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# METHODS FOR ESTIMATING STANDING CROP IN *POPULUS* FORESTS OF ALBERTA

by

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# METHODS FOR ESTIMATING STANDING CROP IN *POPULUS* FORESTS OF ALBERTA

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E. B. Peterson[1]

## INTRODUCTION

Several published summaries on methodology for biomass and net primary productivity estimates are available, the most notable of which are by Lieth (1962), Ovington (1962), Olson (1964), Bray and Gorham (1964), Eckardt (1965, 1968), Ecological Society of America (1967), and Newbould (1967), but none of these deals in detail with ways in which one may partition and sample the standing crop of trees or forests. This report records the methodology that evolved in the 1968 and 1969 field seasons during studies of above-ground standing crop in the tree component of *Populus*-dominated ecosystems in Alberta.

The methods reported below represent a generalized sequence of steps that were used in data collection for various specific research objectives that included:

(a) Determination of mathematical relationships between fresh weight, dry weight, surface areas, and other more readily measurable parameters of *Populus* trees;

(b) Determination of phenotypic variation within clones and genotypic variation between clones for total above-ground standing crop and for relative proportions between *Populus* standing crop components such as stem, bark, live branches, dead branches

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and foliage;

(c) Description of the production structure of Populus forests and determination of the magnitude of age, genotype, and geographic influences on production structure.

Although the criteria for stand and tree sample selection were determined by the clonal nature of the Populus species, the general methodology performed on sample trees may be taken as an example of a detailed, yet inexpensive, approach to estimation of standing crop in any broad-leaf deciduous forest. To assist others in planning similar research, a summary of manpower, equipment, and time requirements is provided for the specific field methods described below. This record of methodology is also pertinent to the objectives of the Mensuration of the Biomass Working Group, Section 25, I.U.F.R.O.(Young, 1969).

## SELECTION OF SAMPLE STANDS

Generally, it is necessary to obtain data from many different genotypes to characterize a population. In vegetatively reproducing species such as aspen (Populus tremuloides Michx.) and balsam poplar (Populus balsamifera L.), many stems in a given stand may represent the same genotype. Hence, to sample genotypic variation in various features of production structure, stands to be harvested were selected from amongst those that contained two or more readily recognizable clones.

Sample plots were located only in stands that were judged to be fully stocked on the basis of a canopy coverage that contained no distinct openings. At a given location, site variation was minimized by placement of two or more sample plots as closely together as possible in places where there were contacts between two or more recognizably different clones. Under these circumstances, plot comparisons represent genotypic comparisons for any given location. Where topographic variability was judged to be great enough to potentially introduce a site influence into the clone-to-clone comparisons, then one plot was located so that it contained stems (ramets) from two adjacent clones and data were accordingly stratified to allow clone-to-clone comparisons within one plot.

## PLOT SIZE AND SELECTION OF SAMPLE TREES

Preliminary examination of intraclonal variation in size and spacing of stems, and trials with various plot sizes and methods of harvest-tree selection, led to acceptance of the following standards of sampling within a clone.

In mature stands, arbitrarily defined as 40 years old or more, a stem-diameter tally was obtained for all ramets within a sample plot of 300 $m^2$. At least one stem from each 2.5 cm (1-in) d.b.h. class was selected for detailed standing crop harvest as described in the next section of this report. A 100 $m^2$ sub-plot (approx. 1/40 acre) was located within the 300 $m^2$ tally plot in such a way as to include the maximum range of diameter classes in the clone. All stems on the 100 $m^2$ plot that were not subjected to the detailed harvest were cut at ground level and partitioned in a less detailed way for determination of plot aggregate fresh weight of the following components: live stems down to a 2-cm diameter outside bark; live branches greater than 2-cm diameter outside bark; live branches less than 2-cm diameter outside bark together with current-year twigs and foliage; attached dead branches; dead standing ramets. Thus, all above-ground components of all stems on 100 $m^2$ were weighed for each plot location. This standing-crop estimate obtained from the weight of all above-ground components of all ramets on the 100 $m^2$ provided a check for an alternative sampling approach that involved summation of fresh weight standing crop for each tree harvested in detail multiplied by the number of trees in each specific diameter class on the 100 $m^2$.

