# TIMING AND IMPACTS OF AERIAL HERBICIDE SPRAYING ON BLACK SPRUCE IN THE GREAT CLAY BELT OF NORTHERN ONTARIO:

## BLACK SPRUCE AND SPECKLED ALDER PHENOLOGY MONITORING

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**REPORT NUMBER 3**
**BLACK SPRUCE AND SPECKLED ALDER PHENOLOGY MONITORING**

## 1.0 INTRODUCTION

Tending is generally recognized as an essential part of forest management in Northern Ontario. Aerial application of herbicides is the most common form of tending in use in Ontario. Currently, there are only two herbicides registered for aerial application in Ontario, 2,4-D and Vision (glyphosate). In Ontario's Clay Belt, the rich clay soils on mineral soil upland sites tend to develop dense growths of graminoids, raspberries and woody shrubs following harvesting. On peatland sites, the main competitor developing after harvesting is Speckled Alder (Alnus rugosa Spreng.). Coniferous plantations established on these sites usually require tending to ensure adequate survival and growth of the new crop.

Herbicide applications for tending purposes should ideally be conducted when the target (or weed) species are most susceptible, and when the crop species is least susceptible to adverse impacts. This optimal period is the 'spray window'. In the Clay Belt, applications of 2,4-D for control of Speckled Alder on peatland sites is typically conducted from late July to early August, and somewhat earlier on upland sites, depending on development of the vegetation. Rich upland sites with severe competition are usually treated with glyphosate from early August to early September.

It is generally agreed that 2,4-D will harm all conifers when it is applied during their period of active growth (Schact and Hansen 1963). Black spruce (Picea mariana) is relatively resistant to application of 2,4-D after hardening of the current year's growth. Hence, it is recommended that conifer release treatments employing 2,4-D should be made only after conifers are hardened off, usually indicated by a sharply pointed bud and an absence of lammas growth (Expert Committee on Weeds 1984, 1986).

With 2,4-D, herbicidal efficacy can be achieved after the target woody shrubs and hardwoods reach full flush and are actively growing, and prior to the onset of fall coloration. Normally, maximum herbicidal efficacy is achieved in the period extending from the beginning of June to the third week in July under normal weather conditions. However, only partial control of 'suckering' species may be achieved in subsequent growing seasons (Expert Committee on Weeds 1986). In the Clay Belt, speckled alder sometimes regenerates profusely by suckering following treatment with 2,4-D.

For conifer release, glyphosate treatment is recommended only after conifers have developed a sharp bud and in the absence of lemmas growth, after hardwoods reach full leaf but prior to hardwood leaf coloration (Expert Committee on Weeds 1984). The Vision label extends this standard slightly to include some leaf coloration in the target species but not major leaf fall (Monsanto 1987). However, Sutton (1984) indicated that application of glyphosate in September generally showed reduced effectiveness for control of target species.

Glyphosate application to a site in the same season as planting of conifers may injure newly planted seedlings (Vanden Born 1984). In Ontario this has been observed particularly in the case of current-crop container black spruce. Glyphosate damage to conifers following mid-July release applications in the same season as planting have also been documented in the Maritimes (Ingratta 1979).

The ability to predict phenological development of target and crop species over the course of a growing season would be of benefit to forest managers for planning aerial tending operations. This information is needed for the development of site and species specific prescriptions, such as a reduction of application rates during times when the target species are more susceptible, or the use of different application rates on different site types. Forest managers would also benefit from improved planning and scheduling of spray operations. However, before a definitive predictive model can be developed, an understanding of the basic interactions between phenology and tolerance of both crop and target species is needed, so that spray windows can be better defined, on a species specific basis. Also, variability in the development of target and crop species over time, and between different site types needs to be better defined, in order to assess risks of crop damage and/or incomplete weed control.

At present there are few studies that correlate climate with the developmental phenomena of black spruce and its more common associates (Richardson 1965, Haavisto 1967). Research work in agriculture has shown that certain climatic variables, especially those related to temperature, such as cumulated degree-days, can be used to predict stages of phenological development in plants (Anstey 1966; Harding et al. 1976). This is important since phenological stage of development is related to the effectiveness of herbicides on weed species. Stages of development also determine the susceptibility of crop species to adverse impacts from herbicide and/or insecticide applications. In agriculture, many well-supported predictive models exist for a variety of crop and weed species, and different chemicals, which are useful for timing chemical applications.

The agricultural models allow predictions of the expected dates of occurrence of the various phenological events at any point during the growing season. For example, Anstey's (1966) predictive model uses the following simple formula:

$$D = (T - A) / M$$

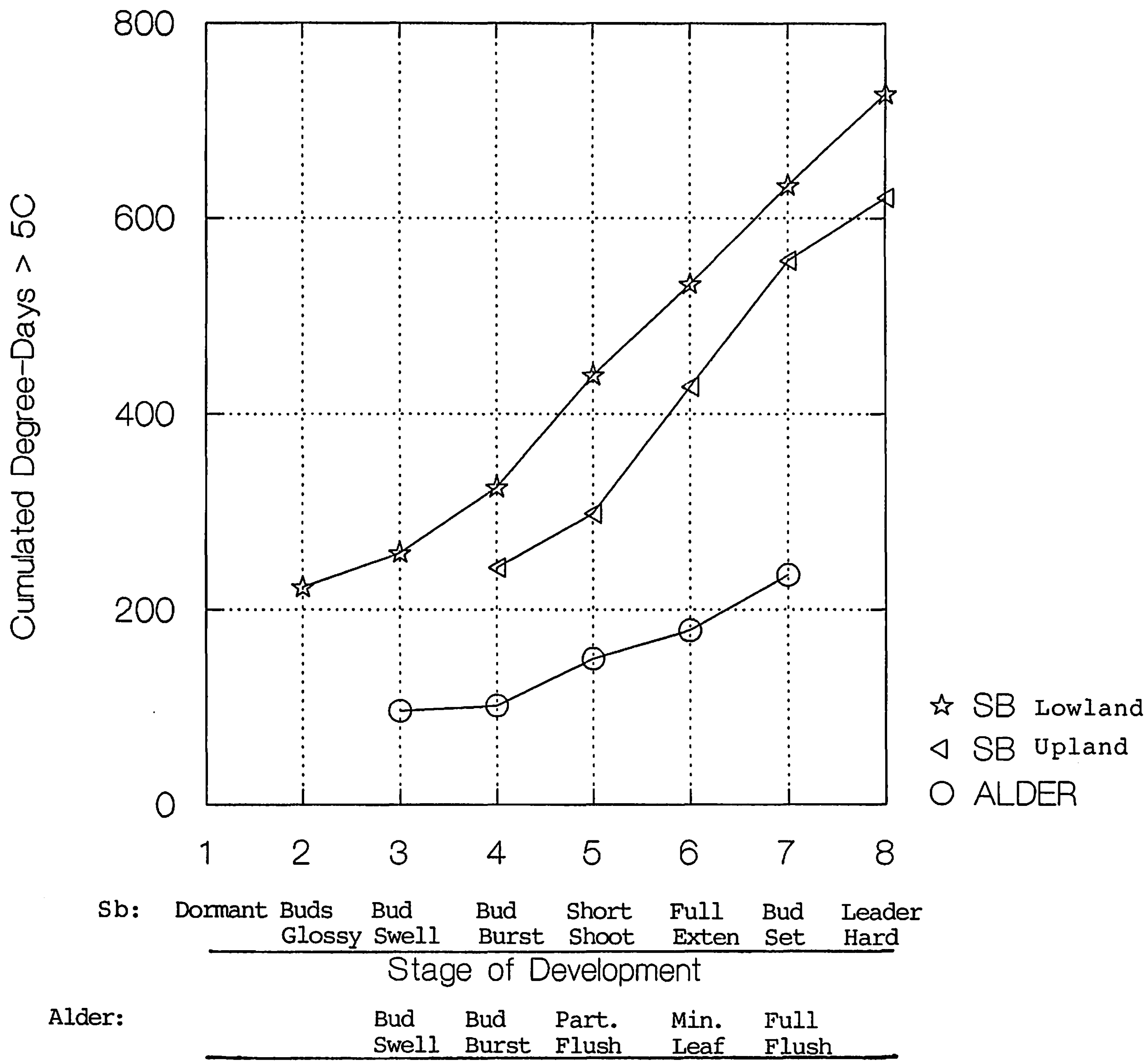
where: $D$ = the predicted number of days from the current date until the event;

T = average number of degree-days to the event;
A = number of degree-days accumulated by the date of prediction;
M = average number of degree-days accumulated per day from the prediction date to the date of the event.

