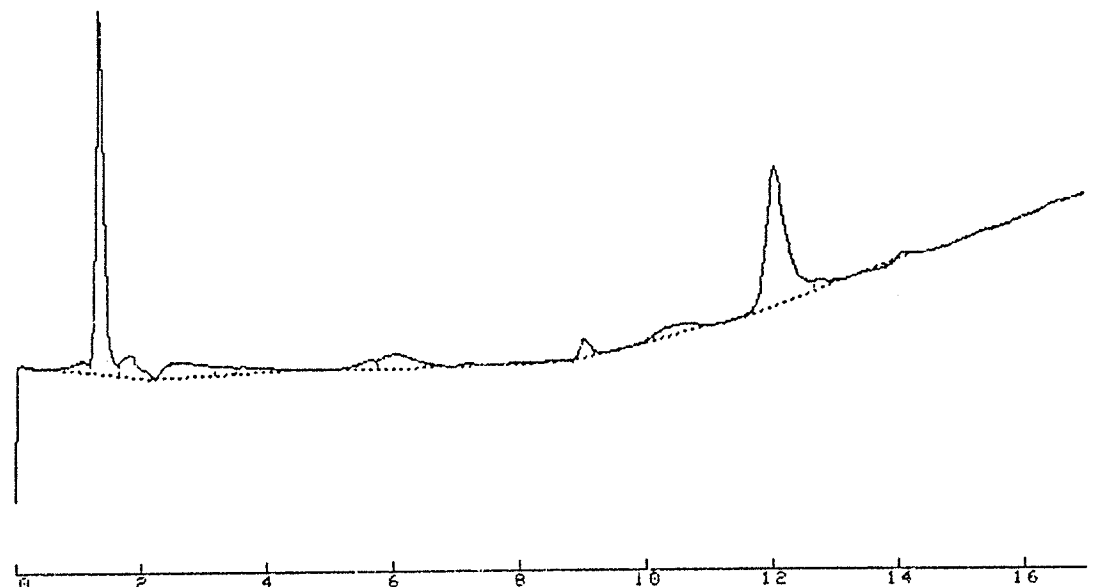

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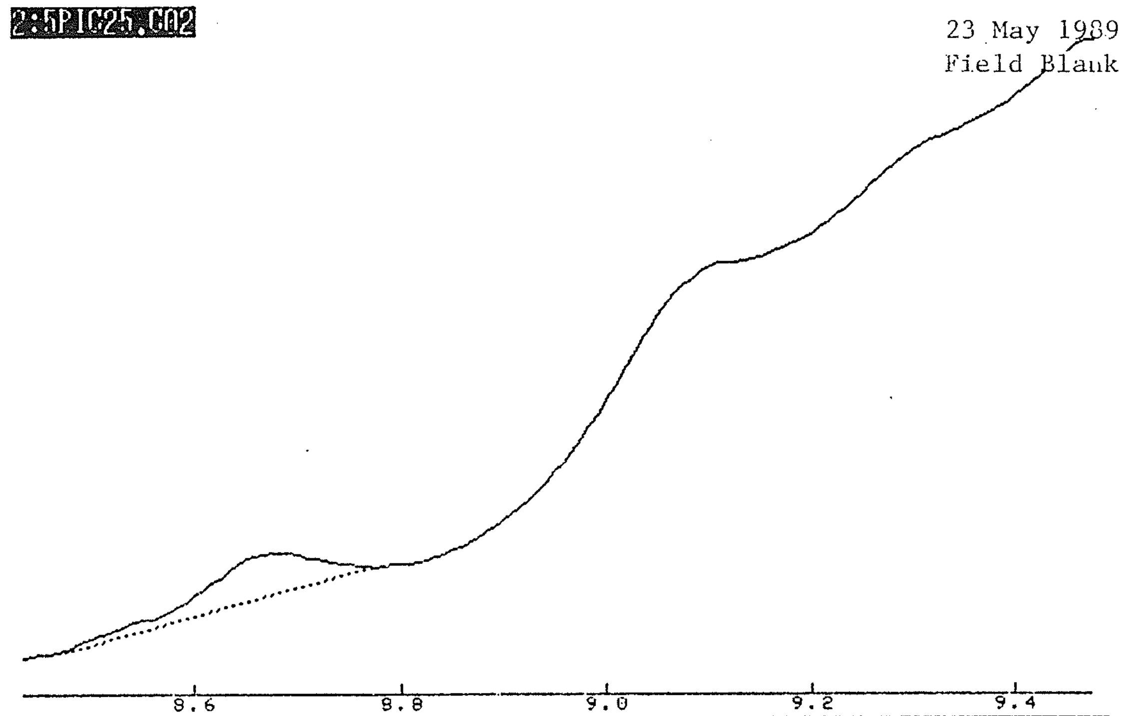

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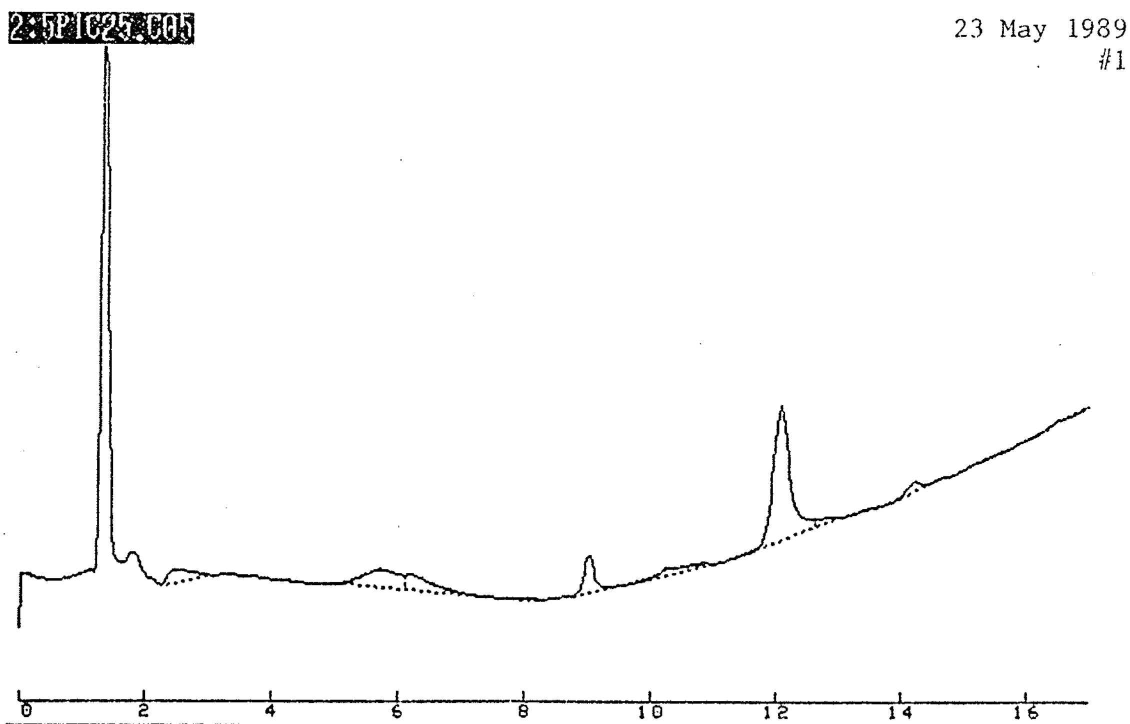

