BI-MONTHLY RESEARCH NOTES

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BI-MONTHLY
RESEARCH NOTES

A selection of notes on current research conducted by the Canadian Forestry Service, Department of the Environment

BOTANY

Survival and Height Growth of Norway Spruce in Central Manitoba.—In the spring of 1963, 12 provenances of Norway spruce [*Picea abies* (L.) Karst.] (Table 1) were planted at Riding Mountain to learn which were most promising for use in central Manitoba.

Planting sites were prepared in the summer of 1962 by cutting stands of scattered white spruce and aspen, removing the hazel understory with a bulldozer, and exposing the mineral soil. The topography was gently rolling and each block was planted on a knoll. The parent soil materials were calcareous clay-loam tills with pH 7.7. Fresh sites predominated, but moderately moist soils also occurred.

The trial, consisting of eight randomized blocks each containing one nine-tree plot from each of the 12 provenances, was planted at an 8-ft-quare spacing. The seedlings, 2+1, were obtained from the Petawawa Forest Experiment Station in 1960 and transplanted for 3 years in the nursery at Riding Mountain before the trial was established. Two rows of white spruce [*Picea glauca* (Moench) Voss] were planted around each block, using 2+2 stock purchased from the Manitoba Forest Service. The soil was moist at the time of planting (2-3 May), and the weather was cloudy and cool (max. less than 60 F).

related to seedling height, while damage by snow mold was negatively related to survival ($r = 0.620$, $n = 12$) and tree height ($r = 0.596$, $n = 12$).

The best provenance on the basis of 1970 height was from eight trees selected for frost hardiness at Hudson Place, Ontario (S.2366). The poorest source was from Borrestad, the most southern source from Sweden. Height and survival of the white spruce in 1965 and 1970 were measured and while the data were not analysed, it appeared that the white spruce exhibited better height growth over the 7 years from planting and poorer survival than the six tallest seedlots of Norway spruce. However, the hardy Norway spruce (S.2366) on the fresh site of this trial grew faster than the white spruce after the outplanting, from 1963 until 1965, and this Norway spruce offered a greater possibility in overcoming planting check.

A multiple range test (Table 1) indicates that there were no differences in height in 1970 among the six tallest seedlots. They promise good growth rate and survival and should be suitable for forestation at Riding Mountain. The coefficient of variation ($C\% = s/\bar{x}$) for height growth of individual trees within seedlots shows high variability (27—40%) which greatly reduces the effectiveness of the multiple range test. Seedlings from Borrestad (S.2313) have a low coefficient of variation due to poor survival.

TABLE 1

Source, survival, and height of the provenances of Norway spruce

Source of seed			Petawawa seedlot number	Survival, 1970 %	Height, cm		1970 height			
Place name	Long. °	Lat. °			1965	1970	Coefficient of variation	Least significant range		
Borrestad, Skane, Sweden	E 14	N 56	S.2313	42	52	78	18			....
Ossjo, Skane, Sweden	E 13	N 56	S.2312	68	45	82	34			....
Kaluga, Russia	E 37	N 54	S.2353	86	53	88	27			....
Maltesholm, Skane, Sweden	E 13	N 56	S.2314	57	50	91	42		....	....
Bialystock, Poland	E 22	N 53	S.2289	75	49	93	32		....	....
Vagaiski, W. Siberia	E 65	N 51	S.2354	65	42	95	54		....	....
Bashkiria, Russia	E 57	N 55	S.2350	85	48	103	28	....	....	
Hudson Place, Ontario	W 77	N 46	S.2365	86	55	104	35	....	....	
Bauske Forest Region, Latvia	E 26	N 57	S.2351	88	55	104	40	....	....	
Minsk, Russia	E 26	N 54	S.2352	81	51	105	35	....	....	
Olsztyn, Poland	E 21	N 53	S.2315	68	59	105	34	....		
Hudson Place, Ontario	W 77	N 46	S.2366	79	57	119	37	....		

NOTE: Lots S.2312, 2313 and 2314—Purchased from German seed dealer.
Lots S.2365 and S.2366—From frost hardy trees; 2365 also weevil resistant.