As the season progresses the predictions made by this model become more accurate. Mean errors for the prediction of fruit tree bloom dates ranged from -5 days, 15 days after the start-date of heat accumulation, to -1 day, 47 days after the start of heat accumulation. The model's accuracy also varied with the tree species to a lesser extent.

From 1982 to 1984, Spruce Falls Power and Paper Company at Kapuskasing collected data regarding the dates of occurrence of various developmental stages of black spruce on both upland and lowland sites, and speckled alder on lowland sites. Using this data, Ecological Services for Planning Limited tested a number of climatic variables as predictive tools, following the agricultural precedent. A preliminary model was developed, using the variable cumulated degree-days above 5 degrees Celsius (i.e. the number of degrees by which the mean daily temperature exceeds the 5 degree C baseline, cumulated over the course of the season). This variable seemed to predict development stage with the greatest accuracy. Figure 1 shows the preliminary model in graphical form. Developmental stages for black spruce and alder are plotted against the mean number of degree-days cumulated to the time of occurrence of the event.

**FIGURE 1:** Preliminary model showing mean number of degree-days (base 5 degrees C) accumulated to the time of different phenological stages of black spruce and speckled alder at Kapuskasing.



These preliminary data indicated that development of black spruce on peatland sites lags behind that of black spruce on mineral soil upland sites. Peatland sites tend to be colder due to poor air drainage and tend to remain frozen longer in the spring, and hence, one would expect the accumulation of degree-days to lag behind that on upland sites.

The intent of this project was to establish a series of "low level research" trials in an operational setting to assess "real world" variation in the phenology and development of black spruce and speckled alder. It was recognized that outputs would not necessarily include definitive answers. Specific objectives of this study were:

i) Collection of phenology data for black spruce conducted over the course of the growing season on two different site types, upland and peatland, to evaluate variability in development of a typical black spruce plantation over time and between the two site types. Phenology data for speckled alder would also be obtained on the peatland site. These data would be used to enhance the database for, and to assess the preliminary predictive model for black spruce and alder described above.

ii) Synthesis and correlation of local climatic data with the phenology data for black spruce and speckled alder.

## 2.0 METHODS

Two sites were established for phenology monitoring during the spring of 1987. The sites are located within 1 kilometre of the glyphosate research plots in Ecclestone Township, south of the town of Kapuskasing (Figure 2). Two fixed plots consisting of 100 trees were established on each of an upland (Operational Group 7, Mixedwood-Herb Rich) and a lowland (Operational Group 12, Alnus-Herb Poor) site. Both plots were located on plantations of black spruce 1.5 x 1.5 bareroot stock (Swastika nursery) planted in the spring of 1984.

A classification system for recording the phenology of black spruce and speckled alder, based on observable features of the buds, leaves and stems, was developed (Table 1). Phenology of the planted black spruce trees was recorded in each of these plots on approximately a weekly basis, beginning in early May and continuing until late August, for both of the 1987 and 1988 field seasons. In the lowland plot only, the phenology of 100 individual clumps of speckled alder was assessed at the same time.

Adjacent to the lowland (O.G. 12) plot in Ecclestone Township, a remote weather monitoring station was established in the spring of 1987 to monitor air and soil temperatures over the course of the growing season, on a continuous basis. The station was active from late April (snow melt) until early October for two years (1987-

FIGURE 2: Locations of phenology monitoring plots in Ecclestone Township and remote weather monitoring station in Cargill Township, Kapuskasing.

Northwest corner of Cargill Township:
Latitude 49.32 (decimal degrees)
Longitude 82.88 (decimal degrees)

L = Peatland phenology monitoring site

U = Upland phenology monitoring site

W = Location of remote weather monitoring station

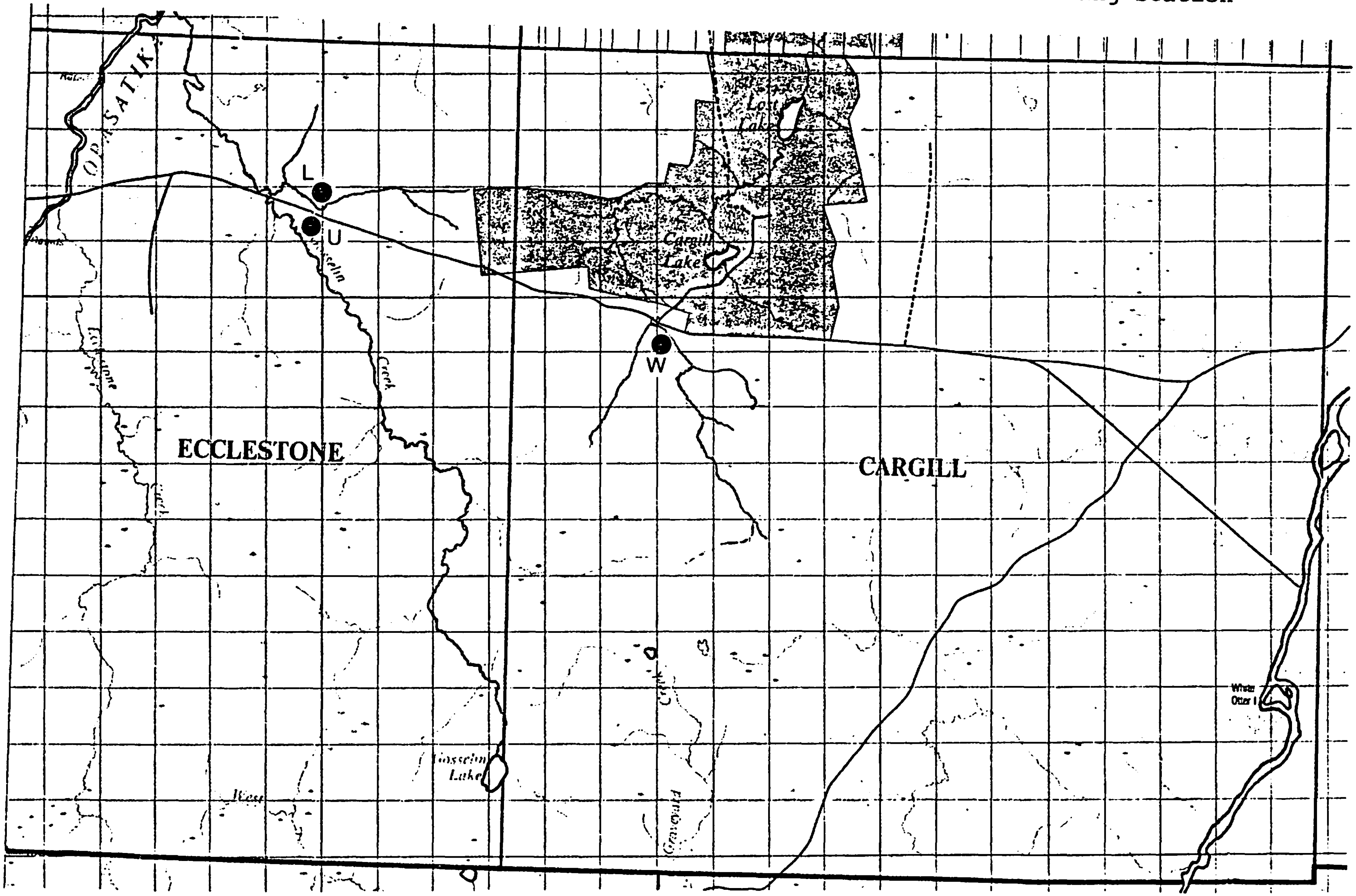


**TABLE 1:** Descriptions of the classifications used to record the developmental stages of Speckled Alder and black spruce.

| SPECIES | STAGE OF DEVELOPMENT | DESCRIPTION |
|---|---|---|
| Alder | 1 | buds swelling |
| | 2 | buds breaking out of cases |
| | 3 | partially flushed (50% of buds) |
| | 4 | 100% of buds broken, some miniature leaves |
| | 5 | 100% miniature leaves |
| | 6 | fully flushed with leaves fully expanded |
| Black Spruce | 1 | Buds fully dormant |
| | 2 | Buds have become shiny or glossy |
| | 3 | Buds swelling, with green and brown flecks |
| | 4 | Greater than 50% of buds burst |
| | 5 | Short shoot elongation |
| | 6 | Full extension of the main leader; buds forming but not yet hardened, main leader stem still fully green, succulent and smooth |
| | 7 | Buds set and hardening (pointed and firm to touch); main leader turning yellowish from the base, but still partly green and succulent |
| | 8 | Leader starting to harden; entirely yellow in colour, developing distinct ridges, with some brown colour at the base |
| | 9 | Leader partially hardened, with > 30% brown colour at the base |
| | 10 | Leader fully hardened off, entirely brown in colour |

1988). The weather station was constructed and located according to standard procedures established by the Atmospheric Environment Service of Environment Canada. A two-probe continuous recording monitor was set up in an enclosed station (see Appendix 1), with the soil temperature probe located at 10 centimetre depth in the soil, and the air probe located in a separate louvred box, at a height of approximately 1.5 metres. This corresponded to methods employed at the Agriculture Canada Experimental Farm at Kapuskasing. Every week, the station was checked, the graph paper roll changed, and the temperature readings for the two probes were checked and calibrated using a separate digital temperature gauge.