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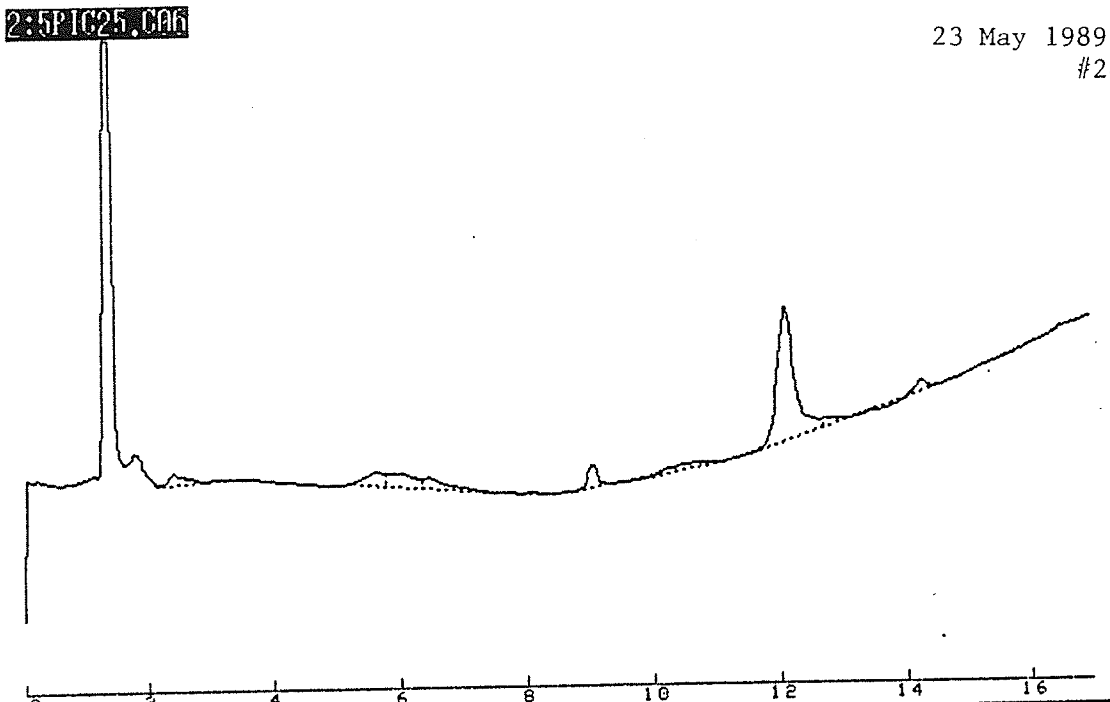

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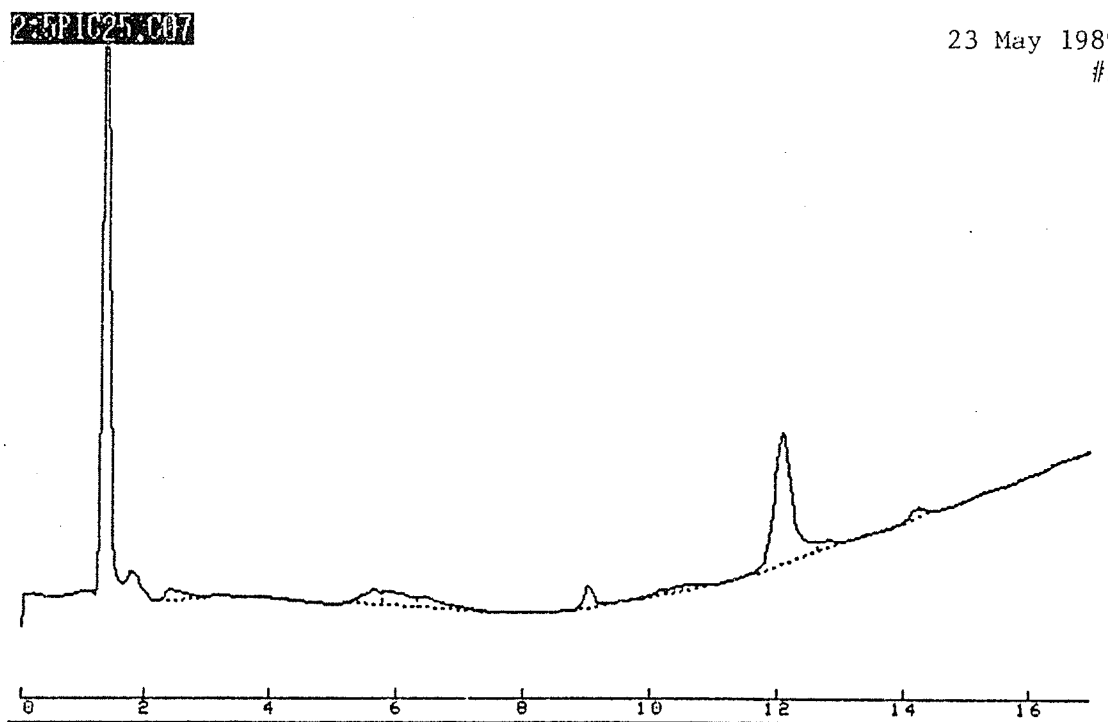

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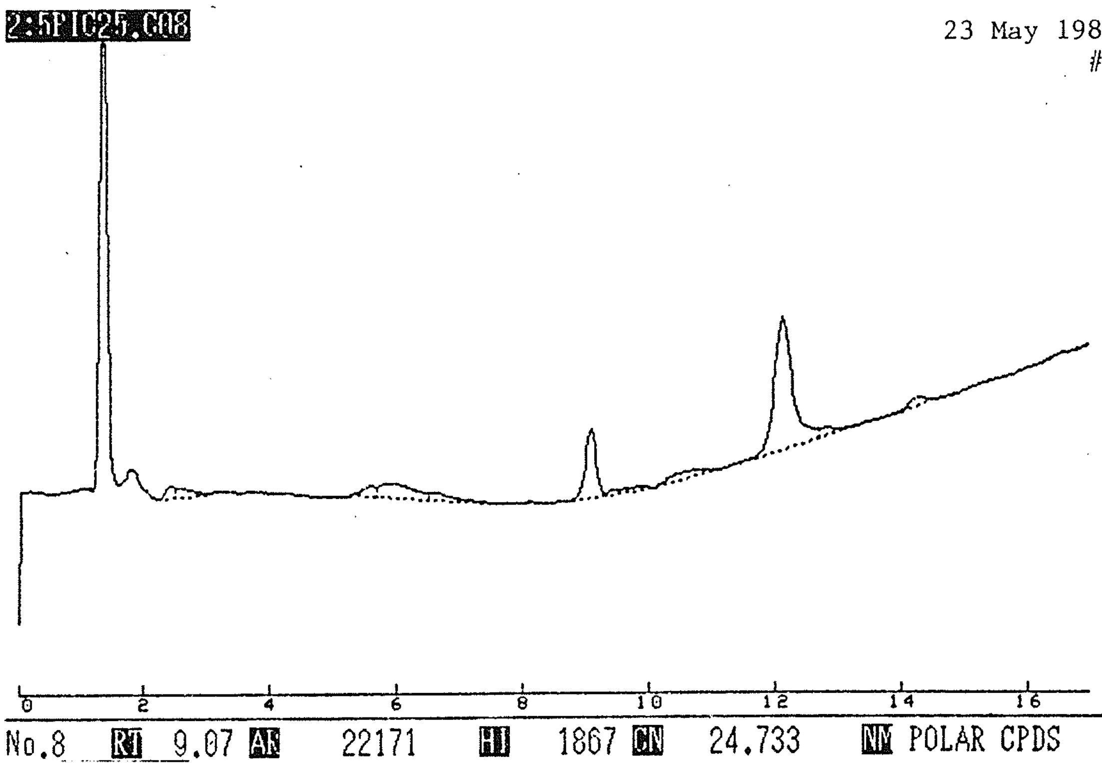
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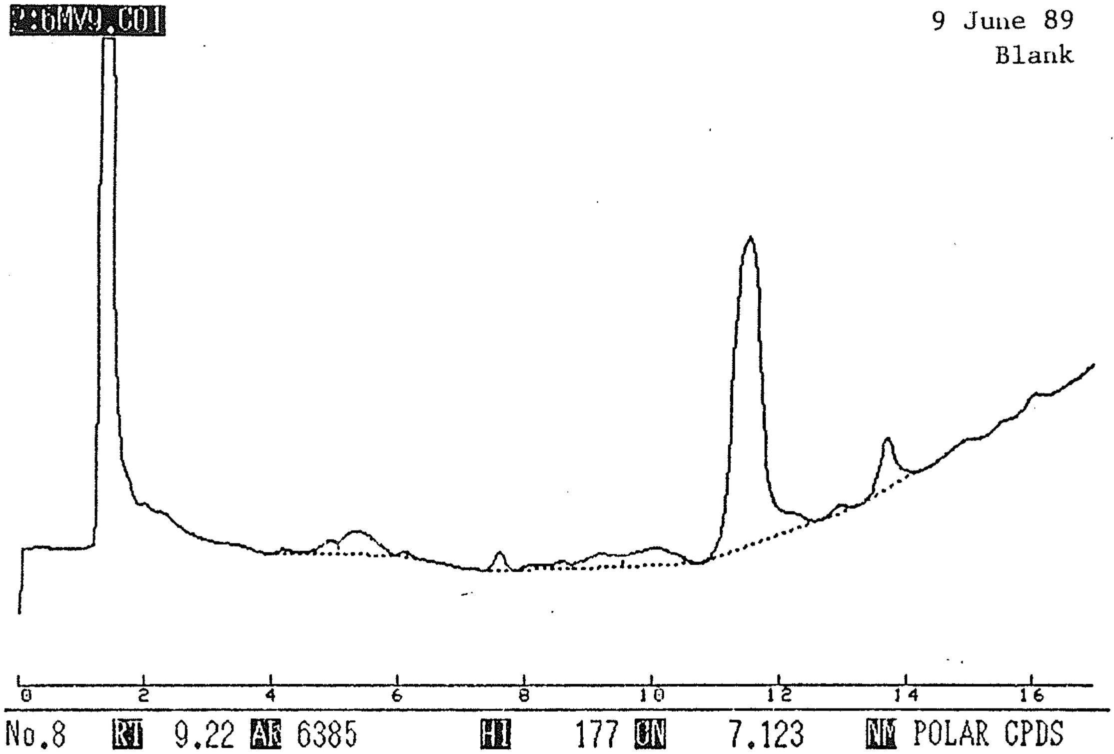