In immature stands between the ages of 10 and 40 years, a diameter tally was obtained for a plot of only 100 $m^2$. As in mature stands, a detailed harvest was carried out for at least one stem from each 2.5 cm d.b.h. class, and all remaining stems on the 100 $m^2$ plot were partitioned and pooled in an aggregate-harvest weighing by the same components as described above.

In stands between the ages of 5 and 10 years, a plot of 30 $m^2$ was used within a clone. Detailed sampling of individual ramets and aggregate harvesting of all remaining ramets on the 30 $m^2$ plots were carried out as for the 100 $m^2$ plots.

In stands of suckers less than 5 years old, standing crop was determined by an above-ground harvest on 20 individual 1-$m^2$ quadrats located at regular intervals along grid lines within the clone or stand. Standing crop of suckers was partitioned into only the two components of foliage and woody material.

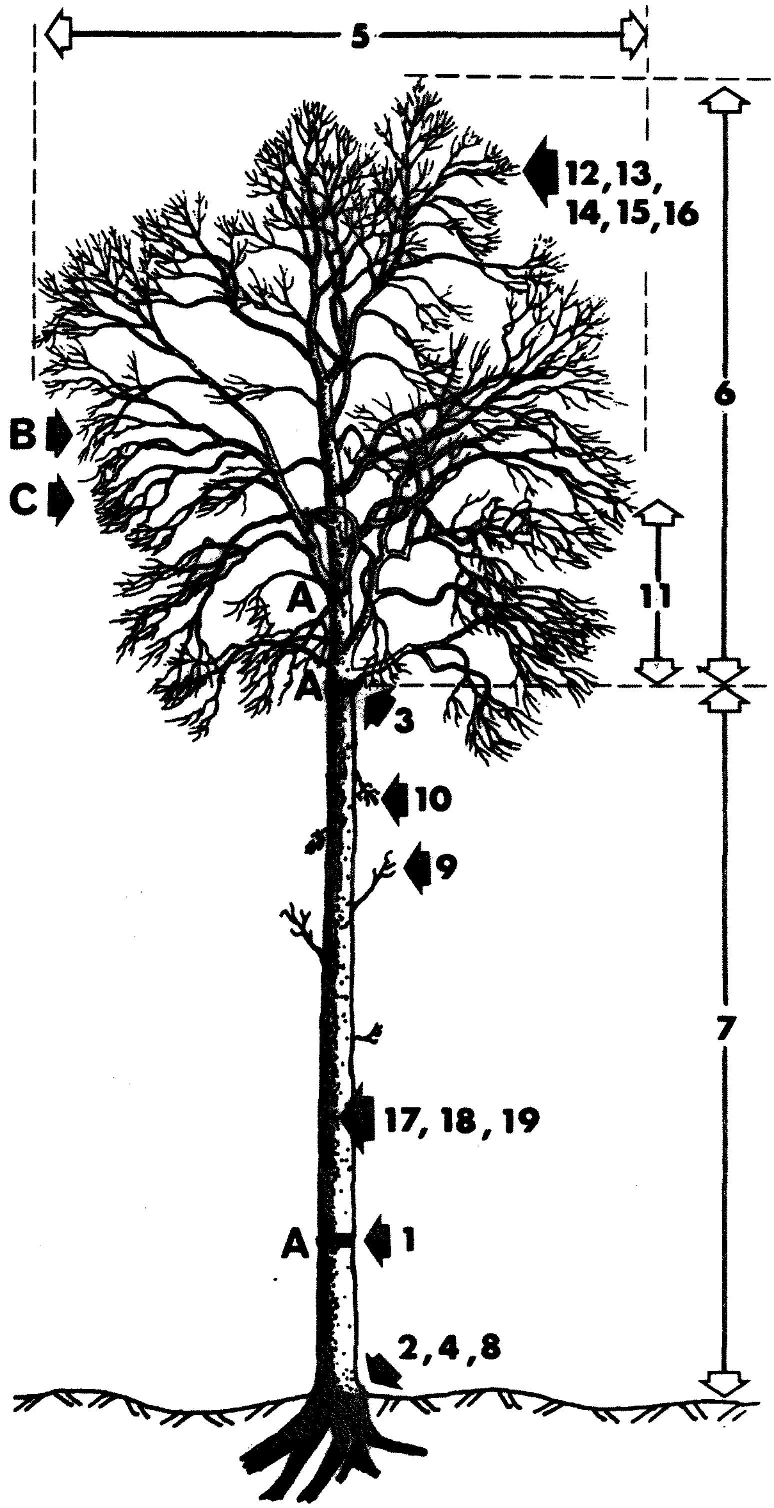


Figure 1. Location of measurements and samples. Legend in text.