The purpose of the phenology monitoring was to assess the development of black spruce plantations over the course of several growing seasons, to determine the frequency distributions of the various developmental stages over time, and to correlate phenological development with climatic variables, especially temperature. The objective of the on-site weather monitoring station in Ecclestone Township was to calibrate the lowland phenology monitoring plots against the more complete data available from the Agriculture Canada Experimental Farm, which is located on an upland site in Kapuskasing..

## 3.0 RESULTS AND DISCUSSION

Results of the phenological monitoring of black spruce on both upland and peatland sites, for the years 1987 and 1988, are summarized in Table 2. Variability in the timing of different developmental stages for individual trees can be observed, as noted by Nienstaedt for white spruce (1974). Bud break occurred over approximately a two to three week period on both sites, while bud set occurred over approximately a one to two week period.

In Kapuskasing, tending of black spruce plantations with the herbicide 2,4-D is usually conducted following bud set. During the one to two week period when the buds are setting, a proportion of the trees will still be actively growing, and may be susceptible to spray damage. Due to weather constraints, the time available for herbicide applications at Kapuskasing is limited, and it may be desirable to push back the window in order to complete annual tending requirements.

To accomplish this, the start of the spray window could be defined as the point in time when a sufficient proportion of the trees have set bud so as to minimize the risk of damage. For example, in 1987, 80% of the trees observed had set bud by approximately July 12 on the upland site, and by July 13 on the lowland site. In 1988, 80% of the trees had set bud on the upland site by July 19, and on the lowland site by July 25. 95% of buds were set in all

**TABLE 2:** Summary of phenology monitoring for black spruce trees on upland and lowland sites, for the years 1987 and 1988. The percent of trees at each stage of development are shown against the date of assessment.

UPLAND SITE

| YEAR | # DAYS FROM MAY 1 | DATE (MDD) | % OF TREES AT PHENOLOGICAL STAGE: 1 | 2 | 3 | BUD BREAK 4 | 5 | 6 | BUD SET 7 | LEADER HARDENING 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | 6 | 506 | 82 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 17 | 517 | 10 | 33 | 49 | 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 26 | 526 | 0 | 2 | 32 | 62 | 4 | 0 | 0 | 0 | 0 | 0 |
| | 41 | 610 | 0 | 2 | 25 | 69 | 4 | 0 | 0 | 0 | 0 | 0 |
| | 46 | 615 | 0 | 0 | 6 | 88 | 6 | 0 | 0 | 0 | 0 | 0 |
| | 56 | 625 | 0 | 0 | 0 | 4 | 30 | 58 | 8 | 0 | 0 | 0 |
| | 67 | 706 | 0 | 0 | 0 | 2 | 17 | 45 | 36 | 0 | 0 | 0 |
| | 71 | 710 | 0 | 0 | 0 | 0 | 0 | 32 | 64 | 4 | 0 | 0 |
| | 74 | 713 | 0 | 0 | 0 | 0 | 0 | 13 | 41 | 28 | 9 | 9 |
| | 85 | 724 | 0 | 0 | 0 | 0 | 0 | 2 | 15 | 44 | 35 | 4 |
| | 105 | 813 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 19 | 72 | 6 |
| | 109 | 817 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 73 | 24 |
| | 110 | 818 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 65 | 33 |
| 1988 | 30 | 530 | 42 | 47 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 38 | 607 | 0 | 0 | 10 | 45 | 45 | 0 | 0 | 0 | 0 | 0 |
| | 45 | 614 | 0 | 0 | 9 | 36 | 55 | 0 | 0 | 0 | 0 | 0 |
| | 57 | 626 | 0 | 0 | 1 | 21 | 76 | 2 | 0 | 0 | 0 | 0 |
| | 66 | 705 | 0 | 0 | 0 | 8 | 80 | 12 | 0 | 0 | 0 | 0 |
| | 70 | 709 | 0 | 0 | 0 | 8 | 32 | 60 | 0 | 0 | 0 | 0 |
| | 73 | 712 | 0 | 0 | 0 | 0 | 20 | 80 | 0 | 0 | 0 | 0 |
| | 76 | 715 | 0 | 0 | 0 | 0 | 0 | 68 | 32 | 0 | 0 | 0 |
| | 81 | 720 | 0 | 0 | 0 | 0 | 0 | 16 | 78 | 6 | 0 | 0 |
| | 83 | 722 | 0 | 0 | 0 | 0 | 0 | 10 | 52 | 38 | 0 | 0 |
| | 89 | 728 | 0 | 0 | 0 | 0 | 0 | 9 | 50 | 41 | 0 | 0 |
| | 100 | 808 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 18 | 51 | 23 |
| | 108 | 816 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 32 | 63 |
| | 115 | 823 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 26 | 72 |
| | 123 | 831 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 18 | 74 |

PEATLAND SITE

| YEAR | # DAYS FROM MAY 1 | DATE (MDD) | % OF TREES AT PHENOLOGICAL STAGE: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | 7 | 507 | 94 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 15 | 515 | 78 | 15 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 27 | 527 | 25 | 49 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 35 | 604 | 10 | 55 | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 45 | 614 | 3 | 5 | 40 | 52 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 55 | 624 | 0 | 5 | 20 | 63 | 10 | 2 | 0 | 0 | 0 | 0 |
| | 63 | 702 | 0 | 0 | 0 | 0 | 3 | 80 | 14 | 3 | 0 | 0 |
| | 66 | 705 | 0 | 0 | 0 | 0 | 0 | 52 | 40 | 8 | 0 | 0 |
| | 69 | 708 | 0 | 0 | 0 | 0 | 0 | 41 | 49 | 10 | 0 | 0 |
| | 72 | 711 | 0 | 0 | 0 | 0 | 2 | 22 | 42 | 32 | 3 | 0 |
| | 74 | 713 | 0 | 0 | 0 | 0 | 0 | 19 | 30 | 43 | 8 | 0 |
| | 76 | 715 | 0 | 0 | 0 | 0 | 0 | 6 | 21 | 43 | 30 | 0 |
| | 84 | 723 | 0 | 0 | 0 | 0 | 0 | 2 | 15 | 46 | 37 | 0 |
| | 91 | 730 | 0 | 0 | 0 | 0 | 0 | 2 | 13 | 40 | 38 | 7 |
| 1988 | 30 | 530 | 90 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 38 | 607 | 50 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 49 | 618 | 23 | 61 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 57 | 626 | 6 | 18 | 32 | 44 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 66 | 705 | 0 | 10 | 24 | 66 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 71 | 710 | 0 | 0 | 24 | 52 | 24 | 0 | 0 | 0 | 0 | 0 |
| | 76 | 715 | 0 | 0 | 0 | 0 | 10 | 90 | 0 | 0 | 0 | 0 |
| | 81 | 720 | 0 | 0 | 0 | 0 | 0 | 57 | 39 | 4 | 0 | 0 |
| | 89 | 728 | 0 | 0 | 0 | 0 | 0 | 13 | 80 | 7 | 0 | 0 |

NOTE: See Table 1 for detailed explanation of stages 1-10.

cases approximately one week later. If spraying were conducted at the point of 80% bud set, at this time approximately 20% of the trees would be potentially susceptible to spray damage. This would be a calculated risk on the part of the manager.

In practice, on alder sites requiring release in the Clay Belt area, tending is usually conducted two to three years after planting. Due to the fast growth of alder on these sites, the alder canopy usually overtops the trees by this time. This would tend to intercept the herbicide and reduce the risk of damage to the trees.