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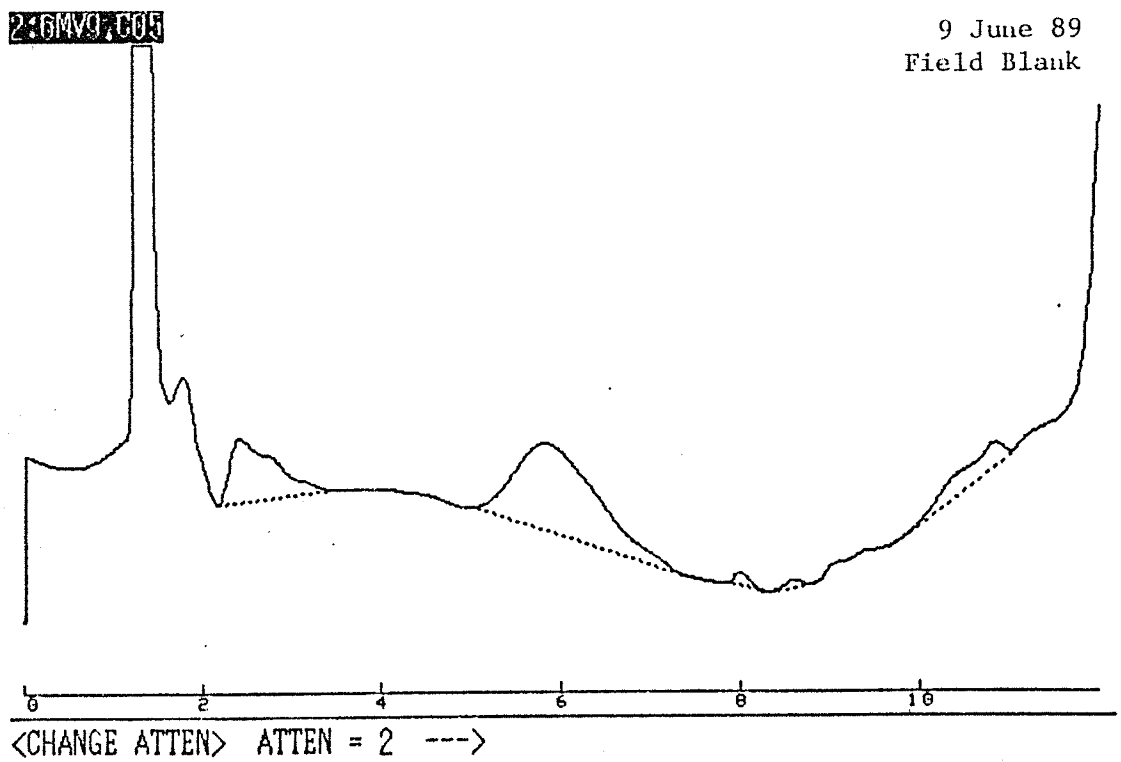

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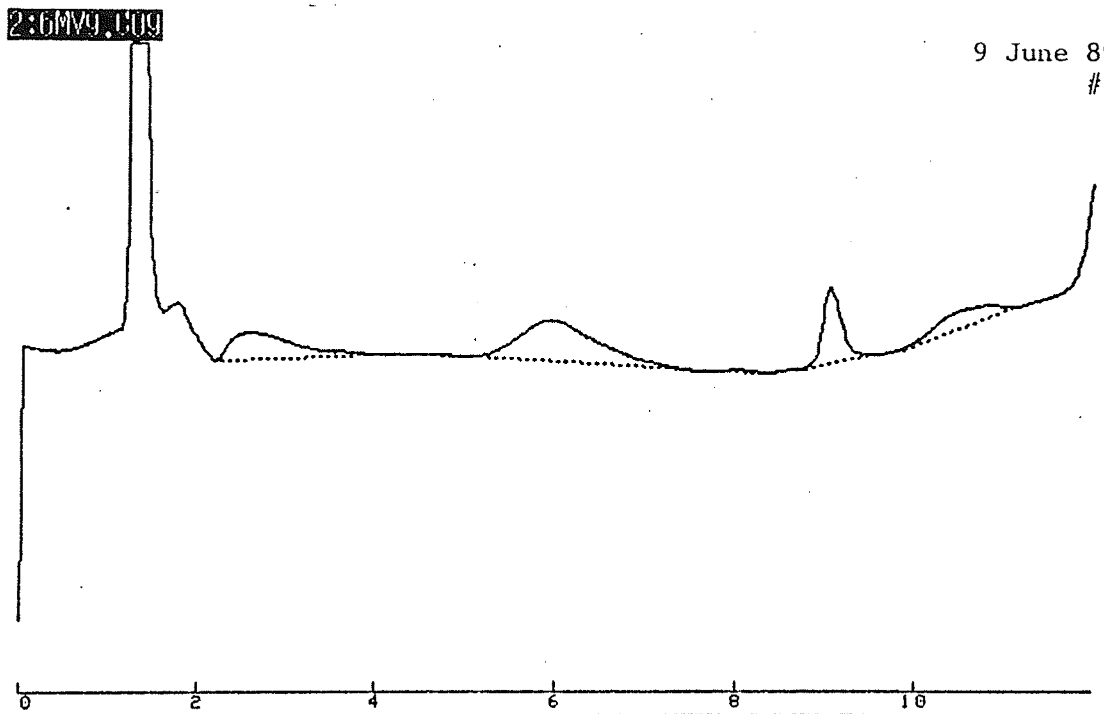

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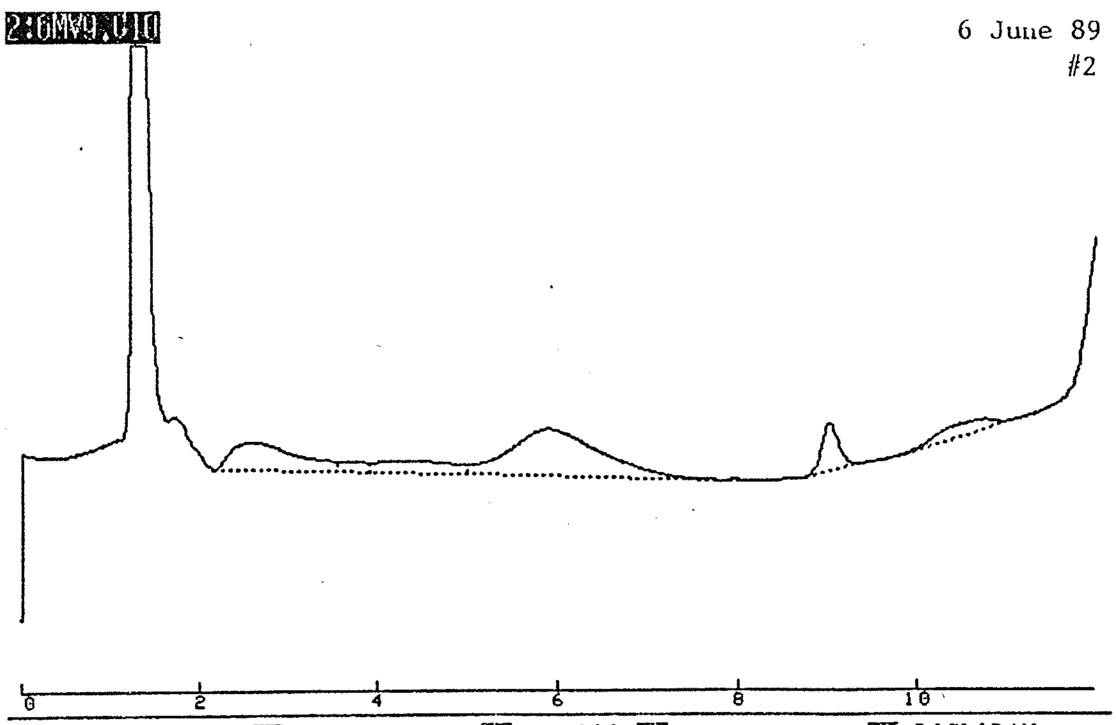