## DETAILED HARVEST OF SELECTED TREES

Samples and measurements obtained in the field from each tree harvested in detail are summarized in Figure 1 and in the following legend:

I. Single measurements per tree:

1 - Diameter at breast height outside bark, cm

2 - Stump diameter outside bark, cm

3 - Diameter at crown base outside bark, cm

4 - Stump height, cm (if above litter layer)

5 - Crown width, dm

6 - Crown depth, cm

7 - Height to lowest leaf-bearing branch, cm

8 - Where possible, field count of stump age

9 - Fresh weight of dead (non-leaf bearing) branches, dg

10 - Aggregate fresh weight of branchlets less than 1 cm diameter, plus epicormic shoots (in the case of P. balsamifera), plus breakage not identifiable with any specific large branch, dg. A separate fresh weight of wood waste, as from the saw undercut, was recorded for each tree.

II. Multiple measurements per tree:

FOR EACH LEAF-BEARING BRANCH

11 - Vertical distance of branch attachment above crown base, cm

12 - Diameter-outside-bark of branch at stem and 2.5 cm from stem, bark thickness at branch base, branch angle from axis of stem and quadrant of tree on which branch is located

13 - Count of number of long shoots and/or number of leaf bunches. (For each clone, average number of leaves per long shoot and per leaf bunch were determined from previous subsampling)

14 - Fresh weight of branch wood (with bark) over 2 cm diameter, dg

15 - Fresh weight of branch wood (with bark) under 2 cm diameter plus current-year twigs and foliage, dg

16 - Length of branch in straight line from branch base to branch terminal, dm

<u>FOR EACH LOG SEGMENT OF MAIN STEM</u>

17 - Log length to 3-in top diameter and to 2-cm top diameter, cm

18 - Basal diameter of log outside bark, cm

19 - Fresh weight of log (with bark), dg

III. Subsamples for determination of: fresh weight-to-dry weight ratios; wood dry weight-to-bark dry weight ratios; laboratory examination of ring width, stump age, and bark thickness; foliage area and average number of leaves per long shoot or per leaf bunch.

A. Fresh weight of 3 wood-plus-bark disc subsamples, g (from breast height, crown base, and base of largest diametered branch in crown).

B. Fresh weight of 50 leaf-bunches including current-year twigs, g (25 leaf-bunches in the case of *P. balsamifera*).

C. Subsample of 12 leaf-bunches per clone for leaf area determination (two leaf-bunches were taken from the base and two from the terminal portion of a branch near crown base; two from the base and two from the terminal of a branch in mid-crown; and two from the base and two from the terminal portion of a branch at the top of the crown).

Data for the above categories were recorded directly on 80-column coding sheets suitable for processing by a key-punch operator. The file of data fields, which represent a combination of field and laboratory measurements for each tree, is shown in Appendix I.

It is beyond the scope of this report to describe the reason for each specific measurement or the hypothesis being tested by each specific measurement. Such discussion will be included in the analyses of results in ensuing reports.

## MAN-DAY REQUIREMENTS FOR FIELD SAMPLING PROCEDURE

Man-day requirements were recorded from 23 May 1968 to 25 September 1968, during which standing-crop sampling was carried out in 22 different clones on 18 sample plots located in four locations in Alberta. A total of 243 trees bearing 4250 live branches were harvested and measured in detail and an additional 309 trees were harvested by the aggregate method on the sample plots.

A total of 60 man-days were required for travel time, stand and clone selection, sample plot establishment, and diameter tallying and 20 man-days were required for the harvest and aggregate weighing of 309 trees. About 125 man-days were required for the detailed measurement of 243 sample trees ranging in diameter from 1.0 in (2.5 cm) to 12.4 in (31.5 cm) and with a diameter-class sampling distribution as shown in Table 1.

