ESTIMATING AERIAL COMPONENT WEIGHTS

OF YOUNG ASPEN TREES

by

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ABSTRACT

Equations and tables for estimating the amount of above ground biomass in young trembling aspen (*Populus tremuloides* Michx.) trees are presented which provide additive component weight estimates. Samples were obtained in the Boreal Mixedwood Forests of Manitoba and Saskatchewan from pure, even aged aspen stands growing on fresh sites. A total of 132 trees were sampled with breast height diameter (D) up to 4.2 in., and total height (H) up to 43 ft. Component weights were related to combinations of D and H; D^2 and D^2H terms were found to be the most important independent variables, accounting for over 90 per cent of the variation in any tree components. Tree size had only slight effect on the relative weight distribution of different components for the range of the sample.

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INTRODUCTION

Growth and yield studies in the past were chiefly concerned with estimating wood production in forest stands. This generally included the stem wood of trees, or only that portion of stems which was considered merchantable, i.e., that above a certain minimum diameter. Although information of this type (compiled as yield tables) has been very useful to forest managers, changing technology and economic conditions limit its application. Also, these studies were not particularly suited to improving understanding of tree and stand growth.

In the last decade, considerable attention has been given to studies of total productivity of forest ecosystems (Ovington 1956, Ovington and Madgewick 1958, Tadaki et al. 1961, 1962, Tadaki 1966, Tadaki and Kawasaki 1966, Whittaker 1961, 1966, Weetman and Harland 1964, Yamamoto 1965, Baskerville 1965a, Johnstone 1967).

Other studies, in the eastern United States (Young et al. 1964, Young and Carpenter 1967, Dyer 1967), are concerned with the estimation of the amount and distribution of woody material in different forest tree species (the "complete tree" concept) as a source of potential wood fibre for pulp manufacture.

One approach to studying total productivity involves determining the total quantity of organic matter, or biomass, present in the system at a given time, which may be related to particular organisms or groups of organisms (Ovington 1962). Because of the complexity of forest ecosystems, determination of biomass and its components is no easy task. However, little information is lost regarding total production by concentrating only on the tree component, because trees in the temperate zone contain by far the greatest portion of the organic matter present in forest stands (Whittaker 1966).

In Canada a start has been made by evaluating total forest productivity in black spruce, *Picea mariana* (Mill.) BSP (Weetman and Harland 1964), in balsam fir, *Abies balsamea* (L.) Mill. (Baskerville 1965a) and lodgepole pine, *Pinus contorta* Dougl. var. *latifolia* Engelm. (Johnstone 1967). Similar information is needed for other species, particularly in the light of rapidly increasing demand for wood fibre (Fowler 1966) and other forest products. In the Prairie Provinces trembling aspen, *Populus tremuloides* Michx. is a species with great potential use. Anticipating such demands,

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the federal Forest Research Laboratory in Winnipeg initiated a program to work out effective procedures for aspen management with special emphasis on short rotation pulp economy[1]. The first phase of this work is concerned with determining above ground biomass of young aspen stands in relation to stand density, site and clonal variation. This report contains an analysis of the amount and distribution by component of dry matter in the aerial parts of young aspen trees. Equations and tables presented here can be used for estimating above ground biomass by components in aspen from the two most common tree size parameters: breast height diameter (D) and total height (H).

DESCRIPTION

Samples were taken at three different localities: (1) Riding Mountain National Park, Manitoba, (2) Porcupine Forest Reserve, Manitoba (southern boundary), and (3) near Hudsons Bay, Saskatchewan. At locations (1) and (2) soils were developed on glacial till, and those at location (3) on lacustrine deposits. Sampling at each location was restricted to fresh sites, using Hill's classification.

Rowe (1959) classified the forest as Mixedwood Section (B.18a) of the Boreal Forest Region. Aspen and white spruce _Picea glauca_ (Moench) Voss are predominant, and occur both in pure stands and in mixtures. Balsam poplar, _Populus balsamifera_ L., white birch, _Betula papyrifera_ Marsh. and jack pine, _Pinus banksiana_ Lamb. are usually present on upland sites, whereas, on poorly drained depressions, black spruce and larch, _Larix laricina_ (Du Roi) K. Koch are more common.

METHODS

Field work for this study was carried out in July and August 1967. It was assumed that, by mid-July, leaf expansion had ceased, and that most of the current year's height and diameter growth had also been completed.