Table 2 shows that development on the peatland sites lags behind that on uplands, especially in the early stages of development. For example, in 1987 peak bud break occurred on the upland site approximately three weeks before that on the peatland site, while bud set on the uplands occurred only a few days before bud set on the peatlands. Annual variation can also be observed. Peak bud break on both site types in 1987 occurred approximately two weeks before that in 1988.

A similar, though less pronounced pattern of more rapid development of speckled alder phenology in 1987 is shown in Table 3. For example, speckled alder reached the full miniature leaf stage in 1987 about two weeks in advance of 1988.

**TABLE 3**: Summary of results from monitoring speckled alder phenology on the peatland site, for the years 1987 and 1988.

| | | | % OF STEMS AT PHENOLOGICAL STAGE: | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | # DAYS | | BUD | | | MIN. | FULL |
| | DATE | FROM | | BREAK | | | LEAF | FLUSH |
| YEAR | (MMDD) | APRIL 1 | 1 | 2 | 3 | 4 | 5 | 6 |
| 1987 | 506 | 35 | 11 | 50 | 26 | 13 | 0 | 0 |
| | 517 | 46 | 5 | 32 | 38 | 25 | 0 | 0 |
| | 526 | 55 | 0 | 0 | 2 | 89 | 9 | 0 |
| | 527 | 56 | 0 | 0 | 0 | 90 | 10 | 0 |
| | 602 | 62 | 0 | 0 | 0 | 45 | 55 | 0 |
| | 608 | 68 | 0 | 0 | 0 | 20 | 80 | 0 |
| | 615 | 75 | 0 | 0 | 0 | 8 | 90 | 2 |
| | 706 | 96 | 0 | 0 | 0 | 0 | 80 | 20 |
| | 710 | 100 | 0 | 0 | 0 | 0 | 0 | 100 |
| 1988 | 507 | 36 | 20 | 40 | 28 | 12 | 0 | 0 |
| | 518 | 47 | 10 | 43 | 30 | 17 | 0 | 0 |
| | 528 | 57 | 0 | 0 | 49 | 32 | 9 | 0 |
| | 607 | 67 | 0 | 0 | 0 | 64 | 36 | 0 |
| | 612 | 72 | 0 | 0 | 0 | 30 | 70 | 0 |
| | 626 | 86 | 0 | 0 | 0 | 5 | 95 | 0 |
| | 702 | 92 | 0 | 0 | 0 | 0 | 100 | 0 |
| | 705 | 95 | 0 | 0 | 0 | 0 | 86 | 14 |
| | 712 | 102 | 0 | 0 | 0 | 0 | 0 | 100 |

NOTE: MIN. LEAF = Miniature leaf stage. See Table 1 for detailed explanation of stages 1-6.

The year 1987 was characterized by an unusually warm spring that probably speeded development of the alder on the peatland site and the spruce on both sites. This is illustrated in Figure 3, which shows the number of degree-days greater than 5°C accumulated from April 1, for the years 1987 and 1988, plotted against the long term mean.

Table 4 shows the progression of bud break, bud set and leader hardening against accumulated degree-days for air and soil temperatures, rainfall, sunshine hours and number of frost days. Table 5 shows the progression of bud break and flushing of speckled alder against similar variables.

Most authors agree that bud break in conifers is an event controlled by temperature, while bud set and hardening is controlled more by photoperiod (eg. Lavender 1988, Nienstaedt 1974). A preliminary study conducted with data provided by Spruce Falls Power and Paper Company Limited suggested the feasibility of developing a predictive model based on heat sums (accumulated degree-days). However, given the limited data set available from this study, detailed correlations of phenology with climate are not possible. Hence, this report will be restricted to reporting the data and making some general observations.

Table 6 summarizes the timing of peak bud break in black spruce and speckled alder and the number of degree-days accumulated to those

FIGURE 3: Cumulated degree-days (base 5 degrees C) for 1987 and 1988 compared to 30-year mean and 95% confidence limits.

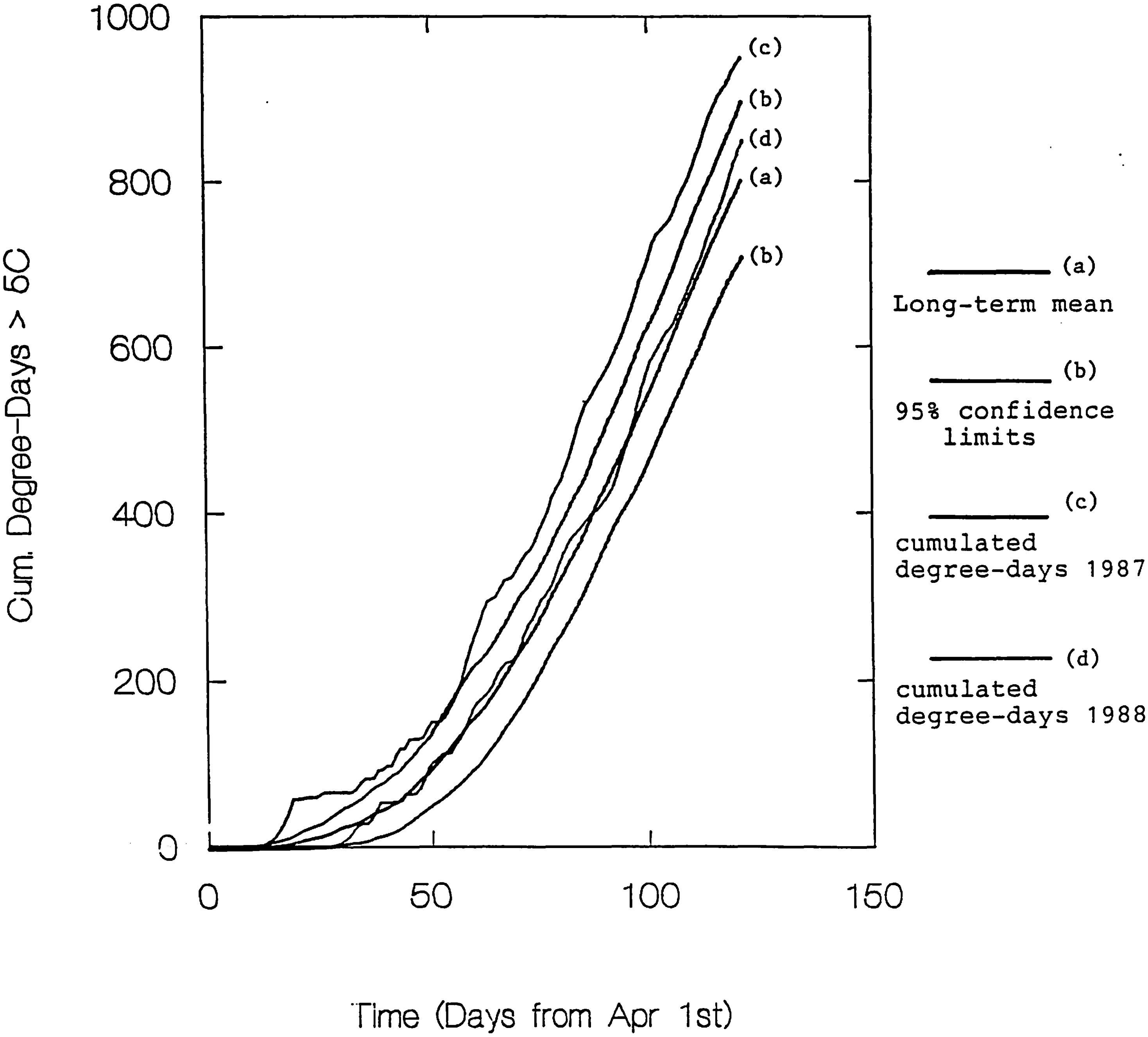


**TABLE 4:** Timing of bud break, bud set and leader hardening for black spruce, for upland and peatland sites, 1987 and 1988, versus cumulated degree-days (base 5 Celsius) for air and soil temperatures, number of frost days and cumulated rainfall.