Tree heights were measured immediately after planting in 1963 and in 1965 and 1970. In 1965, trees with snow mold or winter drying were recorded. Differences in the size and condition of the Norway spruce from various seed sources were apparent at the time of planting, although all stock had been grown in the same nursery.

Analysis of variance was applied to assess tree-height, survival, snow mold, and winter drying with respect to seed source. Differences in mean height and snow mold incidence were statistically significant at the 1% confidence level, and differences in survival were significant at the 5% level.

Snow mold damage and winter drying occurred each winter after planting. Winter drying was positively, although weakly,

This plantation will be maintained and remeasured at periodic intervals to determine if Norway spruce will continue to grow well under Prairie conditions. Selected surviving trees will be of considerable value in developing superior strains of Norway spruce in the future.—K. J. Roller, Forest Research Laboratory, Fredericton, N.B.

ENTOMOLOGY

Delayed Budbreak and Spruce Budworm Survival. — A laboratory experiment on the effect of delayed budbreak on establishment survival of the spruce budworm [*Choristoneura fumiferana* Clemens] was described by Eidt and Little (J. Econ. Entomol. 63:1966-1968, 1970). They described the effects of asynchrony of larvae and trees expressing asynchrony as the difference in time of removal from cold storage of larvae and host trees. Development rates of balsam fir trees vary considerably and a temporal scale is not the best one for expressing tree development. Development rates of buds vary within trees and we are interested in the relationship between individual budworms and buds, as well as that between populations of budworms and trees. Therefore, in a refined experiment, we have made observations in terms of bud development.

In late January, 120 potted 4-year-old balsam fir seedlings were brought indoors and stored at 32 F. On each of the next 20 consecutive days, six trees constituting six replicates were moved from 32 F to room temperature (ca. 70 F). The pots were placed in trays of water so that irrigation was constant among trees and so that larvae escaping from the trees would be trapped in the water. The photoperiod was extended to 16 hours with fluorescent and incandescent lights.

On the 22nd day, two late third- or early fourth-instar larvae were placed on each tree and were watched until they became established. These larvae had been reared on artificial diet at 71 F for the first part of the feeding stage to by-pass the leaf-mining stage. At this time, in general, trees that had been at room temperature for 6 days or less had no obvious bud development, trees at room temperature for 11 or more days had some green and broken buds. Specifically, on 22 trees the most advanced bud was open, on 16 broken, on 12 green, on 12 swollen, and on 58 trees there was no bud development. Buds were said to be "swollen" if any swelling was detectable, "green" when this color could be seen through the scales using a 10X hand lens, "broken" when the bud scales separated and exposed leaf tissue, and "open" when the needles were separated by their own diameters. The trees were examined twice to determine larval survival. It was not essential that all replicates be examined the same day, nor was it possible, thus the times of the examinations were:

Replicate	1	2	3	4	5	6
Day of first examination	5	6	7	8	8	8
Day of second examination	9	12	13	13	13	13

The best survival at both examinations was on trees which initially had broken buds and the poorest was on trees which initially had no bud development (Fig. 1). At the end of the experiment, successful larvae were in the late fifth or sixth instar. Survival on trees with open buds was lower than on those with broken buds, indicating that such trees may have developed beyond the most favorable stage.

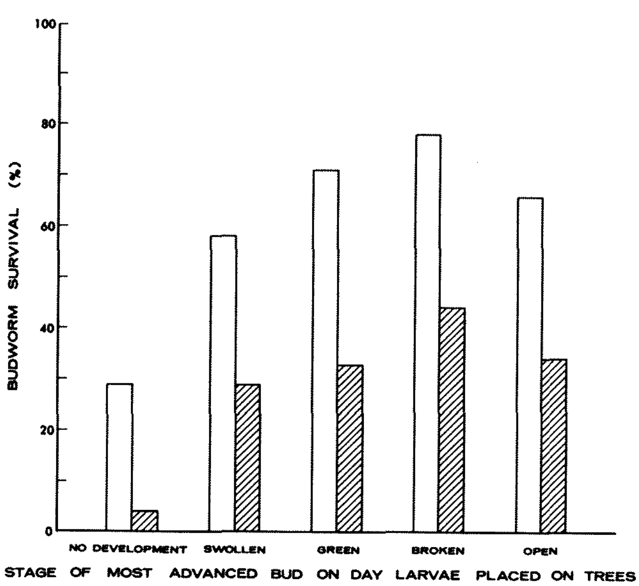

FIGURE 1. Survival of spruce budworms on balsam fir trees at five stages of bud development. First examination, open bars; second examination, hatched bars.