Pure, fully stocked, even aged aspen stands between ages 5 and 25 years were sampled. An effort was made to sample a wide range of stand density conditions. Stands showing excessive browsing damage or other disturbance were not included. A soil pit was dug in each stand and the soil profile was examined and described. Soil samples were collected for laboratory analysis.

Three or four rectangular plots of variable size were established in each sample stand. Minimum plot size, as used in the youngest stands, was defined as either 10 by 10 ft, or the area required to support 20 trees. Care was taken to avoid noticeable differences in site conditions between plots in a stand. All trees on each plot were tagged and measured for breast height diameter to the nearest 1/10 inch and total height to the nearest 1/10 foot (over 15 feet, to 1/2 foot).

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[1] Bella, I.E. and G.A. Steneker. 1967. Aspen--Short rotation management and its implications. Project proposal. Can. Dept. of For. and Rur. Dev., 2 pp. Mimeo.

To determine weight distribution of tree components, two sampling procedures were used for individual trees. In some stands, sample trees were taken from a single plot of average stand density, in others, from two plots representing extreme stand densities in terms of number of trees per acre. Weight data from these latter plots were to provide information on influences of stand density on component weight distribution. On some plots all trees were felled and measured; on others five to ten trees were selected covering a representative range of tree sizes on the plot.

The selected sample trees were felled, their total length (height) measured and branches removed and bundled. The stems were cut into 3 ft. sections and the material was transported immediately to camp (within 10 miles) for dissection and weighing.

At the camp, total fresh weight of stem over 1/2 inch diameter was obtained (all weight measurements were taken to the nearest gram). A one inch section was cut from the lower end of each three foot stem section and retained for determination of specific gravity, age, diameter and height growth. Stem wood and bark were then separated and their weights ascertained. The leaves were then removed from the branches and fresh weights of these components were also determined.

Drying of all tree components was done in a hut heated by a wood stove to a temperature between 30° and 35°C. Leaves, branches and bark, which were kept in large paper bags, were periodically turned over to facilitate drying.

After four weeks of drying in this way, the leaves were considered air dry and of fairly stable moisture content. Oven dry weight of leaves was then obtained after drying for two hours at 105°C, using all leaves for smaller trees, and representative samples of leaves of larger trees.

Oven dry weights of branches, and stem wood and bark, were obtained after drying these components in an oven at 105°C for 24 hours.

Graphical procedures and multiple regression techniques were used in the analysis[2]. The following variables were included:

1) Total fresh weight (Tf); the total weight of all aerial tree components immediately after cutting.
2) Total dry weight (Td); oven dry weight of all aerial tree components.
3) Leaf fresh weight (Lf).
4) Leaf dry weight (Ld).
5) Branch fresh weight (BRf); all branches plus the main stem under 1/2 inch diameter.
6) Branch dry weight (BRd).

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2 Mrs. A. Torok (Vancouver Forest Products Laboratory, Dept. of Fisheries and Forestry) provided a program for computer data plotting. A regression program by Dr. A. Kozak (Faculty of Forestry, Univ. of British Columbia) was used for the multiple regression analysis.

7) Total stem fresh weight (STf); stem wood and bark over 1/2 inch diameter.
8) Total stem dry weight (STd).
9) Stem wood fresh weight (SWf).
10) Stem wood dry weight (SWd).
11) Stem bark fresh weight (SBf).
12) Stem bark dry weight (SBd).

and the following stem dimensions:

13) Diameter at breast height over bark (D).
14) Total height (H); from root collar to tip.

ANALYSES OF RESULTS

A total of 132 trees were included in the analysis. Table 1 is a data summary including means, standard deviation and range. Fresh weight, and separate stem wood and stem bark information was obtained only for sample trees taken at Riding Mountain (Area 1). The amount of stem wood and stem bark for the Porcupine and the Hudson Bay (Areas 2 and 3) samples will be estimated later from the 1-inch stem discs mentioned in the previous section.

The table below shows the distribution of dry matter in leaves, branches and stem (wood and bark) for the sample. Percentages were calculated from mean values shown in Table 1, but as such, they are not descriptive of any "average tree". They are intended only to give a general picture of the distribution. Baskerville (1965b) demonstrated the error that results from using "average tree" based on one criterion (e.g. average diameter) as a basis of estimating other average tree parameters.