UPLAND SITE

| YEAR | # DAYS FROM MAY 1 | DATE (MMDD) | % OF TREES FLUSHED | % OF TREES BUD SET | % OF TREES LEADER HARDENED | CUMULATED NO. FROST DAYS | CUMULATED DEGREE-DAYS > 5C (AIR TEMP.) | CUMULATED DEGREE-DAYS > 5C (SOIL TEMP.) | CUMULATED SUNSHINE HOURS | CUMULATED PRECIPITATION (MM) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | 6 | 506 | 0 | 0 | 0 | 23 | 84 | 149 | 279 | 21 |
| | 17 | 517 | 9 | 0 | 0 | 28 | 132 | 250 | 347 | 26 |
| | 26 | 526 | 66 | 0 | 0 | 33 | 177 | 337 | 407 | 56 |
| | 41 | 610 | 73 | 0 | 0 | 34 | 336 | 558 | 528 | 87 |
| | 46 | 615 | 94 | 0 | 0 | 34 | 381 | 634 | 573 | 100 |
| | 56 | 625 | 100 | 8 | 0 | 34 | 521 | 835 | 685 | 136 |
| | 67 | 706 | 100 | 36 | 0 | 34 | 644 | 1036 | 765 | 160 |
| | 71 | 710 | 100 | 68 | 4 | 34 | 708 | 1118 | 801 | 168 |
| | 74 | 713 | 100 | 87 | 46 | 34 | 743 | 1177 | 813 | 210 |
| | 85 | 724 | 100 | 98 | 83 | 34 | | | | |
| 1988 | 30 | 530 | 0 | 0 | 0 | 41 | 163 | 270 | 433 | 113 |
| | 38 | 607 | 90 | 0 | 0 | 41 | 220 | 372 | 504 | 114 |
| | 45 | 614 | 91 | 0 | 0 | 42 | 284 | 464 | 555 | 119 |
| | 57 | 626 | 99 | 0 | 0 | 42 | 391 | 629 | 617 | 186 |
| | 66 | 705 | 100 | 0 | 0 | 42 | 485 | 770 | 689 | 191 |
| | 70 | 709 | 100 | 0 | 0 | 42 | 563 | 855 | 731 | 191 |
| | 73 | 712 | 100 | 0 | 0 | 42 | 598 | 915 | 753 | 194 |
| | 76 | 715 | 100 | 32 | 0 | 42 | 623 | 966 | 767 | 214 |
| | 81 | 720 | 100 | 84 | 6 | 42 | 683 | 1057 | 822 | 216 |
| | 83 | 722 | 100 | 90 | 38 | 42 | 709 | 1095 | 843 | 217 |
| | 89 | 728 | 100 | 91 | 41 | 42 | 799 | 1212 | 904 | 221 |

PEATLAND SITE

| YEAR | # DAYS FROM MAY 1 | DATE (MMDD) | % OF TREES FLUSHED | % OF TREES BUD SET | % OF TREES LEADER HARDENED | CUMULATED NO. FROST DAYS | CUMULATED DEGREE-DAYS > 5C (AIR TEMP.) | CUMULATED DEGREE-DAYS > 5C (SOIL TEMP.) | CUMULATED SUNSHINE HOURS | CUMULATED PRECIPITATION (MM) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | 7 | 507 | 0 | 0 | 0 | 24 | 84 | 157 | 290 | 21 |
| | 15 | 515 | 0 | 0 | 0 | 28 | 120 | 230 | 341 | 26 |
| | 27 | 527 | 0 | 0 | 0 | 33 | 191 | 349 | 411 | 57 |
| | 35 | 604 | 0 | 0 | 0 | 34 | 299 | 475 | 469 | 72 |
| | 45 | 614 | 52 | 0 | 0 | 34 | 368 | 617 | 559 | 96 |
| | 55 | 624 | 75 | 0 | 0 | 34 | 505 | 814 | 681 | 124 |
| | 63 | 702 | 100 | 17 | 3 | 34 | 590 | 960 | 731 | 149 |
| | 66 | 705 | 100 | 48 | 8 | 34 | 628 | 1016 | 760 | 160 |
| | 69 | 708 | 100 | 59 | 10 | 34 | 680 | 1078 | 788 | 161 |
| | 72 | 711 | 100 | 77 | 35 | 34 | 726 | 1139 | 813 | 197 |
| | 74 | 713 | 100 | 81 | 51 | 34 | 743 | 1177 | 813 | 210 |
| | 76 | 715 | 100 | 94 | 73 | 34 | 756 | 1210 | 830 | 211 |
| | 84 | 723 | 100 | 98 | 83 | 34 | 864 | 1351 | 872 | 258 |
| | 91 | 730 | 100 | 98 | 85 | 34 | 943 | 1487 | 951 | 264 |
| 1988 | 30 | 530 | 0 | 0 | 0 | 41 | 163 | 270 | 433 | 113 |
| | 38 | 607 | 0 | 0 | 0 | 41 | 220 | 372 | 504 | 114 |
| | 49 | 618 | 0 | 0 | 0 | 42 | 317 | 519 | 576 | 144 |
| | 57 | 626 | 44 | 0 | 0 | 42 | 391 | 629 | 617 | 186 |
| | 66 | 705 | 66 | 0 | 0 | 42 | 485 | 770 | 689 | 191 |
| | 71 | 710 | 76 | 0 | 0 | 42 | 580 | 877 | 738 | 194 |
| | 76 | 715 | 100 | 0 | 0 | 42 | 623 | 966 | 767 | 214 |
| | 81 | 720 | 100 | 43 | 4 | 42 | 683 | 1057 | 822 | 216 |
| | 89 | 728 | 100 | 87 | 7 | 42 | 799 | 1212 | 904 | 221 |

TABLE 5: Timing of bud break and "miniature leaf" stage for speckled alder for peatland site, 1987 and 1988, versus cumulated degree-days (base 5 Celsius) for air and soil temperatures, total number of sunshine hours and cumulated rainfall.

| YEAR | DATE (MMDD) | # DAYS FROM APRIL 1 | % STEMS WITH BUD BREAK | % STEMS AT MINIATURE LEAF STAGE | CUMULATED PPT. (MM) | CUMULATED DEGREE-DAYS > 5C (AIR TEMP) | CUMULATED DEGREE-DAYS > 5C (SOIL TEMP) | CUMULATED SUNSHINE HOURS |
|---|---|---|---|---|---|---|---|---|
| 1987 | 506 | 35 | 13 | 0 | 21 | 84 | 40 | 279 |
| | 517 | 46 | 25 | 0 | 26 | 132 | 86 | 347 |
| | 526 | 55 | 98 | 9 | 56 | 177 | 127 | 407 |
| | 527 | 56 | 100 | 10 | 57 | 191 | 135 | 411 |
| | 602 | 62 | 100 | 55 | 68 | 285 | 201 | 457 |
| | 608 | 68 | 100 | 80 | 86 | 323 | 255 | 504 |
| | 615 | 75 | 100 | 92 | 100 | 381 | 325 | 573 |
| | 706 | 96 | 100 | 100 | 160 | 644 | 621 | 765 |
| | 710 | 100 | 100 | 100 | 168 | 708 | 684 | 801 |
| 1988 | 507 | 36 | 12 | 0 | 39 | 32 | 15 | 275 |
| | 518 | 47 | 17 | 0 | 100 | 69 | 43 | 353 |
| | 528 | 57 | 98 | 9 | 109 | 139 | 97 | 421 |
| | 607 | 67 | 100 | 36 | 114 | 220 | 173 | 504 |
| | 612 | 72 | 100 | 70 | 114 | 264 | 213 | 554 |
| | 626 | 86 | 100 | 95 | 186 | 391 | 335 | 617 |
| | 702 | 92 | 100 | 100 | 191 | 434 | 389 | 660 |
| | 705 | 95 | 100 | 100 | 191 | 485 | 431 | 689 |
| | 712 | 102 | 100 | 100 | 194 | 598 | 541 | 753 |

**TABLE 6**: Comparison of observed peak date for bud break of black spruce versus cumulated degree-days (base 5 degrees Celsius, on upland and peatland sites, and peak dates for speckled alder bud break versus cumulated degree-days, for the years 1983-1988. Degree-days are summarized from data obtained from the Kapuskasing experimental farm, and includes data collected by Spruce Falls Power and Paper Co. Ltd. at Kapuskasing for the years 1983-1985. No data is available for the year 1986.

| | | YEAR OF OBSERVATION | | | | |
|---|---|---|---|---|---|---|
| EVENT | SITE | 1983 | 1984 | 1985 | 1987 | 1988 |
| Approximate peak date of bud break, black spruce | Upland | JUN 13 | JUN 10 | JUN 12 | JUN 3 | JUN 10 |
| | Lowland | JUN 23 | JUN 17 | JUN 22 | JUN 9 | JUN 26 |
| Degree-days accumulated on date | Upland | 171.4 | 247.3 | 243.7 | 241.5 | 234 |
| | Lowland | 324.4 | 305.6 | 335.4 | 326.0 | 391.3 |
| Approximate peak date of bud break, speckled alder | Lowland | JUN 8 | MAY 24 | MAY 28 | MAY 17 | MAY 28 |
| Degree-days accumulated on date | Lowland | 105.9 | 138.4 | 165.5 | 131.8 | 138.5 |

dates. This table enhances the results of the original Spruce Falls study with the data collected in 1987 and 1988. All of the degree day data in this table is summarized from observations at the Kapuskasing Experimental Farm, and hence, may not reflect actual heat accumulated on the peatland site.