The 78% survival on favorable trees was higher than in the work of Eidt and Little (*loc. cit.*) but the larvae, as before, did not orient to opening buds. They settled in a variety of sites, including buds and, except for a few that never became established, the larvae spun up in silk before attempting to feed. The reason for the choice of site is unknown but a thigmotropic mechanism is suspected. When, as a consequence of feeding or any other reason, the site became unsuitable the larva again had to seek a feeding site with all the attendant hazards.

When the survival data are considered against a time scale, results consistent with those obtained by Eidt and Little (*loc. cit.*) are obtained (Fig. 2). Although trees were brought from storage daily in this experiment, survival data were combined into five lots of 4 days each to facilitate comparison. The stage where synchrony should have occurred for the rearing temperatures used was not identified because the larvae had been started on artificial diet, but it probably occurred on or near trees removed from storage on the sixth day, most of which had green buds when the larvae were placed on them. A drop in survival on the trees which were out of storage the longest is also evident and is remarkably consistent with the results shown in Fig. 1 where development is expressed in terms of bud condition.

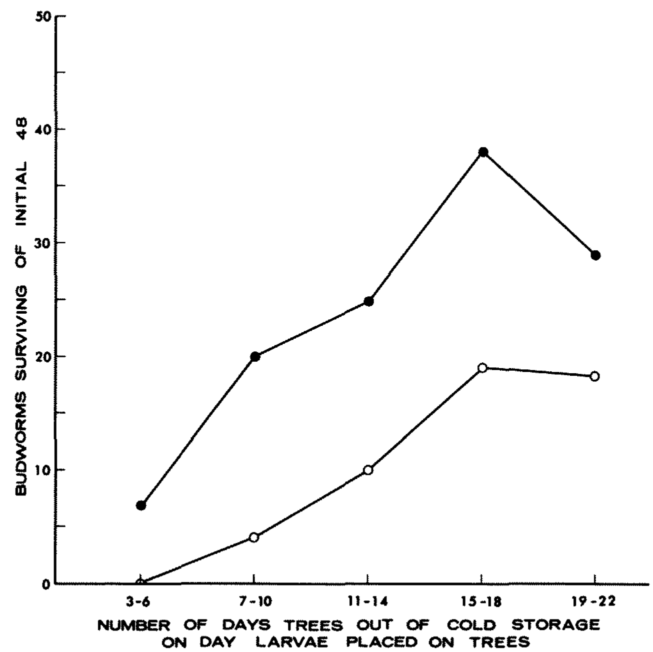

FIGURE 2. Establishment survival of spruce budworms on balsam fir trees removed from cold storage at different times. First examination (●), second examination (○).

Notwithstanding the role of staminate flowers (Blais, Can. J. Zool. 30:1-29, 1952), the implications of these observations are that asynchrony between the trees and the budworm does effect mortality. This seems to occur if the buds are too far advanced or if they are retarded. Anything that affects synchrony, whether natural or artificial, therefore must affect budworn survival.—D. C. Eidt and Margaret D. Cameron, Forest Research Laboratory, Fredericton, N.B.

FOREST PRODUCTS

Lignins of Sapwood and Mineral-Stained Maple—The dark color of protection wood or mineral-stained areas of sugar maple [*Acer saccharum* Marsh.] cannot be removed by any of the common solvents which will remove extractives (Levitin, Bi-mon. Res. Notes 26:57, 1970). The color is considered to be caused by the presence of oxidized polymerized polyphenols (Hillis and Inoue, Phytochem. 5:483-490, 1966; Gagnon, Can.