## LABORATORY HANDLING OF WOOD, BARK, AND FOLIAGE SUBSAMPLES

Three types of subsamples, for which field-fresh weights were available, were measured and weighed in the laboratory:

(1) Two wood and bark discs, 1 to 2 in thick, from breast height and crown base;

(2) One wood-and-bark subsample from the base of the largest diametered branch in the tree crown;

(3) Fifty leaf-bunches (25 bunches in the case of *P. balsamifera*) including current year twigs from the largest-diametered branch in the tree crown.

Laboratory procedures for these three categories of subsamples were as follows:

### Stem Disc Subsamples

As a check against the field measurement, diameter-outside-bark was determined as the mean of two diameter measurements at right angles to each other. Bark thickness was recorded as the mean of single bark

Table 1. Man-day requirements for detailed standing-crop sampling by diameter classes for 243 Populus trees harvested in 1968.

| D.b.h. class in. | D.b.h. class cm.(approx.) | No. trees harvested | Man-days required | No.trees sampled a day per 2-man crew |
|---|---|---|---|---|
| 1.0-1.9 | (2.5-5.0) | 22 | 3.5 | 12 |
| 2.0-2.9 | | 29 | 6.5 | 9 |
| 3.0-3.9 | | 50 | 20.0 | 5 |
| 4.0-4.9 | | 45 | 18.0 | 5 |
| 5.0-5.9 | | 29 | 14.5 | 4 |
| 6.0-6.9 | | 22 | 14.5 | 3 |
| 7.0-7.9 | | 16 | 10.5 | 3 |
| 8.0-8.9 | | 12 | 12.0 | 2 |
| 9.0-9.9 | | 8 | 8.0 | 2 |
| 10.0-10.9 | | 7 | 14.0 | 1 |
| 11.0-11.9 | | 2 | 4.0 | 1 |
| 12.0-12.9 | (30.0-32.5) | 1 | 2.0 | 1 |
| TOTAL | | 243 | 127.5 | |

thickness at three points on the circumference of the disc. Because of rapid shrinkage upon drying, this procedure was later replaced by a method of field measurement of bark thickness as shown in the format of the data-coding forms (Appendix I).

Next, the bark was removed from each disc and the bark and corresponding wood subsamples were placed in tinfoil plates and oven-dried to a constant weight at 105°C. Stem-disc subsamples required from 24 to 96 hr to reach a constant weight at 105°C, depending upon the size of the wood disc. Bark was readily separable from the wood from May until the end of July; after July bark could be easily peeled from the discs if they were soaked in water for a few hours. After 600 samples of various diameters from 200 different trees had been analysed for wood dry weight-to-bark dry weight ratios and for bark thickness, a satisfactory regression was established to allow prediction of these parameters on future samples without laboratory separation of bark from wood.

A radial wood block, approximately 2 cm x 2 cm and extending along the average radius of the disc from cambium to cambium, was sawn from the breast-height disc. These blocks, one from each sample tree, were stored for microscopic examination of ring width and tree age.

Heartwood decay near the base of the tree and occasional splitting of the basal portion of the stem during felling sometimes made it impossible to obtain an unbroken basal disc. Therefore, the laboratory aging procedure was done on the breast-height disc. In stands of sucker origin, where first year sucker height growth may be as great as 1m, age determined at breast height is not markedly different from that at the tree base.

## Branch Subsamples

Branch subsamples were treated similarly to the stem subsamples except that no branch diameter or branch bark thickness measurements were taken in the laboratory. Branch age was recorded, where possible, by examination with a dissecting microscope. Branch subsamples were more difficult to debark and required longer periods of drying to achieve constant weight than did the stem subsamples.

## Foliage Subsamples

The entire subsample of 50 or 25 leaf-bunches per tree was oven-dried at 105°C for 6 to 8 hr. The oven-dry sample was transferred directly from the oven to a top-loading balance and weighed before the rapid uptake of ambient moisture caused an increase in weight.