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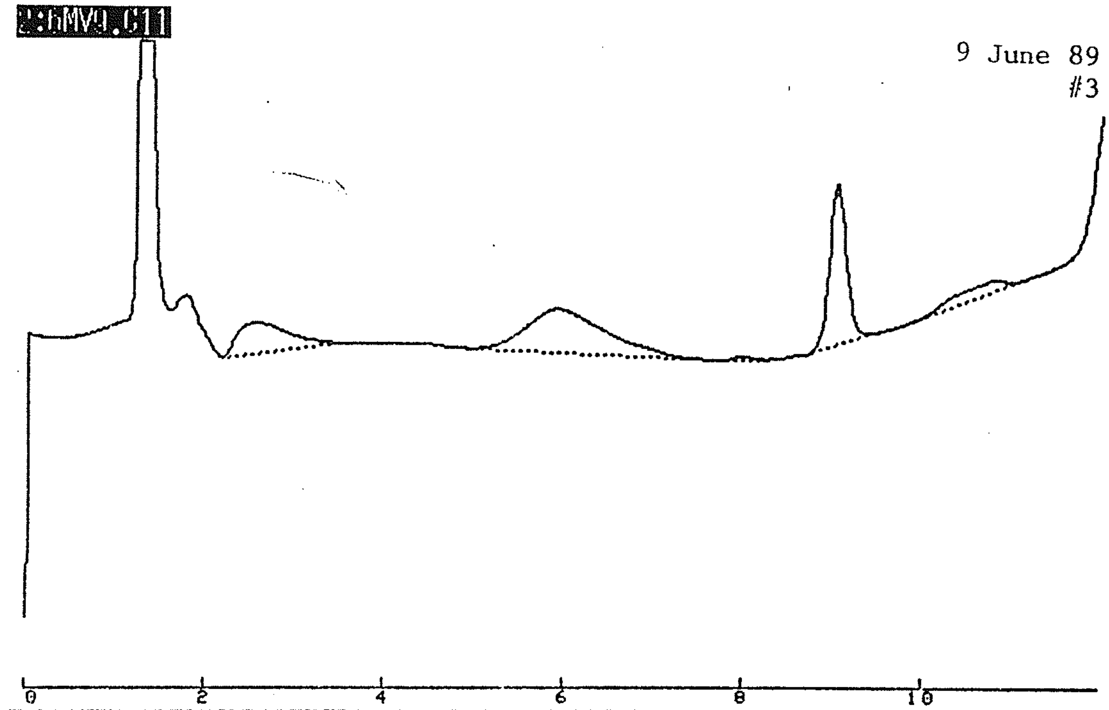

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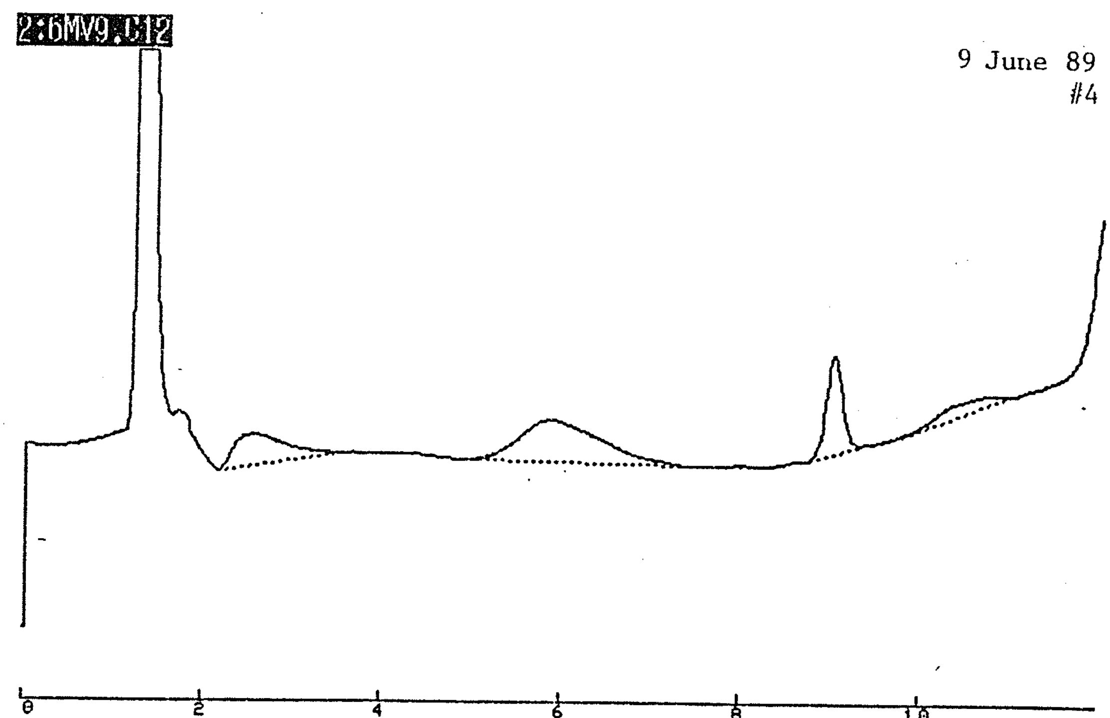