J. Bot. 45:2119-2123, 1967;Good, Basham and Kadzielawa, Can. J. Bot. 46:27-36, 1968) which are insoluble because of their high molecular weights or because they are intimately bound with the wood. It is also possible that the lignin may be changed to a darker-colored material.

In order to determine if the lignin of heavily stained maple differed in any way from the lignin of clear sapwood, milled-wood lignin (MWL) was isolated from solvent extracted sapwood and mineral-stained wood by the method of Brownell (Tappi 48: 513-519, 1965). The lignins were highly purified by dissolution in dry dioxane, extraction with hot water, precipitation from 90% acetic acid, and finally by reprecipitation from solution in 1,2-dichloroethane-ethanol (2:1) by the addition of ether (Bjorkman, Svensk Papperstidn. 59:477-485, 1956).

Approximately 55% of the total lignin in the wood was isolated as pure MWL, soluble in dry dioxane (Fig. 1). It was immediately evident that there was no difference in the color of the MWL of sapwood or stained wood when redissolved. The lignin-carbohydrate fraction of the stained wood, which is soluble in dioxane-water (9:1), was slightly darker than the comparable sapwood fraction, but the main difference in color was concentrated in the insoluble fraction which was largely carbohydrate with some high-molecular-weight lignin. Thus the color was not associated with the lower-molecular-weight lignin which was isolated by the ball-milling technique.

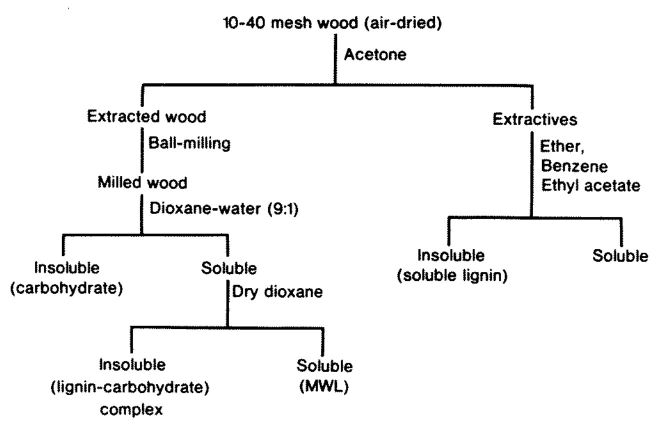

FIGURE 1. Isolation of lignin fractions.

Analyses of the MWL did not indicate the presence of chromophores or precursors of staining material in the stained-wood lignin. Ultraviolet, infrared and NMR spectra of these lignins indicated no significant difference in phenolic content (Table 1). The higher carbon and methoxyl contents of the stained-wood MWL (Table 2) also indicated no increased phenolic content. The presence of more syringyl groups in the stained-wood lignin, indicated by its higher methoxyl content, would have no bearing on the darker color of the wood.

TABLE 1
Ultraviolet absorption data of lignins from maple

Sample	E_{cm}% in neutral solution		△ E difference spectra	
	279 nm	253 nm	296 nm	362-375 nm
MWL sapwood	145.3	77.4	20.6	47.7a
MWL stained wood	140.6	85.8	27.6	45.9b
Soluble lignin, sapwood	131.3	128.8	57.2	38.0c
Soluble lignin, stained wood	127.2	106.0	39.3	46.0c

a—measured at 362 nm maximum. b—measured at 370 nm maximum. c—measured at 375 nm maximum.

Lignin samples were also isolated from the acetone-soluble extractives of air-dried unmilled sapwood and stained wood after extracting the acetone solubles successively with ether, benzene and ethyl acetate (Fig. 1). The remaining material from stained wood still contained phenolic substances which were then removed by column chromatography. These substances, not found in sapwood, were largely responsible for the larger yield of extractives from stained wood, and might be precursors of the staining material in the wood. The ultraviolet and infrared spectra of the remaining lignins again indicated no significant differences which would affect the color of the wood.