The reason for using the Experimental Farm data rather than the peatland data is that at the present time local managers are not equipped to monitor climate on peatland sites independently. Data from the Experimental Farm is freely available to local managers from year to year. Ideally, local managers should be able to use the experimental farm data to predict development on both upland and peatland sites, assuming there is a consistent relationship between the two site types with regard to heat accumulation. The relationships between the Experimental Farm data and the data obtained on the peatland site will be discussed subsequently.

The number of degree-days accumulated each year to bud break shows some consistency, which supports the use of this variable as a predictive tool. However, it is likely that the relationship of phenology to climate is more complex. Considerably more data would be required to develop a testable model.

From Table 6, note that the lowest degree day requirements for bud break occurred in the year 1983. This year was characterized by unusually low temperatures in April and May, coupled with high rainfall (see Table 7). This corresponds to Nienstaedt's (1974) observations from his field and greenhouse studies of white spruce, that the lowest degree day requirement for flushing was recorded in the year with the coolest spring and latest date for flushing. Thus it would seem that some physiological process may interact with spring temperatures to control flushing.

Table 8 compares air and soil temperatures monitored on the peatland site with data from the Kapuskasing Experimental Farm. In general, daily fluctuations on the peatland site were larger than those observed on the Experimental Farm, particularly early and late in the growing season. Although mean air temperatures recorded were similar, mean soil temperatures tended to be lower except in the early summer of 1987. Hence, under normal weather conditions, one might expect development on peatlands to lag behind that on uplands, as we observed in this study. However, this effect may be reduced during unusually warm years especially with little rainfall as in 1987. Further study is required to confirm these observations and to clarify the climatic and physiological interactions with the phenology of black spruce and speckled alder.

**TABLE 7:** Monthly summary of climatic data from the Agriculture Canada Kapuskasing Experimental Farm weather monitoring station, April to September, for the years 1982 to 1988.

| VARIABLE | MONTH | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|---|---|---|
| Mean air temperature | APRIL | -2.9 | -0.5 | 5.2 | 0.7 | 3.4 | 4.7 | 0.7 |
| | MAY | 12.3 | 5.5 | 6.8 | 8.6 | 11.4 | 10.4 | 9.9 |
| | JUNE | 12.1 | 15.6 | 14.6 | 12.6 | 12.1 | 15.4 | 13.1 |
| | JULY | 16.8 | 18.7 | 16.6 | 15.5 | 17.1 | 17.3 | 19.0 |
| | AUGUST | 13.2 | 18.0 | 17.5 | 15.6 | 14.8 | 14.9 | 15.4 |
| | SEPTEMBER | 10.9 | 12.5 | 9.3 | 11.6 | 9.0 | 11.9 | 10.2 |
| Monthly degree-days | APRIL | 24 | 8 | 66 | 59 | 58 | 68 | 4 |
| | MAY | 227 | 68 | 82 | 120 | 218 | 189 | 168 |
| | JUNE | 215 | 320 | 289 | 229 | 213 | 313 | 243 |
| | JULY | 367 | 425 | 360 | 326 | 375 | 383 | 433 |
| | AUGUST | 253 | 402 | 387 | 329 | 303 | 303 | na |
| | SEPTEMBER | 179 | 225 | 140 | 202 | 121 | 207 | na |
| Cumulated degree-days at month end | APRIL | 24 | 8 | 66 | 59 | 58 | 68 | 4 |
| | MAY | 251 | 76 | 148 | 180 | 276 | 256 | 172 |
| | JUNE | 466 | 396 | 436 | 409 | 489 | 569 | 415 |
| | JULY | 833 | 821 | 797 | 735 | 864 | 951 | 848 |
| | AUGUST | 1086 | 1223 | 1184 | 1064 | 1166 | 1254 | na |
| | SEPTEMBER | 1265 | 1447 | 1324 | 1266 | 1287 | 1460 | na |
| Mean Maximum air temperature | APRIL | 3.5 | 4.5 | 12.9 | 7.2 | 9.0 | 11.8 | 6.2 |
| | MAY | 19.1 | 11.5 | 13.0 | 15.3 | 18.5 | 17.2 | 17.2 |
| | JUNE | 18.0 | 22.2 | 20.1 | 18.8 | 18.9 | 22.0 | 19.5 |
| | JULY | 23.2 | 25.2 | 22.4 | 21.4 | 23.7 | 23.4 | 25.9 |
| | AUGUST | 18.2 | 24.2 | 23.8 | 21.8 | 20.8 | 20.8 | 23.2 |
| | SEPTEMBER | 14.9 | 17.2 | 19.5 | 16.7 | 13.9 | 16.9 | 17.0 |
| Mean Minimum air temperature | APRIL | -9.3 | -5.4 | -2.4 | -5.8 | -2.2 | -2.4 | -4.9 |
| | MAY | 5.4 | -0.5 | 0.8 | 1.9 | 4.7 | 3.6 | 2.5 |
| | JUNE | 6.1 | 9.0 | 9.1 | 6.3 | 5.4 | 8.9 | 6.8 |
| | JULY | 10.4 | 12.2 | 10.8 | 9.6 | 10.4 | 11.3 | 12.1 |
| | AUGUST | 8.0 | 11.6 | 11.1 | 9.4 | 8.5 | 9.0 | 7.6 |
| | SEPTEMBER | 6.8 | 7.7 | 4.8 | 6.5 | 3.9 | 6.8 | 3.5 |
| Number frost days | APRIL | 25 | 23 | 22 | 21 | 17 | 19 | 27 |
| | MAY | 6 | 15 | 18 | 6 | 5 | 14 | 14 |
| | JUNE | 2 | 2 | 0 | 1 | 4 | 1 | 1 |
| | JULY | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | AUGUST | 0 | 0 | 0 | 0 | 0 | 0 | na |
| | SEPTEMBER | 3 | 1 | 4 | 3 | 8 | 5 | na |
| Monthly precipitation | APRIL | 68.8 | 45.4 | 19.6 | 43.4 | 36.6 | 20.0 | 39.2 |
| | MAY | 56.4 | 95.6 | 35.2 | 68.4 | 51.6 | 46.4 | 74.3 |
| | JUNE | 43.6 | 59 | 182.2 | 49 | 90.7 | 79.0 | 77.3 |
| | JULY | 126.1 | 83 | 139.3 | 150.9 | 51.3 | 118.2 | 54.9 |
| | AUGUST | 73.5 | 61.4 | 46 | 60.1 | 70.1 | 82.9 | na |
| | SEPTEMBER | 148.3 | 155 | 77.2 | 82.7 | 62.2 | 60.4 | na |
| 10 cm soil temperature (4:15 p.m.) | APRIL | 1.4 | 0.4 | 2.9 | 0.6 | 1.4 | 3.6 | 0.3 |
| | MAY | 14.5 | 6.9 | 8.6 | 7.8 | 11.0 | 9.8 | 8.8 |
| | JUNE | 13.8 | 15.2 | 14.6 | 12.6 | 14.4 | 17.1 | 13.3 |
| | JULY | NA | 20.2 | 18.3 | 17.5 | 19.4 | 18.7 | 19.1 |
| | AUGUST | NA | 20.3 | 18.6 | 17.2 | 17.2 | 16.8 | na |
| | SEPTEMBER | 12.0 | 14.3 | 11.6 | 13.4 | 11.5 | 13.0 | na |
| Date soil temperature reached and maintained 5 degrees Celsius | | APR 28 | MAY 10 | MAY 2 | MAY 9 | MAY 6 | APR 18 | MAY 3 |

**TABLE 8:** Comparison of air and soil temperatures recorded at the on-site remote monitoring station located in the peatland site versus data obtained from the Kapuskasing Experimental Farm.