Component Per Cent

	Leaf	Branch	Stem wood	Stem bark	Stem total	Total
Fresh	11	14	57	18	75	100
Dry	9	15	56	19	75	100

Component weight data were plotted over tree dimensions and over total weight to discover general curve-form between sets of dependent and independent variables. Logarithmic transformation of the dependent and independent variables (D and H) produced linear trends. Using D^2 and D^2H as independent variables in relation to component weights provided even better linearity (see Appendix). The plots of the data shown in the Appendix indicate homogeneous variance of observations along a second degree curve. On the other hand, logarithmic transformation produced non-homogeneous variance--with very large variance at the lower values of the dependent variable,

TABLE 1. Data summary with variable means and measures of dispersion for 132 young aspen trees (weight in grams).

Variable	Mean	Standard Deviation	Minimum	Maximum
Area 1 (N = 83)				
Lf	401	371	21	1,659
BRf	527	524	69	2,511
SWf	2,146	2,488	49	11,014
SBf	697	714	28	3,047
STf	2,843	3,200	77	14,061
Tf	3,771	4,072	239	17,879
Ld	164	157	8	689
BRd	269	274	36	1,296
SWd	984	1,135	27	5,199
SBd	329	340	13	1,471
STd	1,313	1,473	40	6,670
Td	1,746	1,895	127	8,583
D (in.)	1.22	.62	.3	2.8
H (ft.)	14.62	5.47	6.2	26.3
D^2H	36.4	49.5	.567	206.2
Area 1, 2 and 3 (N = 132)				
Ld	214	217	8	1,194
BRd	424	516	36	3,539
STd	2,548	3,592	00	21,608
Td	3,187	4,232	71	26,341
D	1.48	.85	.2	4.2
H	17.52	8.33	6.2	42.9
D^2H	75.0	113.8	.26	756.8

and small variance at the higher values. For this reason, and because logarithmic transformation results in meaningless standard error of estimates, untransformed variables were used in the ensuing multiple regression analysis.

Simple linear correlation coefficients were calculated between the variables studied and are shown in Table 2. All the coefficients are positive and are highly significant, indicating strong positive correlations between these variables. The best independent variables, D^2 and D^2H, generally accounted for over 90 per cent of the variation in aspen component weight. The best independent variable describing leaf weight, and to a certain extent branch weight, was D^2; whereas stem components and total tree weight were most strongly correlated with D^2H. As anticipated, strong positive correlations were found between various tree component weights.

As sampling areas 2 and 3 were about 150 miles northeast of sampling area 1, growing conditions may differ considerably between these two localities. This could account for differences in dry matter component distribution between aspen trees over the areas sampled. This hypothesis was tested by including "area" as independent variable in the multiple regression analysis (as code 1 and 2) and determining its significance by F-tests.

To ascertain whether the relative distribution of different components changes with tree weight or tree dimension, and whether locality has any influence, a series of multiple regression analyses were conducted with total weight and area as independent variables and weight of components as dependent variable (Table 3). Significance of the quadratic total weight term (T^2) would indicate a relative increase or decrease--depending on the sign--of the particular tree component in relation to total weight. The basic premise of this analysis is that, if the proportion of one component (e.g. leaves) increases or decreases, there must be a complementary decrease or increase in the proportion of the remaining components, as they are all expressed in terms of the sum of components.

Condensed results of these multiple regression analyses are presented in Table 3. This includes regression coefficients (b_1), their significance (Fx_1), the number of observations (N), coefficients of determination (R^2 or r^2) and standard error of the estimate both in absolute units (grams) and as a percentage of the mean. Only the significant independent variable terms were included in the table. The stepwise reduction shown here always provided the best possible regression for a given number of variables, because such a regression was selected from all possible combinations of regressions for that number of independent variables. However, for purposes of comparison, two regression equations (for Ld and BRd) are given in the lower part of the table which do not fulfil this prerequisite.

All regressions were highly significant and generally accounted for more than 90 per cent of the variation in the dependent variable. The linear total weight term (T) was most important. Although in some instances (e.g. Lf, BRf, BRd, SWd, STd) the quadratic total weight was significant, no conclusive trends were revealed. Negative T^2 regression coefficients in

TABLE 2. Simple linear correlation between variables.