TABLE 2
Analyses of lignins from maple

Sample	%C	%H	%O	$\%OCH_3$
MWL sapwood	58.12	5.61	36.27	19.9
MWL stained wood	58.93	5.57	35 50	20.9
Soluble lignin, sapwood	60.47	5.60	33.93	18.5
Soluble lignin, stained wood	58.36	5.41	36.23	17.7

Although the acetone-soluble lignins were similar to each other they did differ from the milled-wood lignins. One of the most significant differences, indicated by the infrared absorption at 1715 cm^{-1}, was the presence of conjugated ester groups which are found in softwood lignins; the milled-wood lignins had peaks at 1735 cm^{-1} which represented non-conjugated acetyl groups commonly found in hardwood MWL (Sarkanen, Hou-min Chang and Allan, Tappi 50:583-590, 1967). Lower methoxyl and higher phenolic hydroxyl contents were found in the soluble lignins. They also had lower conjugated carbonyl contents than the MWL as shown by the lower peaks at 1665 cm^{-1}. The higher carbon and lower oxygen content of the sapwood soluble lignin (Table 1) may be due to the low conjugated carbonyl content.

Since the milled-wood lignins of the sapwood and stained wood were similar in color and chemical composition, the dark color of the stained wood cannot be attributed to the lignin and is probably due to phenolic materials which are not soluble in the organic solvents. The soluble lignins differed from the milled-wood lignins, but again the lignins from sapwood and stained wood were similar. Phenolic products found as impurities with the soluble lignins of stained wood might be precursors of the staining material. This possibility is being investigated.—N. Levitin, Forest Products Laboratory, Ottawa, Ont.

MENSURATION

The Use of Current Stand Characteristics in the Prediction of Growth.—The diameter of the tree of mean basal area, called the quadratic mean diameter, when plotted against a mean stand height, e.g. Lorey's height, shows much less scatter than when plotted against either stand age or site index (Evert and Lowry, Pulp Pap. Res. Inst. Can., Woodlands Rep. WR/26, 31 p., Oct., 1970. Figs. 6,7,8). This feature has been applied in yield table construction in Great Britain, where all the important stand characteristics are plotted against the mean top height (Hummel and Christie, Rep. Forest, Res., HMSO London, March, 1957). Most of the residual variation in the quadratic mean diameter at a given height can probably be related to the number of trees per unit area (Fig. 1). Figure 1 is based on data for thinned stands of Norway spruce [*Picea abies* (L.) Karst.] (Carbonnier, Svenska Skogsvardsföreningens Tidskrift, hafte 5, 463-476, 1957; Stiell and Berry, Dep. Forest, Rural Develop. Publ. No. 1200, 15 p., 1967). However, by combining Lorey's height (h_L), stand age (T), and number of trees per hectare (N) in one independent variable expressed as $\sqrt[4]{h_L T/N}$, the quadratic mean diameter (d_g) plots close to a straight line (Fig. 2). This relationship maybe expressed in terms of a regression equation:

$$d_g = -0.8 + 7.207\sqrt[4]{100 h_L T/N}$$

with coefficient of determination $R^2 = 0.995$ and standard error of estimate SE = ±0.5 cm.

The high correlation indicates that the equation can give accurate predictions of both the quadratic mean diameter and its increase, and, consequently, the basal area per acre and its increase, provided height/age relationship of the stand is known. The predicted basal area per acre will be gross growth in both managed and unmanaged stands unless mortality can be predicted at an acceptable level of accuracy.

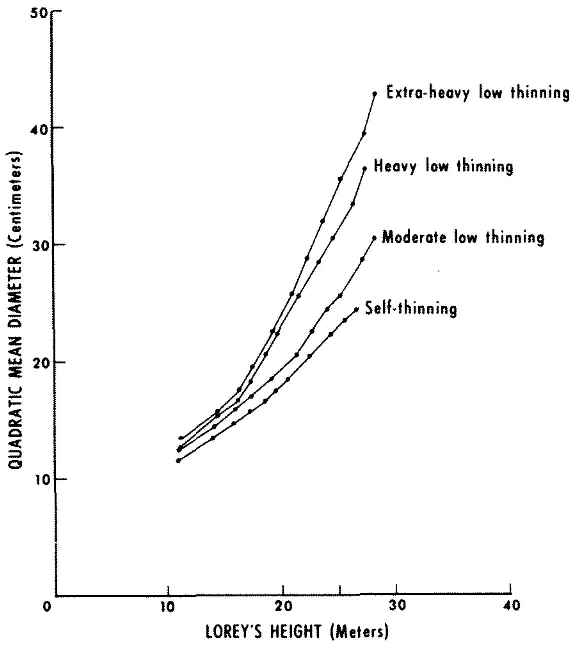

FIGURE 1. The relationship between the quadratic mean diameter and the mean height by thinning grades.