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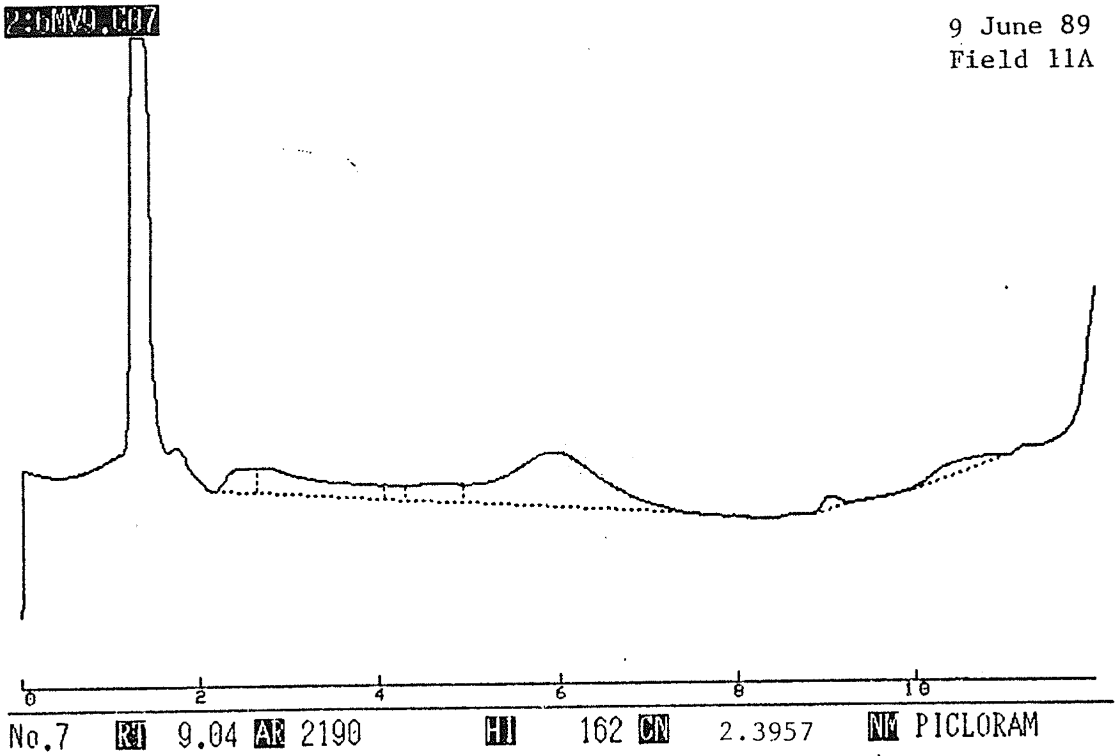
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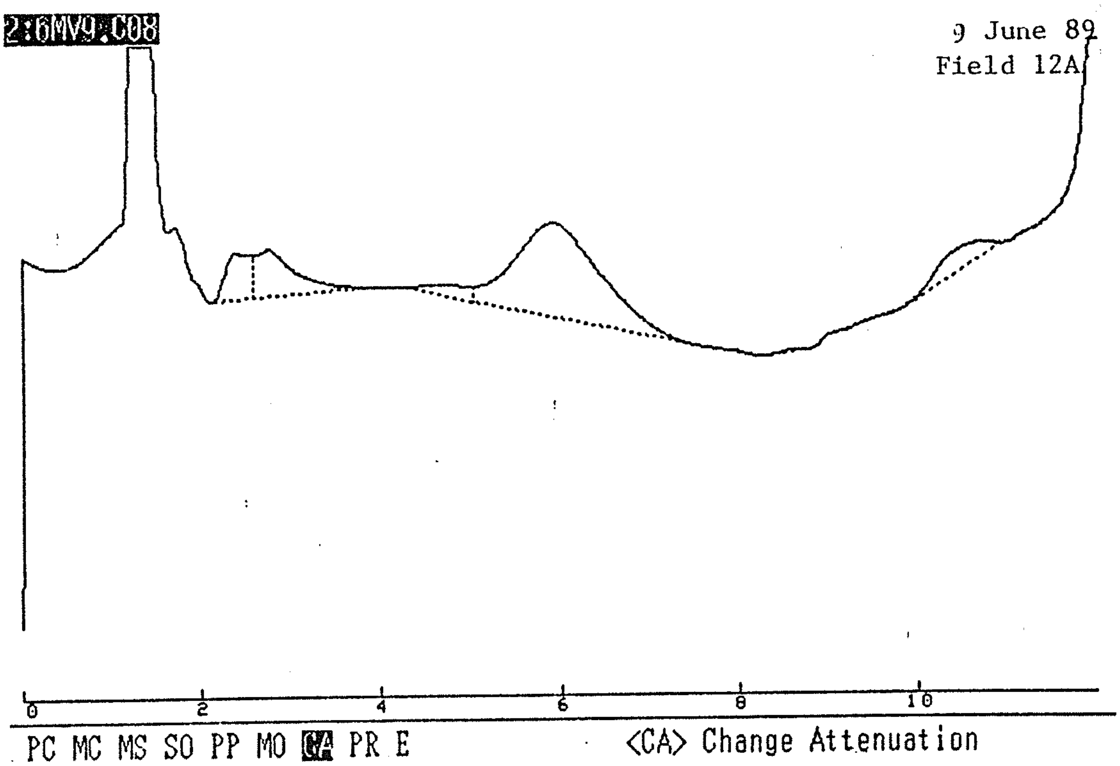
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30 June 89
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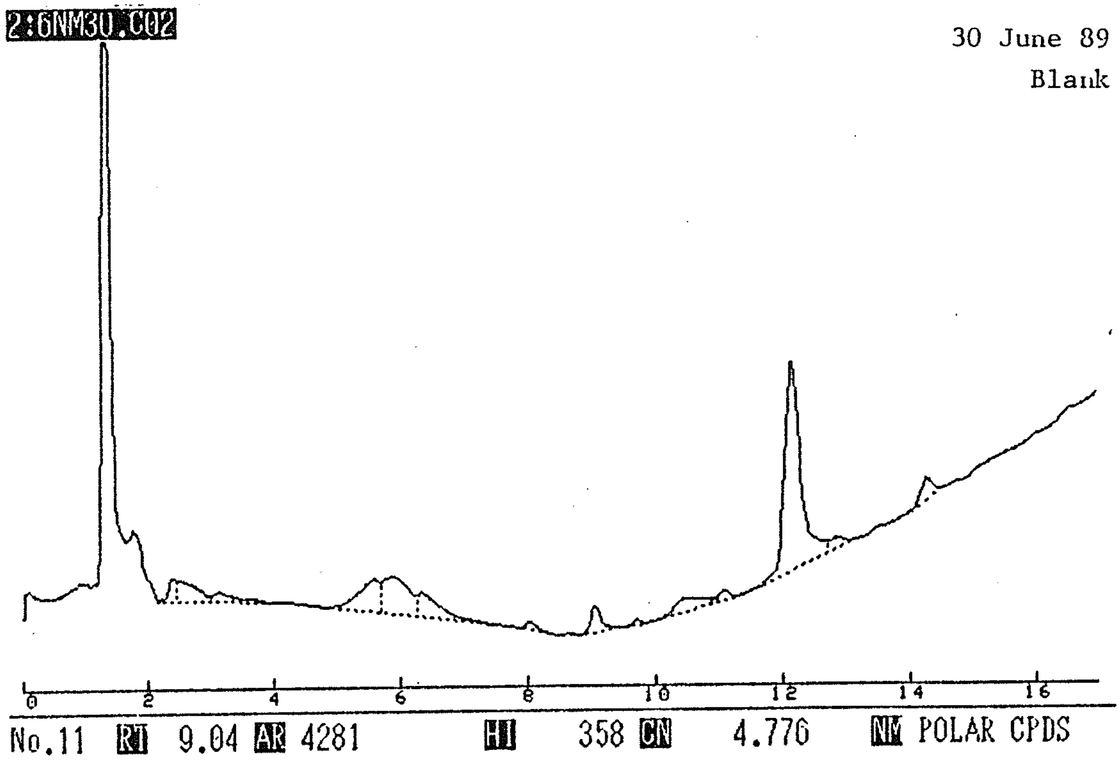