From a separate subsample of 12 leaf bunches from each clone, various methods of leaf area determination were tested. An electric area calculator with a digital readout, as listed under equipment in Appendix II, was finally adopted because of its great accuracy, moderate efficiency in terms of time requirement, and the adaptability of its transparent grid to area determination of either fresh leaves or pressed leaves. Leaf area (one surface only) was recorded for each leaf in the subsample of 12 leaf-bunches from each clone. The average number of leaves per bunch was frequently around 6; thus, the estimate of average leaf area for a clone is based on area measurements of about 70 leaves per clone.

## COMPUTATIONS

Although many specific computations are possible from the various field and laboratory measurements described above, following are some examples of intermediate variables that were computed for each sample tree:

- total fresh weight of stem, dg
- total fresh weight of pulpable branches (over 2 cm diameter), dg
- total fresh weight of foliage, current twigs and branches under 2 cm diameter, dg
- total fresh weight of dead branches, dg
- total number of leaf bunches, or total number of long shoots, per tree
- average number of leaves per bunch or per long shoot
- average leaf area $cm^2$
- percent to convert fresh to dry weight, stem
- percent to convert fresh to dry weight, branch
- percent to convert fresh to dry weight, foliage
- bark weight as a percent of wood plus bark weight, stem
- bark weight as a percent of wood plus bark weight, branch

Further computations resulted in printout of the following parameters for each sample tree:

- total leaf area on tree (one surface of foliage), $cm^2$
- total fresh weight of tree, above ground, dg
- total water in tree, above ground, dg
- total dry weight of tree, above ground, dg
- dry weight of stem wood, dg
- dry weight of branch wood over 2 cm diameter, dg
- dry weight of branch wood under 2 cm diameter, dg

dry weight of stem bark, dg
dry weight of bark on branches over 2 cm diameter, dg
dry weight of bark on branches under 2 cm diameter, dg
dry weight of foliage and current twigs on tree, dg

These two lists of variables, together with the various measurements for each tree and its branches outlined in the legend for Figure 1, represent the basic data for ecological description and mensurational prediction of production structure in this example of broad-leaf deciduous forest, the details of which will be presented in separate reports.

## CONCLUSIONS

The methods described here provided a satisfactory approach to estimation of standing crop in clonally-distributed species such as *Populus tremuloides* and *P. balsamifera*. In such shade-intolerant forests, where regeneration has generally resulted from a disturbance such as fire, there is a tendency for all ramets in a clone to be of similar age, height, and general form although there may be considerable diameter variation within a clone. These circumstances, plus the morphological uniformity of foliage within a clone, reduced the variability and hence the sampling requirements within a sample plot (clone). According to the clonal sampling requirements prescribed by Zahner and Crawford (1965), the 18 clones studied for standing crop characteristics in 1968 were apparently over-sampled. For proper characterization of *Populus* species, greater numbers of clones and fewer ramets within clones should be sampled.

The methodology selected for detailed partitioning of the above-ground standing crop of Populus is efficient in manpower requirements (Table 1) and equipment requirements (Appendix II). For 243 trees between 2.5 and 31.5 cm d.b.h., detailed standing crop information was obtained for an average cost of about $150 plus 0.5 man-day per tree. This estimate includes the cost of necessary laboratory equipment, but the estimated man-day requirement per tree refers to field-sampling time only and does not include the time required for the laboratory steps and computations.

## ACKNOWLEDGMENT

I am indebted to my technical assistants, Mr. R. D. Erickson and Miss C. Rudolf, for numerous suggestions that resulted in improved methodology and increased efficiency in the field and laboratory procedures.

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## APPENDIX I

For each tree, there is one Card 1, one Card 2, and as many of Card 3 as are required to record all tree branches (two per card). Branch numbering always begins at crown base and the "leader" of the crown is arbitrarily taken as that portion of the main stem with a diameter-outside-bark of 2 cm together with everything supported above that diameter. The last branch card per tree is coded as 99 in columns 78 and 79 and this card ends with the appropriate data for the "leader". However, where the tree possessed epicormic shoots less than 1 cm diameter or where there was branch breakage, aggregate weight and number of long shoots for this "waste" are recorded in the appropriate columns after the "leader" on the last branch card for the tree.

For trees 004 to 218, columns 25, 26, and 27 and columns 63, 64, and 65 record the number of leaf bunches per branch; for 219 to 320 these columns record the number of long shoots per branch.