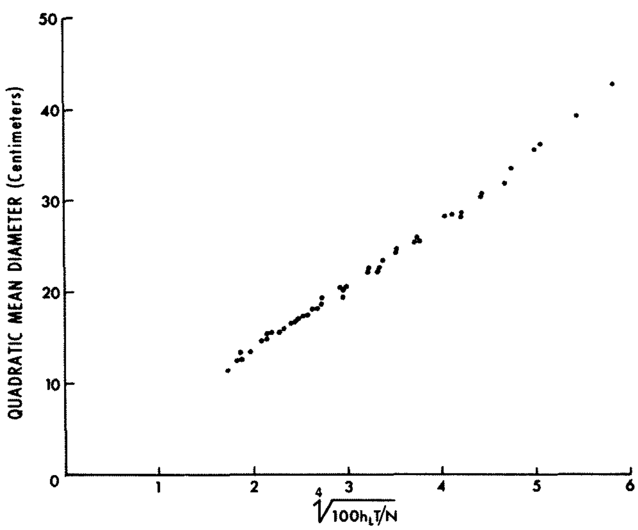

FIGURE 2. The relationship between the quadratic mean diameter and the height/age/spacing expression.

The equation was tested on data from permanent sample-plot records for thinned stands of Norway spruce from Norway (Eide and Langsaeter, Meddelelser fra det Norske Skogforsoksvesen, Bind VII, hefte 24-26, 355-500, 1941). The test data satisfied two conditions: (1) height over age data were nearly identical to Carbonnier's data, and (2) for a given age, the number of trees per hectare was within the range of his data.

The results of this test are shown in Table 1. The errors in predicting the diameters with the equation range from an underestimate of 0.8 to an overestimate of 2.9 cm; the errors in predicting the diameter increment range from an underestimate of 0.5 to an overestimate of 1.4 cm.

These results are very promising and may well justify further studies of the use of current stand characteristics for growth prediction purposes. The form of the regression equation may even be more useful than its direct predictive potential because, while the constants and regression coefficients would change for different species and sites, the form of the independent variable $\sqrt[4]{h_L T/N}$ could have general application in much the same way as d^2h as often used in tree volume equations.—F. Evert, Forest Management Institute, Ottawa, Ont.

SILVICULTURE

Stemflow In A Young Stand of Aspen Suckers.—This report presents results of a stemflow study in a 5-year-old, dense, sucker stand of largetooth aspen [*Populus grandidentata* Michx.]. The purposes of this study were to determine the relation of stemflow volume per tree to gross rain per storm, to determine the proportion of gross rain reaching the ground as stemflow, and to derive an equation to predict rain equivalent of stemflow from gross rain for use in other studies of water relations of this sucker stand.

The sucker stand, at Petawawa Forest Experiment Station, developed after a fire in May 1964. In October 1968, there was an average of 28,900 stems per ha, ranging in diameter at breast height from 1 to 5 cm. Average basal area was 13.1 m^2 per ha. Average tree height was 4.6 m and average depth of the leafy canopy was 2.0 m. The site was a gently rolling plain about 150 m above sea level. Soils were non-calcareous fine sand (about 22 cm deep) of deltaic origin re-worked by wind, overlying silt. Regional climate is continental, local mean annual precipitation is 78.8 cm and local mean annual temperature is 4.2 C.

Nine trees were selected for study, one from each diameter class of 0.6 cm. Stemflow channels were attached to the stem about 25 cm above ground surface, and connected to plastic containers. Channels were about 1 cm wider than the stems. Gross rain was measured in three M.S.C. rain gauges in a clearing about 45 m from the selected trees. Diameter of the clearing was about 13.8 m. The orifices of the gauges were 64.5 cm^2 in area and were 76 cm above ground surface (i.e. above splash height).