MEAN TEMPERATURE DIFFERENCES, PEATLAND MONITORING STATION DATA FROM KAPUSKASING EXPERIMENTAL FARM DATA, 1987 (DEGREES CELSIUS)

| MONTH | Maximum Air Temp. | Minimum Air Temp. | Mean Air Temp. | Soil Temp. @ 10 cm 4:15 p.m. |
|---|---|---|---|---|
| MAY | 3.6 | -2.8 | 0.4 | 2.6 |
| JUNE | 4.0 | -0.3 | 1.8 | 0.9 |
| JULY | 2.4 | -1.4 | 0.5 | 0.5 |
| AUGUST | 1.6 | -1.1 | 0.2 | -0.6 |
| SEPTEMBER | 2.9 | -3.0 | 0.3 | -2.7 |
| MEAN | 2.8 | -1.5 | 0.7 | -0.2 |

MEAN TEMPERATURE DIFFERENCES, PEATLAND MONITORING STATION DATA FROM KAPUSKASING EXPERIMENTAL FARM DATA, 1988 (DEGREES CELSIUS)

| MONTH | Maximum Air Temp. | Minimum Air Temp. | Mean Air Temp. | Soil Temp. @ 10 cm 4:15 p.m. |
|---|---|---|---|---|
| MAY | 0.9 | -4.0 | -1.8 | -4.5 |
| JUNE | 1.7 | -4.0 | -1.2 | -4.2 |
| JULY | 0.9 | -5.7 | -2.4 | -3.9 |
| AUGUST | 2.8 | -3.6 | -0.4 | -0.7 |
| SEPTEMBER | 1.8 | -2.9 | -0.6 | -1.2 |
| MEAN | 1.6 | -4.0 | -1.3 | -2.9 |

## 4.0 SUMMARY

Little information is available correlating climate with the phenological development of black spruce and associated vegetation. The purpose of this study was to observe the phenology of black spruce on two site types, upland and peatland, and speckled alder on a peatland site to quantify variability from year to year, variability within and between site types, and to identify possible climatic relationships. This was accomplished by recording phenology on two fixed plots of 100 black spruce trees each over the two years 1987 and 1988. Climatic data was obtained from the local Atmospheric Environment Service Monitoring Station at the Kapuskasing Experimental Farm, and a remote weather monitoring station located on the peatland site.

With only two years of data available, no detailed analyses were possible, however, several interesting trends were observed.

1. The timing of phenological events varied between trees within each plantation. This probably reflects genetic control over timing of development in black spruce. Bud set is a key event used by local foresters to determine when 2,4-D release spraying can be conducted. Within the plantations studied, bud set occurred over approximately a one to two week period each year.

2. Timing of the events on the peatland site lagged behind those on the upland site. The lag was most pronounced in the early part of the season (two to four weeks), and the timing on the two sites converged to within approximately one week or less by the time of bud set in July.

3. Timing of the events for black spruce varied considerably from year to year. For example, timing of bud break occurred between June 3 and June 13 on the upland sites, and from June

9 to June 26 on the peatland sites between 1983 and 1988. Bud set occurred between July 5 and July 20 on the upland site, and between July 10 and July 28 on the peatland site over the same period. Hence, the time available for release spraying of 2,4-D will vary considerably from year to year, depending on phenological development of plantations. Release tending with glyphosate is normally conducted on black spruce plantations in the Clay Belt later in the year, following full hardening of the leaders. Data from this study indicates that this occurs by the end of July under normal weather conditions, but may be delayed until the second week of August with unusually cold spring temperatures.

4. Timing of the phenological events seem to be related to heat accumulation, especially heat accumulated in the early part of the season, but this trend could not be statistically confirmed. However, it appeared that the trend was not linear. Unusual weather in early spring seems to alter the degree-day requirements for bud break and other events. Other climatic factors, such as rainfall and frost frequency, may also affect phenology.

5. The remote weather monitoring station data obtained on the peatland site showed similar mean temperature values, but wider ranges in daily maximum and minimum air temperatures, compared with the data obtained from the Kapuskasing Experimental Farm. In general, lower mean soil temperatures were also observed on the peatland site.

Agricultural studies relating climate to phenology generally use long term data (20 years of more) for climatic correlations and the building of predictive models. Clearly, further study and larger data sets will be needed to quantify these trends for black spruce and alder. Basic research is also needed into the physiological and biochemical processes underlying phenological changes in order to clarify the implications of phenological change to potential herbicide effects.

Herbicide applications should ideally be timed so as to maximize effects on target species and to minimize effects on crop species.

This requires knowledge of the effects of the herbicide being used, in relation to phenology of the plant species being treated (Anon. 1985). This report deals only with the timing of the application in relationship to the phenology of the target and crop species, but does not take into account the availability of climatic conditions suitable for aerial applications during the potential spray window. Hence, although the phenological development stages of the target or crop species at that time may be ideal for herbicide application, climatic conditions suitable for spraying may not be available during a given time period.

For example, interest has been expressed by local industry in conducting release applications of 2,4-D for alder control in late May and early June, after the alder has flushed but while the black spruce crop trees are still dormant (Arnup 1985), but this has proven impractical due to the lack of weather conditions suitable for aerial applications.

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# APPENDIX 1

Specifications for construction and location of remote weather monitoring stations.

INSTRUMENT MANUAL 20

## 2. LOCATION AND EXPOSURE OF AIR TEMPERATURE THERMOMETERS.

### 2.1. General.

2.1.1. A thermometer, located at a point in the atmosphere in which temperature is steady, will come to a steady reading. When the reading is steady the thermometer has attained thermal equilibrium with its surroundings by the processes of conduction, convection and radiation.

2.1.2. The meteorological requirement is to measure the true ambient temperature of the air that flows past the thermometer. It is evident however, that an exposed thermometer will receive heat by radiation from all surrounding objects and from reflecting surfaces and especially from the direct rays of the sun* which is the principal source of heat radiation. Radiative effects will tend to cause the thermometer to read higher than the true ambient air temperature by day and conversely lower than the true air temperature by night. It is therefore necessary to shield the thermometer from radiation and the method of accomplishing this is discussed in para. 2.3.

### 2.2. Conditions to be fulfilled in Temperature Measurements.

2.2.1. Most of the instruments mentioned in 1.3. are for the purposes of measuring ambient temperature of the air, and in order that this may be done as accurately as possible, it is necessary to fulfill certain conditions in locating and exposing such instruments. These conditions are three in number.

2.2.1.1. The thermometers are placed at a standard height above the ground. By International agreement, the standard height is 1.25 to 2 meters (4 ft. to 6½ ft.) above the surface of the ground. The standardization of height is necessary so that meaningful comparisons may be made between stations in a region and internationally.

2.2.1.2. They must be located on a level plot of ground at a distance from buildings, fences or trees at least twice the height of such objects. If practicable, the soil cover underneath the screen should be short grass or failing this, the natural earth of the district. Care should be taken to locate them so as not to be affected by large areas of tarmac.

*(The effects of the sun may be easily tested by an Observer by exposing a mercury thermometer to its direct rays. The thermometer, which previously was in the shade will rapidly rise and indicate a much higher temperature than the thermometer registered in the shade. This rise is due to the great transparency of the surrounding air to the radiation of the sun and the inferior capacity of the air to carry away by conductive and radiative processes, the heat absorbed by the thermometer.)*

# INSTRUMENT MANUAL 20

2.2.1.3. With the exception of the grass minimum thermometer, the instruments must be sheltered from the sun and rain, while being freely exposed to the air.

2.2.2. Before discussing the means by which this last condition may be fulfilled, a few remarks on the location of the thermometers may be in order. This is usually chosen by an Inspector but if the Observer is obliged to select it, he should send to the Head Office, a sketch plan showing the location of nearby structures and trees and their approximate heights. In general, the most open location available will be chosen, preferably a plot of level land and at least 20 x 20 ft. in size and covered with grass. The plot should not be on top of a hill nor in a narrow valley, since the temperature (and other meteorological elements) at such places often differs greatly from that on the level. Exposures on roofs are on no account to be adopted, unless by express consent of the Controller of the Meteorological Branch.

## 2.3. Thermometer Screens.

2.3.1. The effects of radiation are minimized by placing the thermometer in a specially constructed shed, which is frequently called a Stevenson screen. The purpose of this shed is to screen the thermometer from the direct rays of the sun as well as from radiation and reflection from the ground and at the same time allow the free flow of the air over the thermometer bulbs.

2.3.2. The M.S.C. standard screen (Fig. 1) is a double louvred box with interior dimensions 19½" x 11" x 20½". The roof is constructed of 1/4" hard asbestos cement board and provided with an air space. The entire screen is given a coat of aluminum paint and then covered with exterior white enamel. The door is arranged to open downward.