Data Fields Used for Recording of *Populus* Standing Crop Information

| Name of Variable | Columns Occupied | Decimal Position |
|---|---|---|
| CARD 1: | | |
| X1 Tree number | 1, 2, 3, 4 | XXXX |
| X2 Date | 5, 6, 7 | XXX |
| X3 Species | 8 | X |
| X4 Location | 9 | X |
| X5 Plot number | 10, 11, 12 | XXX |
| X6 Clone number | 13 | X |

APPENDIX I (Cont'd)

| Name of Variable | | Columns Occupied | Decimal Position |
|---|---|---|---|
| X7 | Stump age | 14, 15, 16 | XXX |
| X8 | Diameter at breast height, outside bark, cm | 17, 18, 19 | XX.X |
| X9 | Diameter at crown base, outside bark, cm | 20, 21, 22 | XX.X |
| X10 | Total tree height, cm | 23, 24, 25, 26 | XXXX |
| X11 | Height to first live branch, cm | 27, 28, 29, 30 | XXXX |
| X12 | Crown diameter, dm | 31, 32 | XX |
| X13 | Fresh weight dead branches, dg | 33, 34, 35, 36 | XXXX |
| X14 | Base diameter outside bark, log 1, cm | 37, 38, 39 | XX.X |
| X15 | Length log 1 incl. stump, cm | 40, 41, 42 | XXX |
| X16 | Fresh weight log 1, dg | 43, 44, 45, 46 | XXXX |
| X17 | Base diameter, o.b., log 2, cm | 47, 48, 49 | XX.X |
| X18 | Length log 2, cm | 50, 51, 52 | XXX |
| X19 | Fresh weight log 2, dg | 53, 54, 55, 56 | XXXX |
| X20 | Base diameter, o.b., log 3, cm | 57, 58, 59 | XX.X |
| X21 | Length log 3, cm | 60, 61, 62 | XXX |
| X22 | Fresh weight log 3, dg | 63, 64, 65, 66 | XXXX |
| X23 | Base diameter, o.b., log 4, cm | 67, 68, 69 | XX.X |
| X24 | Length log 4, cm | 70, 71, 72 | XXX |
| X25 | Fresh weight log 4, dg | 73, 74, 75, 76 | XXXX |
| X26 | Fresh weight of wood waste, dg | 77, 78, 79, 80 | XXXX |
| CARD 2: | | | |
| X27 | Card number | 1 | X |
| X28 | Base diameter, o.b., log 5, cm | 2, 3, 4 | XX.X |

APPENDIX I (Cont'd)

| Name of Variable | | Columns Occupied | Decimal Position |
|---|---|---|---|
| X29 | Length log 5, cm | 5, 6, 7 | XXX |
| X30 | Fresh weight log 5, dg | 8, 9, 10, 11 | XXXX |
| X31 | Base diameter, o.b., log 6, cm | 12, 13, 14 | XX.X |
| X32 | Length log 6, cm | 15, 16, 17 | XXX |
| X33 | Fresh weight log 6, dg | 18, 19, 20, 21 | XXXX |
| X34 | Base diameter, o.b., log 7, cm | 22, 23, 24 | XX.X |
| X35 | Length log 7, cm | 25, 26, 27 | XXX |
| X36 | Fresh weight log 7, dg | 28, 29, 30, 31 | XXXX |
| X37 | Base diameter, o.b., log 8, cm | 32, 33, 34 | XX.X |
| X38 | Length log 8, cm | 35, 36, 37, 38 | XXXX |
| X39 | Fresh weight log 8, dg | 39, 40, 41, 42 | XXXX |
| X40 | Fresh weight breast height disc, g | 43, 44, 45 | XXX |
| X41 | Dry weight breast height disc, g | 46, 47, 48 | XXX |
| X42 | Double bark thickness at breast height, mm | 49, 50 | XX |
| X43 | Fresh weight crown base disc, g | 51, 52, 53 | XXX |
| X44 | Dry weight crown base disc, g | 54, 55, 56 | XXX |
| X45 | Double bark thickness at crown base, mm | 57, 58 | XX |
| X46 | Fresh weight branch sample, g | 59, 60, 61 | XXX |
| X47 | Dry weight branch sample, g | 62, 63, 64 | XXX |
| X48 | Dry weight leaf sample, g | 65, 66 | XX |
| X49 | Fresh weight leaf sample, g | 67, 68 | XX |
| X50 | Average leaf area, sq. in. | 69, 70, 71 | XX.X |
| X51 | Average no. leaves per long shoot | 72, 73, 74 | XXX |
| X52 | Tree number | 75, 76, 77, 78 | XXXX |