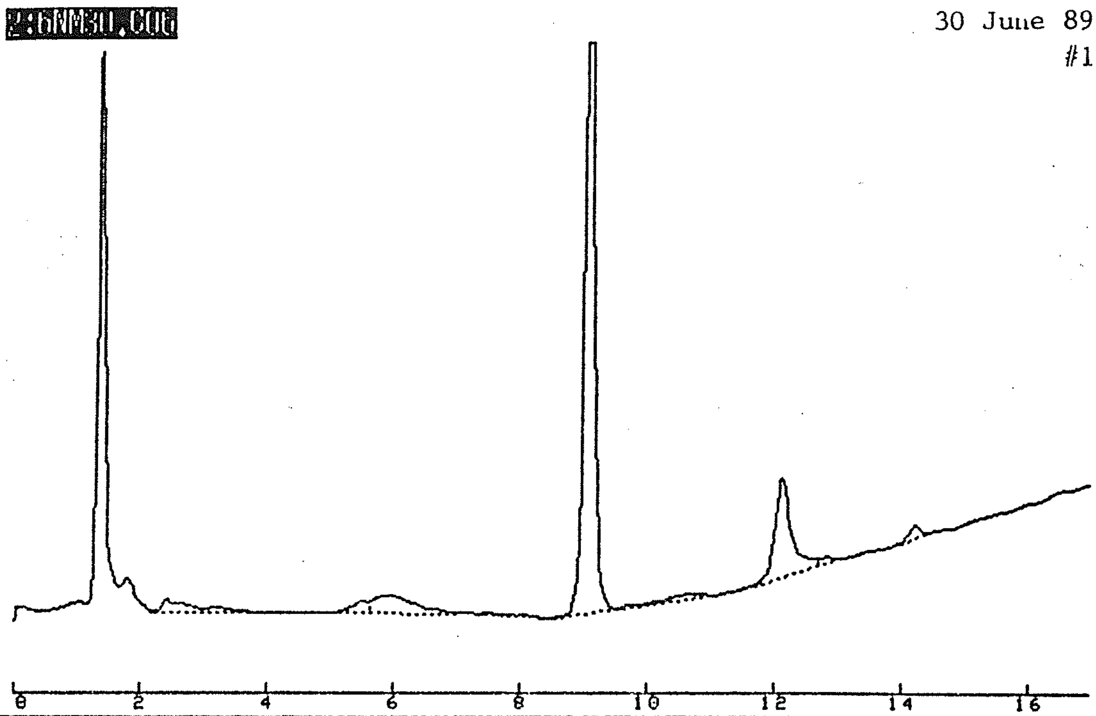

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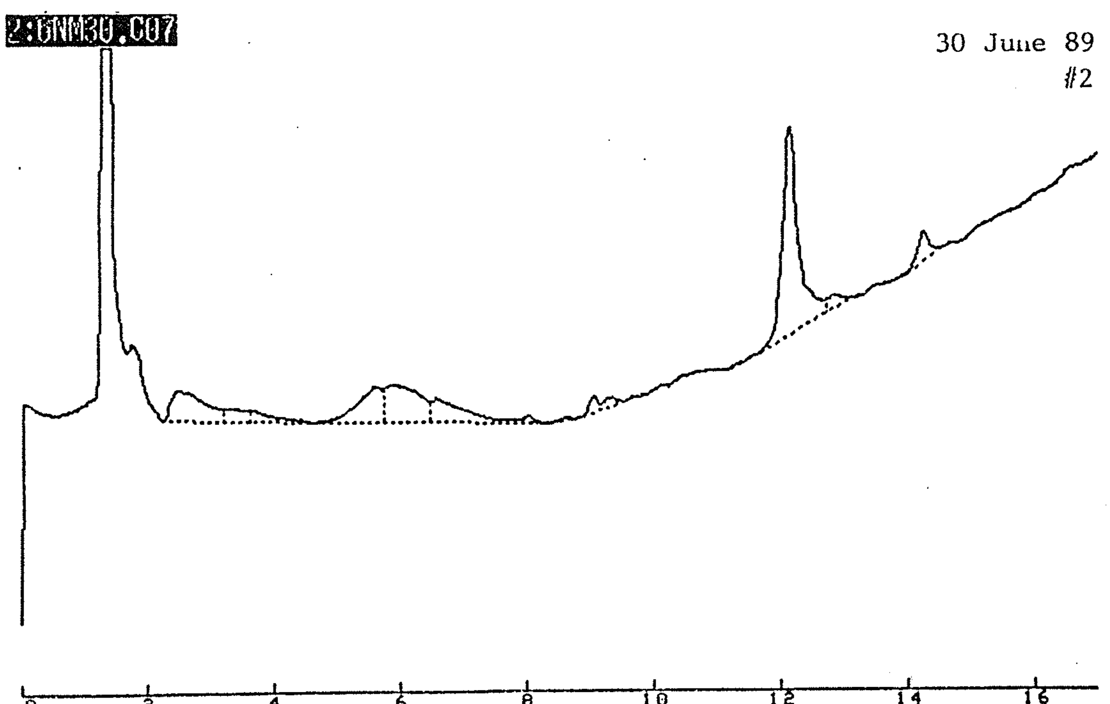

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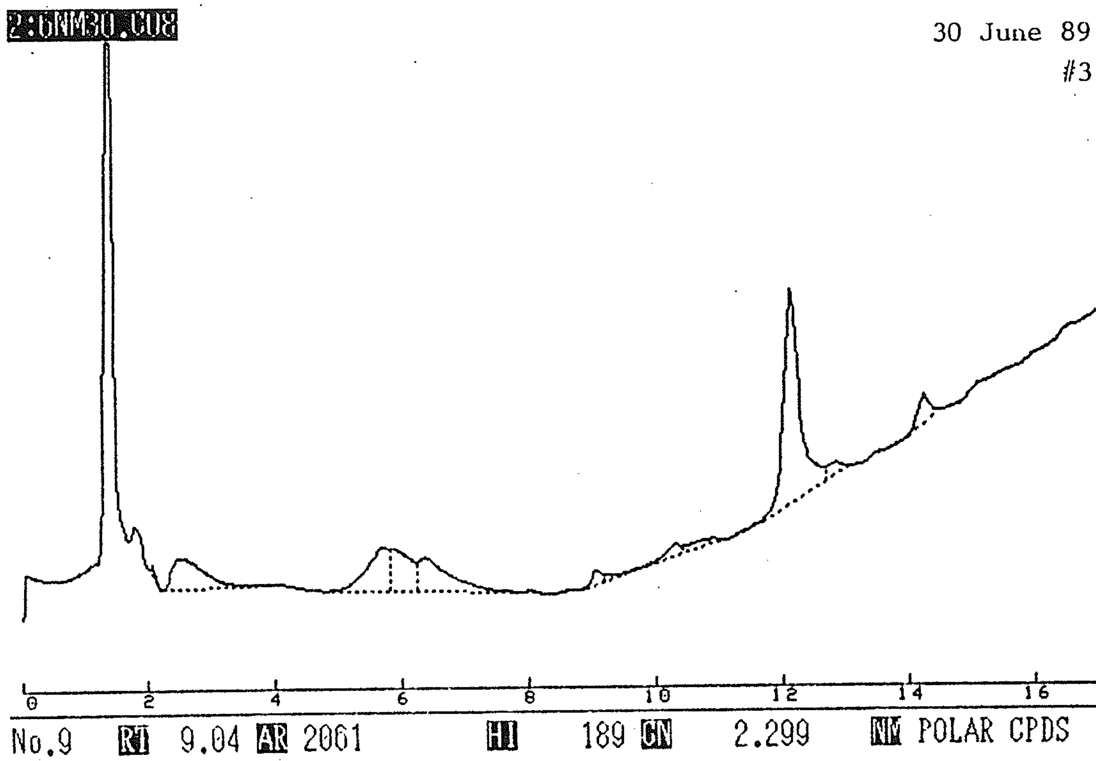
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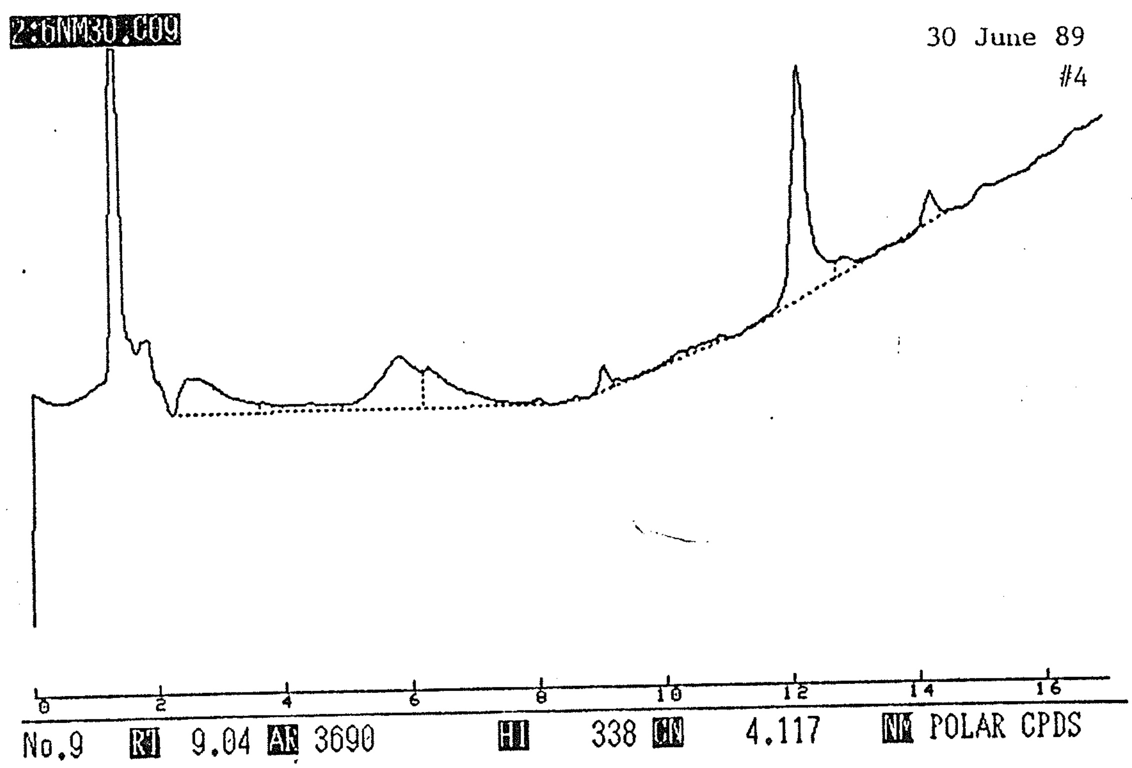
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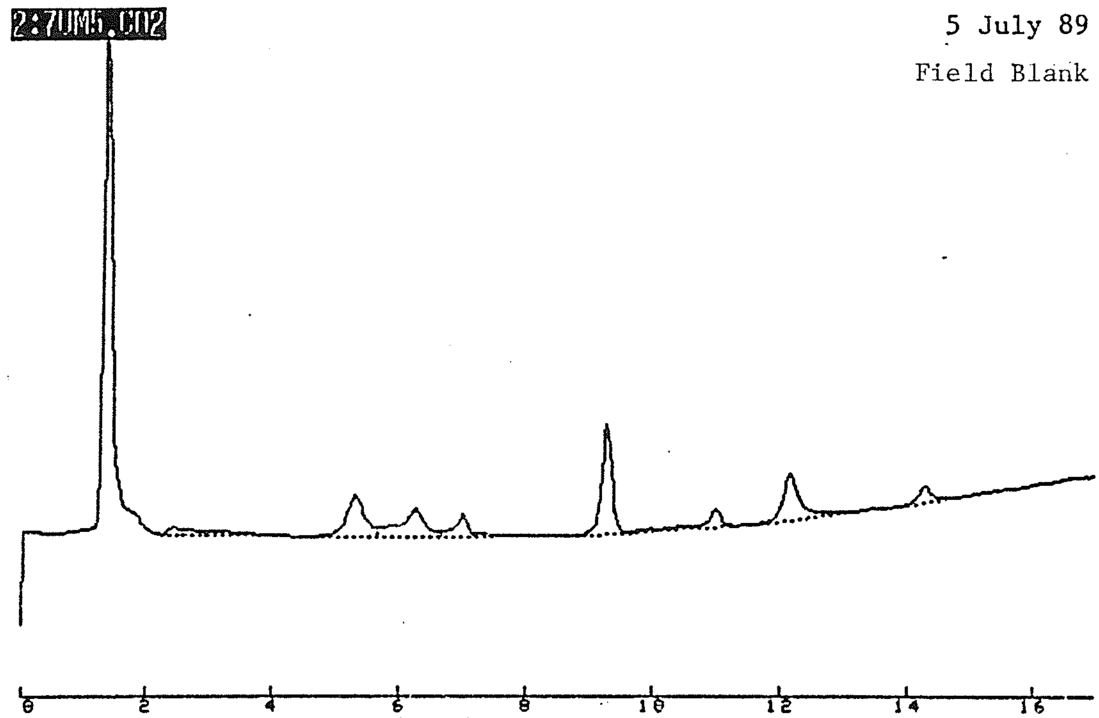