Variables	D	H	D^2	D^2H	L	BR	SW	SB	ST	T
	Tree Dimensions				Weights (fresh or dry)					
Area 1 (N = 83)										
D	1.000									
H	0.960	1.000								
D^2	0.972	0.911	1.000							
D^2H	0.936	0.883	0.990	1.000						
Lf	0.941	0.864	0.971	0.959	1.000					
BRf	0.912	0.824	0.967	0.964	0.977	1.000				
SWf	0.942	0.891	0.988	0.994	0.969	0.968	1.000			
SBf	0.956	0.911	0.992	0.992	0.967	0.962	0.995	1.000		
STf	0.946	0.896	0.990	0.995	0.969	0.967	0.999	0.997	1.000	
Tf	0.946	0.889	0.991	0.993	0.978	0.978	0.999	0.996	0.999	1.000
Ld	0.931	0.848	0.970	0.961	1.000					
BRd	0.905	0.818	0.963	0.964	0.979	1.000				
SWd	0.936	0.886	0.985	0.994	0.970	0.971	1.000			
SBd	0.951	0.905	0.991	0.993	0.966	0.967	0.995	1.000		
STd	0.940	0.891	0.987	0.994	0.970	0.971	0.999	0.997	1.000	
Td	0.940	0.882	0.988	0.993	0.979	0.981	0.998	0.996	0.999	1.000
Area 1, 2 and 3 (N = 132)										
D	1.000									
H	0.960	1.000								
D^2	0.960	0.908	1.000							
D^2H	0.889	0.859	0.975	1.000						
Ld	0.922	0.827	0.954	0.907	1.000					
BRd	0.866	0.790	0.955	0.958	0.940	1.000				
STd	0.908	0.884	0.980	0.994	0.913	0.952			1.000	
Td	0.911	0.877	0.984	0.994	0.930	0.967			0.998	1.000

TABLE 3. Regression statistics for evaluating possible trends in aspen aerial component distribution and the effect of geographic location (weights in grams).

Dependent Variables- Weight Comp. (in grams)	Independent variables and their significance: $X_1=T$			$X_2=T^2$		X_3=Area		N	R^2 or r^2	SE of Est.	
	Regression coefficients and F-ratios										
	a	b_1	Fx_1	b_2	Fx_2	b_3	Fx_3			grams	Percent of mean
	Based only on data from Area 1										
Lf	40.8	0.1038	288	-0.0000010	6.36			83	0.960	74.7	18.6
Lf	65.0	0.0892	1819					83	0.957	77.1	19.2
BRf	91.6	0.1021	140	0.0000016	8.50			83	0.960	105.4	20.0
BRf	52.1	0.1258	1774					83	0.956	110.1	20.9
SWf	-155.4	0.6102	28293					83	0.997	133.8	6.2
SBf	- 0.4	0.1980	1671	-0.0000016	26			83	0.993	59.2	8.5
SBf	38.3	0.1747	9042					83	0.991	67.7	9.7
STf	-117.1	0.7849	32334					83	0.997	160.9	5.6
Ld	21.4	0.0378	1992					83	0.961	31.2	19.0
BRd	51.2	0.0474	118	0.0000013	20			83	0.963	53.4	19.9
BRd	20.6	0.0658	1673					83	0.954	59.3	22.1
SWd	- 24.9	0.2544	1735	0.0000016	17			83	0.996	74.6	7.6
SWd	- 64.1	0.2779	15786					83	0.995	81.6	8.3
SBd	15.6	0.0832	9391					83	0.991	31.6	9.6
STd	- 16.6	0.3420	2059	0.0000013	7.23			83	0.996	92.1	7.0
STd	- 48.5	0.3611	19395					83	0.996	95.6	7.3
	Based on data from Area 1 and Area 2 plus 3										
Ld	123.6	0.0679	369	-0.0000010	29	-71.77	26	132	0.902	68.9	32.1
Ld	136.8	0.0508	842			-61.59	16	132	0.879	75.9	35.4
Ld	62.4	0.0477	827					132	0.864	80.2	37.4
Ld	40.1	0.0621	287	-0.0000009	19			132	0.881	75.2	35.1
BRd	147.6	0.1175	286	0.0000009	6.51	-89.91	11	132	0.943	135.2	31.9
BRd	135.3	0.1333	1756			-99.35	13	132	0.940	138.0	32.5
BRd	15.2	0.1283	1858					132	0.935	144.0	34.0
BRd	43.0	0.1102	260	0.0000011	8.49			132	0.939	140.2	33.1
STd	-272.2	0.8158	38292			160.95	20	132	0.997	180.8	7.1
STd	- 77.6	0.8240	42609					132	0.997	193.3	7.6
STd	- 83.1	0.8276	7663	-0.0000002	0.18			132	0.997	194.0	7.6