Stemflow and gross rain measurements, made only while the trees were in leaf, began 4 Aug. and ended 28 Oct. 1968. Measurements of stemflow and gross rain were made after each storm. A storm was defined as any rainy period separated from any other rainy period by at least 6 hours and storm size was the amount of gross rain measured from a storm. During the study there were 18 storms ranging in size from 1.0 to 18.9 mm (total 178.8 mm), and stemflow volumes ranged from a trace to 1.3 l per tree per storm.

The relation between stemflow volume per storm and gross rain per storm was expressed for each tree separately by the general rectilinear equation

$$S_t = a + b\,P \qquad \text{liters per storm} \qquad (1)$$

where S_t = stemflow per storm in liters; P = gross rain per storm in mm; and *a*, *b* are equation coefficients.

There was no evidence of curvilinearity on graphs of plotted data. Values of r^2 for the separate equations for each tree ranged from 0.51 to 0.94, and were significant at $P = 0.005$. Values of standard errors of estimated stemflows per storm for mean storm size, expressed as percentage of mean stemflow per storm, ranged from 4.4–21.6%.

A single equation was calculated to interpolate between measured storm sizes and measured tree basal areas. To do this the *a* and *b* coefficients computed after question (1) for each tree were separately expressed as statistical functions of basal area per tree according to the equations

$$a = c\,BA \qquad \text{liters per storm} \qquad (2)$$

$$b = d\,BA \qquad \text{liters stemflow per mm gross rain} \qquad (3)$$

where *a*, *b* are the regression coefficients from equation (1), BA = basal area per tree in cm^2 and *c*, *d* are equation coefficients.

For equation (2), $c = -0.0044$, $r^2 = 0.69$, standard error of $c = 0.0005$, and $n = 9$. For equation (3), $d = 0.0038$, $r^2 = 0.86$, standard error of $d = 0.0005$, and $n = 9$.

Then the functions for *a* and *b* were substituted in equation (1) and the general stemflow equation for the sucker aspens is

$$S_t = BA(-0.0044 + 0.0038\ P) \text{ liters per tree per storm} \quad (4)$$

where the symbols are as before.

Total volume of stemflow per hectare was easily computed for each storm size using equation (4) and the average number of stems per hectare in each diameter class. Then, total volume for each storm size was converted to mm equivalent rain. Computed values of stemflow in mm rain equivalent, were plotted over gross rain per storm and the equation representing this relationship is

$$S = -0.058 + 0.050\ P \quad \text{mm per storm} \quad (5)$$

where S = stemflow per storm in mm per storm and
P = gross rain per storm in mm.

With this equation, rain equivalent of stemflow in the sucker stand can be computed for any amount of gross rainfall.

From the coefficients in equation (5), it is apparent that stemflow in terms of rain equivalent is nearly 5% of gross rain. This percentage is higher than that for mature largetooth aspen in a nearby forest reported by Clements (Can. J. Forest Res. *1*:20-31, 1971). In the mature forest, stemflow amounted to 1.5 to 2.2% of total June-to-September gross rainfall.

Although it is a small proportion of gross rain, stemflow may play a significant role in the sucker trees' water and nutrient cycles. Carlisle *et al.* (J. Ecol. *55*:615-627, 1967) found that stemflow had a high nutrient concentration. If stemflow from the aspen suckers in this study also have a high nutrient concentration, then nutrients and stemflow would be readily available to fine feeding roots which arise adventitiously on aspen suckers at the stem base or near the stem base on the parent root (Maini, *In* Growth and Utilization of Poplars in Canada. Dep. Forest. Rural Dev., Dep. Publ. No. 1205, pp. 20-69, 1968).

Availability of stemflow to feeding roots may be further demonstrated: 5% of gross rain enters the ground at the base of trees whose combined basal area is 13.1 m^2/ha or about 0.13% of ground surface area. This method of water entry into the soil represents a substantial funneling of rain to the feeding roots.—John R. Clements, Petawawa Forest Experiment Station, Chalk River, Ont.

(*Continued from back cover*)

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