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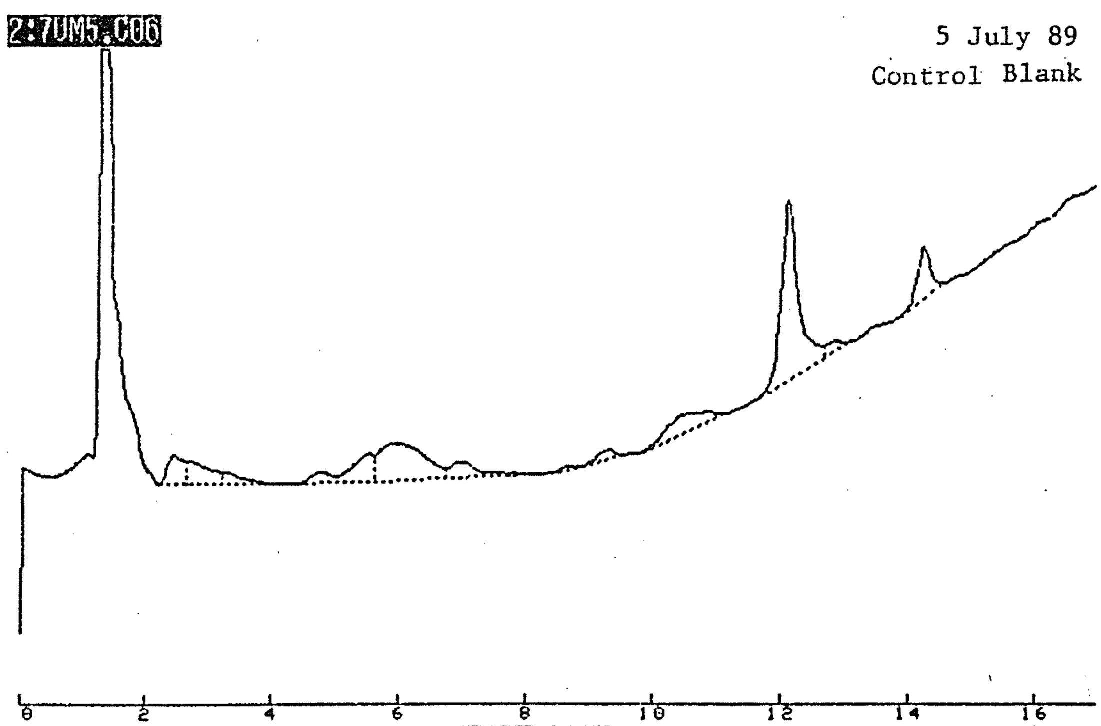