2.3.3. The screen is mounted on a stand which is assembled as indicated in Fig. 2.

### 2.3.4. Mounting the Screen (See Fig. 2).

The stand is inserted into two parallel trenches so orientated that the door of the screen will face the true North. The trenches are firmly filled in with the earth and the screen placed on the stand and fastened with four screws. If practicable, grass should be sown beneath the screen and kept clipped.

### 2.3.5. Maintenance.

The screen should be painted every two years with white enamel requisitioned from Headquarters.

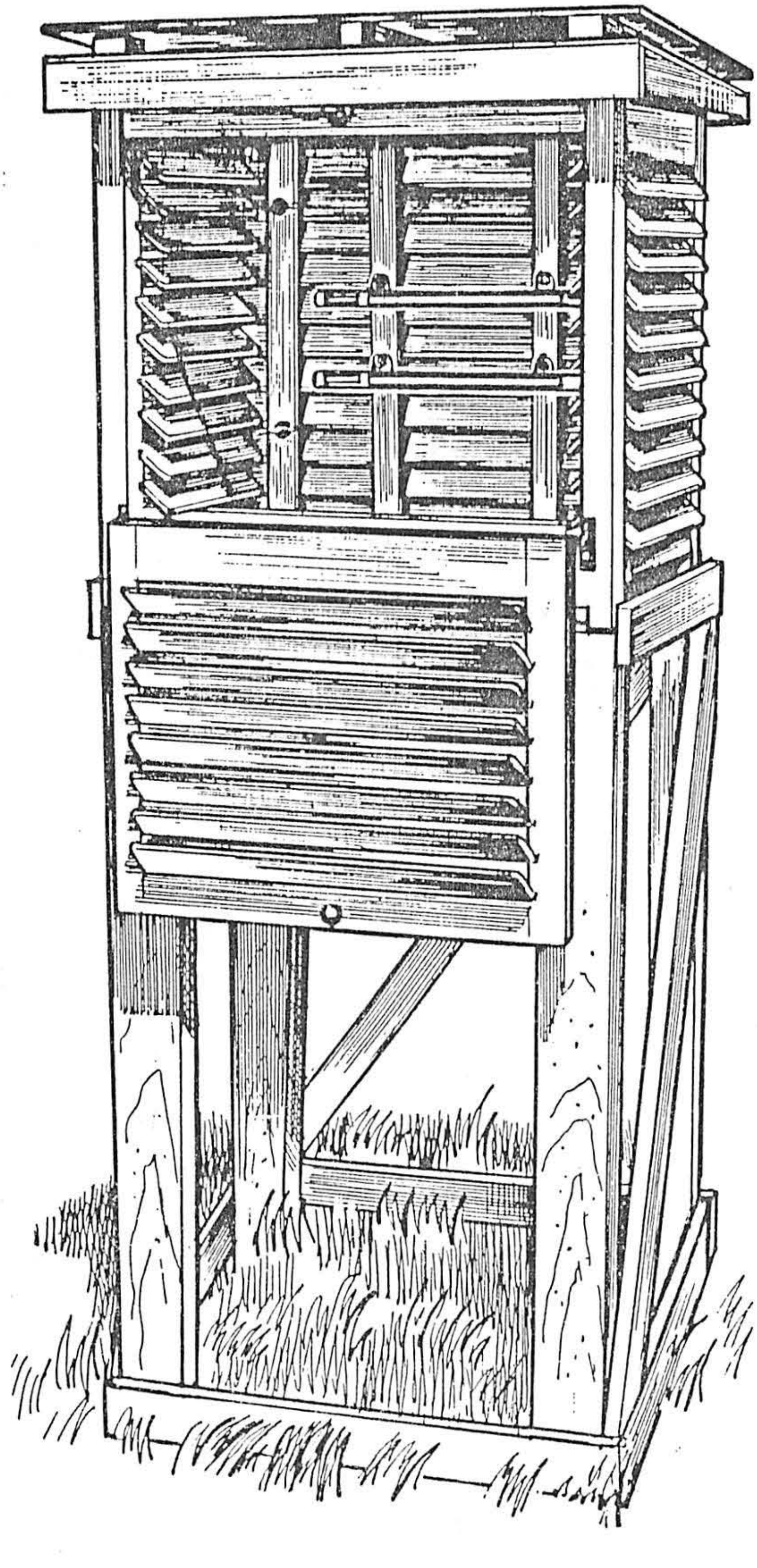

Fig. 1. Thermometer Screen.

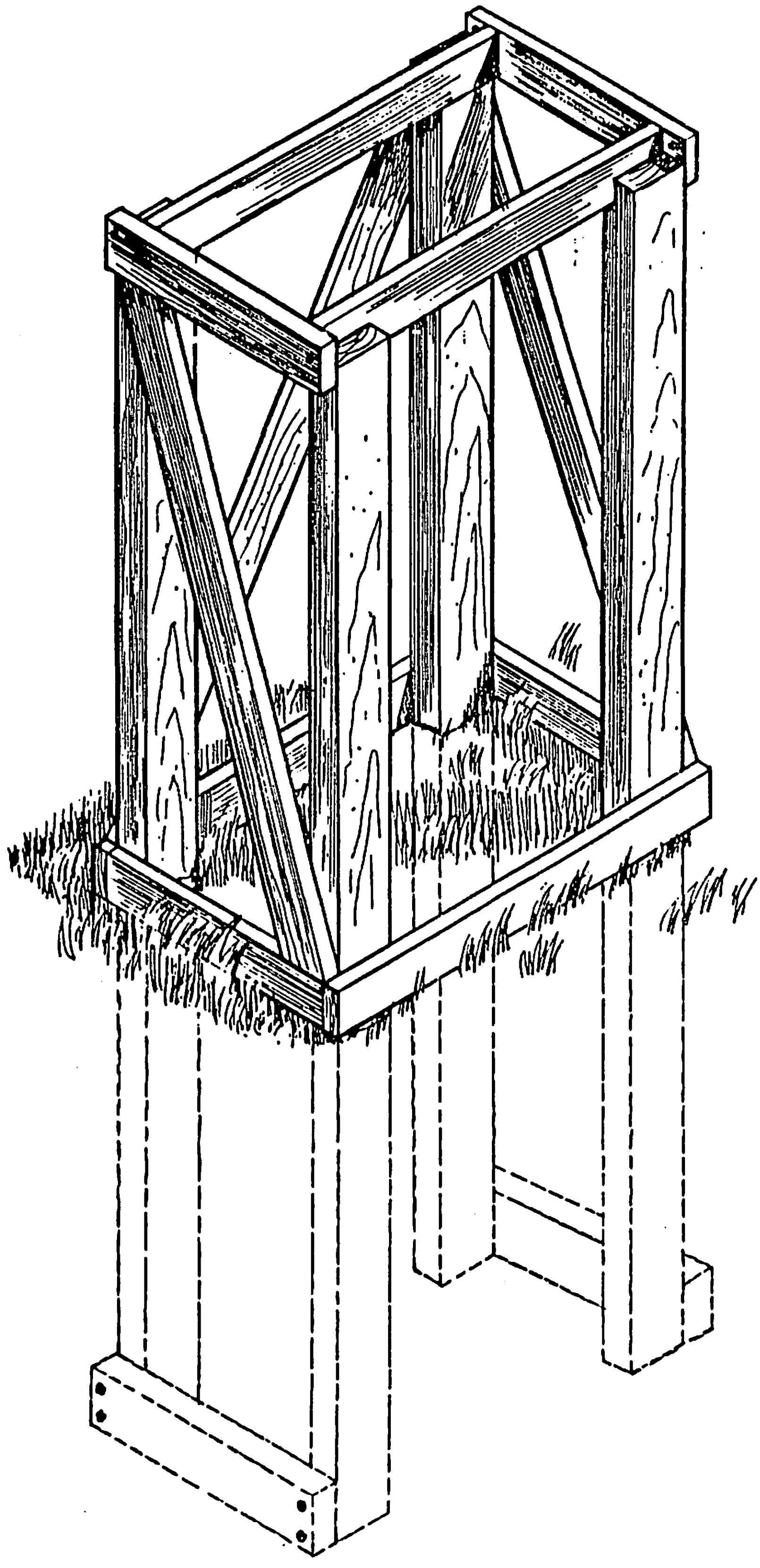

Fig. 2. Details of assembled stand inserted in the ground.