APPENDIX I (Cont'd)

| Name of Variable | | Columns | Decimal Position |
|---|---|---|---|
| X53 | Blank column | 79 | X |
| X54 | Species | 80 | X |
| CARD 3: | | | |
| X55 | Tree number | 1, 2, 3, 4 | XXXX |
| X56 | Branch number | 5, 6 | XX |
| X57 | Distance from crown base, cm | 7, 8, 9, 10 | XXXX |
| X58 | Branch angle, degrees | 11, 12, 13 | XXX |
| X59 | Quadrant of branch attachment | 14 | X |
| X60 | Branch base diameter, o.b., cm | 15, 16, 17 | XX.X |
| X61 | Branch diameter, o.b., 1 inch from base, cm | 18, 19, 20 | XX.X |
| X62 | Branch length, dm | 21, 22, 23 | XXX |
| X63 | Number of long shoots | 24, 25, 26, 27 | XXXX |
| X64 | Fresh weight branch over 2 cm, dg | 28, 29, 30, 31 | XXXX |
| X65 | Fresh weight under 2 cm and foliage, dg | 32, 33, 34, 35 | XXXX |
| X66 | Branch age | 36, 37 | XX |
| X67 | Double bark thickness at branch base, mm | 38, 39 | XX |
| X68 | Blank columns | 40, 41, 42 | |
| X69 | Branch number | 43, 44 | XX |
| X70 | Distance from crown base, cm | 45, 46, 47, 48 | XXXX |
| X71 | Branch angle, degrees | 49, 50, 51 | XXX |
| X72 | Quadrant of branch attachment | 52 | X |
| X73 | Branch base diameter, o.b., cm | 53, 54, 55 | XX.X |
| X74 | Branch diameter, o.b., 1 inch from base, cm | 57, 57, 58 | XX.X |
| X75 | Branch length, dm | 59, 60, 61 | XXX |

APPENDIX I (Cont'd)

| Name of Variable | | Columns | Decimal Position |
|---|---|---|---|
| X76 | Number of long shoots | 62, 63, 64, 65 | XXXX |
| X77 | Fresh weight branch over 2 cm, dg | 66, 67, 68, 69 | XXXX |
| X78 | Fresh weight under 2 cm and foliage, dg | 70, 71, 72, 73 | XXXX |
| X79 | Branch age | 74, 75 | XX |
| X80 | Double bark thickness at branch base, mm | 76, 77 | XX |
| X81 | Card number | 78, 79 | XX |
| X82 | Blank column | 80 | XX |

## APPENDIX II

Summary of Field Sampling Costs for Standing-Crop Harvest of 243 *Populus* Trees in Alberta

| | | |
|---|---|---|
| **Field Equipment and Supplies:** | | |
| Power saw | $ 105 | |
| Two Homs portable scales (24 kg and 150 kg capacities) | 315 | |
| Ladder and tree pruner | 50 | |
| Misc. measuring devices | 45 | |
| Misc. sampling supplies | 200 | $ 715 |
| **Laboratory Equipment and Supplies:** | | |
| Two forced-air drying ovens | 1,050 | |
| Area calculator | 210 | |
| Top-loading laboratory balance | 650 | |
| Misc. laboratory supplies | 40 | $ 1,950 |
| **Transportation:** | | |
| Four months' vehicle rental | 660 | |
| Vehicle operating expenses for 9500 miles of travel | 300 | $ 960 |
| Approximate total cost, exclusive of local costs for overhead, salary and living expenses for 210 man-days | | $ 3,625 |

For 243 trees between 2.0 and 31.5 cm d.b.h. (Table 1), detailed field data on standing crop was obtained for an average cost of approximately $150 plus 0.5 man-day per tree.