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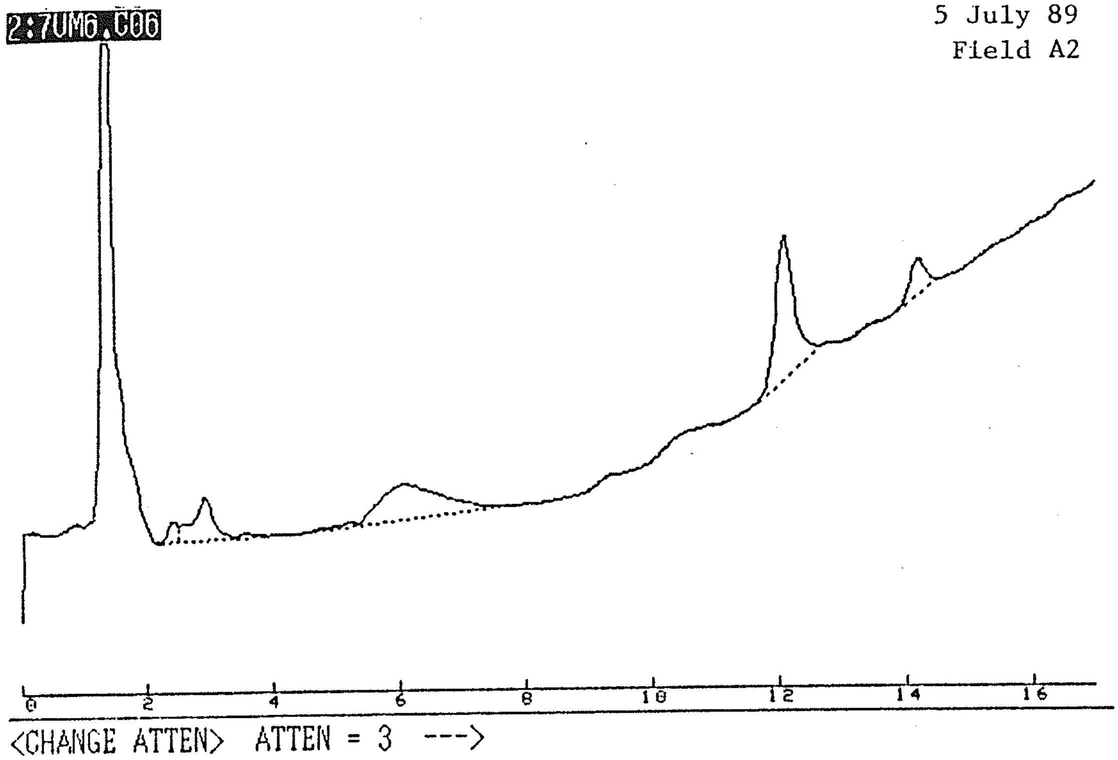
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5 July 89
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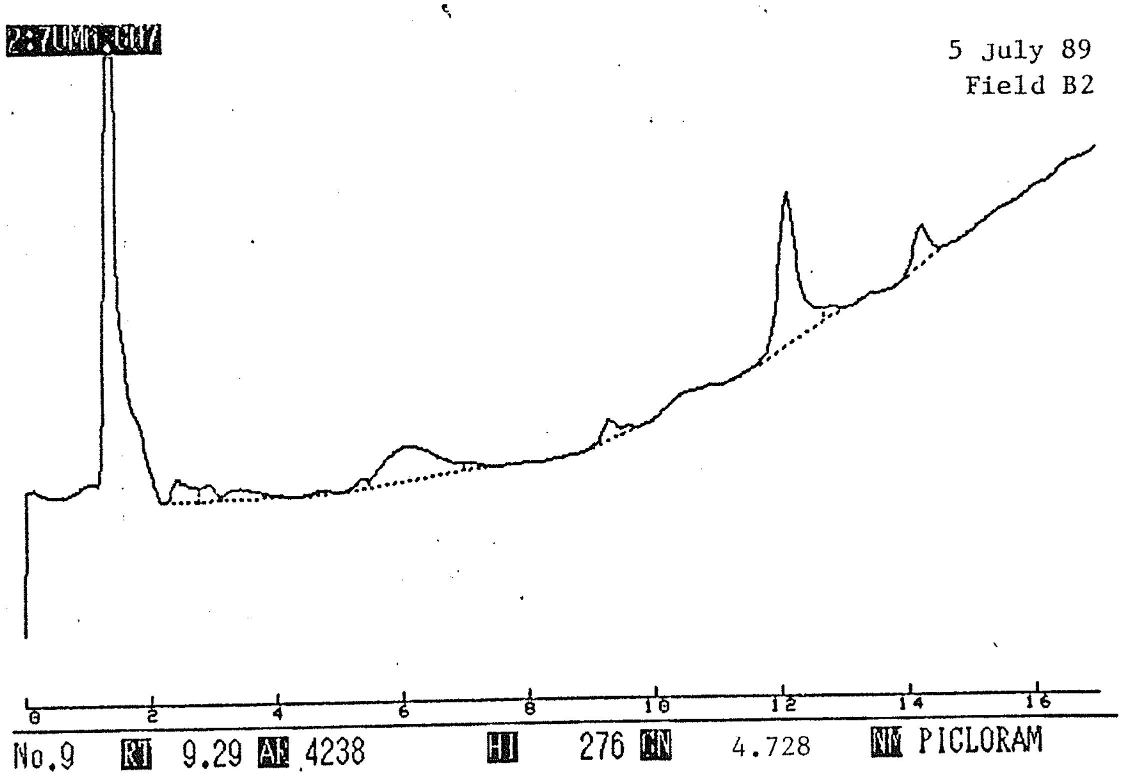
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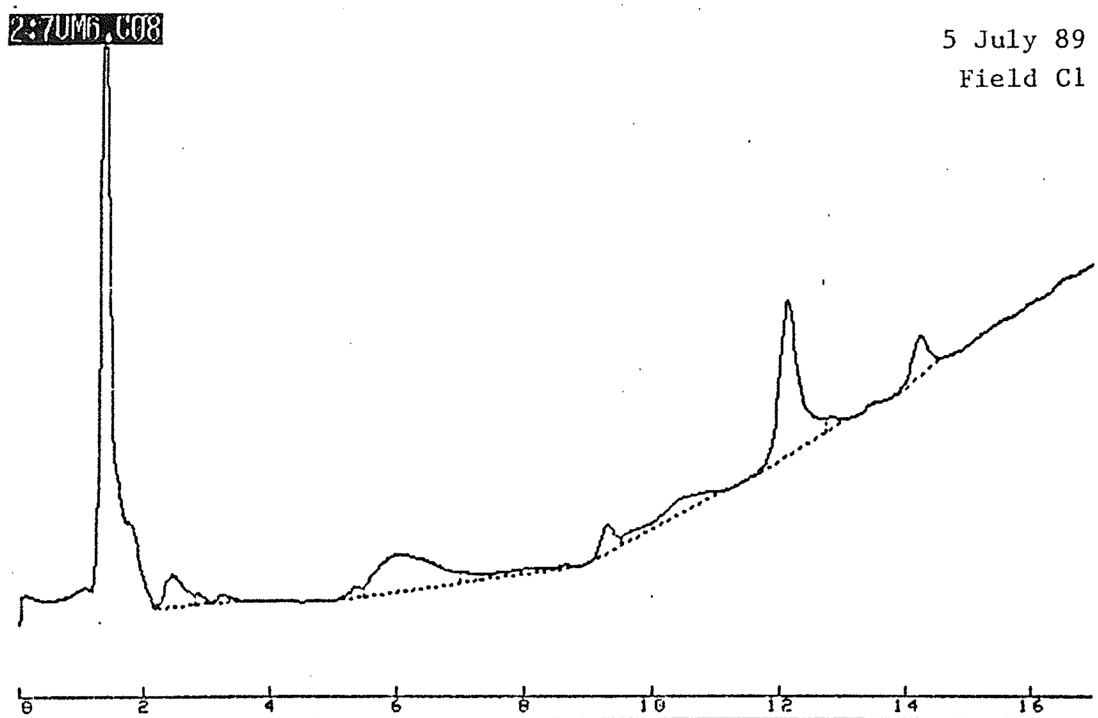
5 July 89
Field C1



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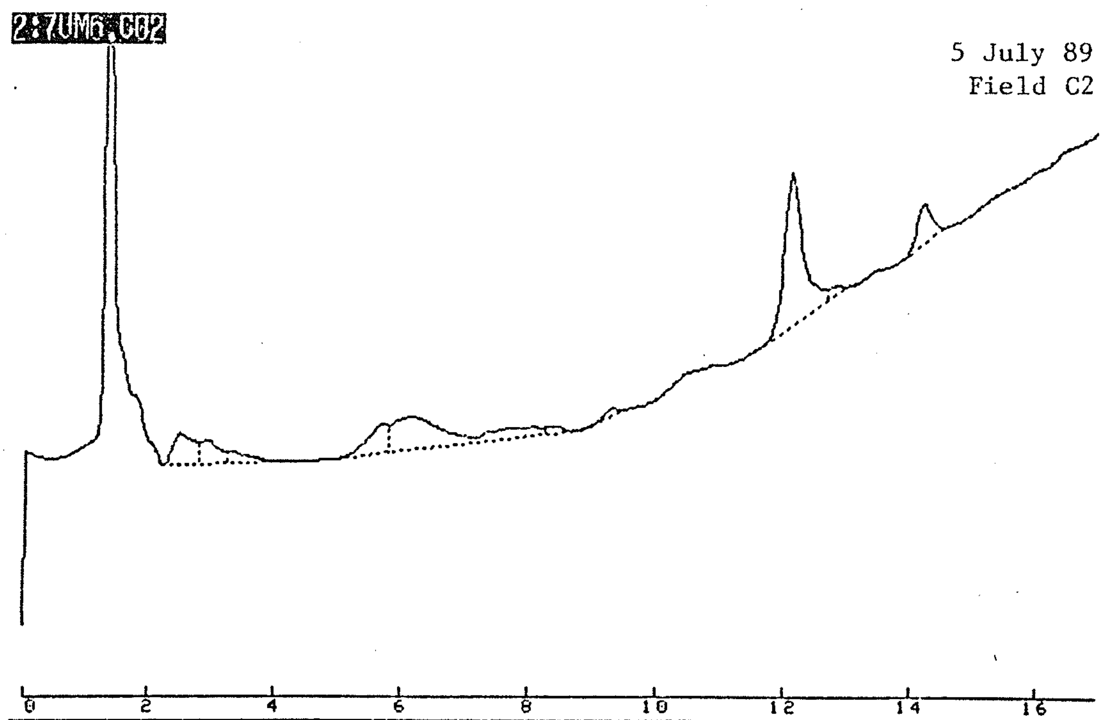

No.9 RT 9.32 AR 1421 HT 96 CN 1.585 NM PICLORAM

Recommedations to

Manitoba Hydro

Recommendations

This research has shown that picloram adversely affects the survival of *Sphagnum fuscum* and that picloram residues at dosages levels used by Manitoba Hydro were detectable in the field one year following application. The reduction of hummock species will result in the replacement of bog by fen habitat, a process which retards peat accumulation and results in a wetter sedge-dominate habitat. The maintenance of the natural bog habitat is desirable in right-of-ways for several reasons:

1. To minimize disruption to the integrity of non-target species in peat forming communities
2. To encourage natural open bog habitats because of their generally poor conditions for tree growth.
3. To slow the conversion to a wetter fen habitat, which will increase costs in the accessibility on the right-of-way line.

Alternative methods of vegetation management, such as hand cutting, should be considered where economically feasible. Labratory methods used in this study, such as culturing and conductivity techniques could observe and measure exsisting and future injury caused by herbicides on targeted and non-targeted species prior to the implementation or commitment of funds. These techniques are relatively inexpensive and give a rapid indication of the effectiveness of the herbicide.

Further areas of research to be considered in the improvement of existing management practices are:

a) The mobility of picloram in the peat matrix and its subsequent influence on the ground water should be studied.

b) An improvement of the extraction process is necessary to compensate for the masking effects of the humic substances.

c) The effect of picloram on other non-target shrub species (eg. *Ledum, Chamaedaphne, Kalmia and Vaccinium*) should also be examined in terms of their resilience, susceptibility and recovery. Such studies could also look into the influence of increasing shrub density on retarding the growth of Black spruce and Tamarack and possibly using this as an alternative method of vegetation management.