Significance levels: 5 per cent $F_{1,80} = 3.96$ $F_{1,129} = 6.96$

1 per cent $F_{1,80} = 3.92$ $F_{1,129} = 6.84$

some of the leaf and stem bark regressions would indicate that the relative amounts of leaves and branches decrease with greater tree size whereas positive T^2 coefficients for branch and stem wood regressions would indicate increase in the proportion of these components with tree size.

The effect of area was also rather slight and contributed but little to improving standard error of estimate values. This suggests that for practical purposes the distribution of different above ground aspen tree components up to 25 years of age may be considered constant, and that no important differences in such distribution arise from possible growing conditions changes due to geographic locality within the range sampled. This was kept in mind when conducting multiple regression analyses for developing equations for estimating weight of tree components.

Table 4 shows the results of a series of multiple regression analyses conducted for developing component weight estimating equations for aspen. Regression statistics presented are: regression coefficients (b_1) and their significance (Fx_1), number of observations (N), coefficients of determination (R^2 or r^2), and standard error of the estimates. The independent variables used were H, D^2 and D^2H. The linear term of D was also included in these analyses, but as it proved generally non-significant, it was omitted from this table. In the table, component regressions including only the significant independent variables are shown first; thereafter the variables are eliminated one by one in order of decreasing importance until only one independent variable remains. The first of the following two lines includes all of the independent variables, regardless of their actual significance, while the second line includes only the D^2 and D^2H terms.

All regressions presented are highly significant. The independent variables accounted for well over 90 per cent of the variation in the dependent variable. D^2 and D^2H were the most important independent terms; H had only minor importance. D^2 and D^2H had a consistently positive affect on tree component weights in the multiple regression, whereas the H term was positive for stem and total weight and negative for branch and leaf weight.

Results in Table 4 indicate that the best estimator of stem components is D^2H whereas, for crown component (leaves and branches) estimation, D^2 is more suitable. However, for the purposes of this study it was necessary to obtain additive component weight estimates, i.e. components estimates which would add up to estimated total weight. Such estimates may be obtained from regressions having exactly the same form and number of independent variables. Only then would the sum of coefficients of component regressions be equal to the corresponding coefficients of the total weight regression, and the sum of estimated component weights equal the estimated total weight[3].

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[3] Dr. A. Kozak (Faculty of Forestry, University of British Columbia) has derived the algebraic proof of the additivity of these component regression coefficients.

TABLE 4. Regression statistics for estimating weights of aerial components in aspen trees.

Dependent Variables - Weight Comp. (grams)	Independent variables and their significance: Regression coefficients and F-ratios	$X_1=H$		$X_2=D^2$		$X_3=D^2H$			R^2 or r^2	SE of Est.	
	a	b_1	Fx_1	b_2	Fx_2	b_3	Fx_3	N		grams	Percent of mean
	Based only on data from Area 1										
Lf	26.5			199.6	1344			83	0.943	89.1	22.2
Lf	98.7	-10.44	5.39	291.1	40	-2.51	2.46	83	0.947	86.9	21.7
Lf	13.0			231.6	35	-1.28	.68	83	0.943	89.2	22.2
BRf	296.2	-31.37	31	366.8	460			83	0.952	115.5	21.9
BRf	0.06			280.2	1150			83	0.934	135.2	25.7
BRf	296.9	-31.03	27	356.7	34	0.37	0.03	83	0.952	116.2	22.1
BRf	42.1			180.1	9.4	4.02	2.98	83	0.936	133.6	25.4
SWf	-121.4	26.76	6.1			51.56	1564	83	0.990	252.2	11.7
SWf	166.5					54.40	7428	83	0.989	260.0	12.1
SWf	-101.9	19.13	2.15	139.8	1.10	46.87	101	83	0.990	252.0	11.7
SWf	55.1			248.7	4.99	44.62	102	83	0.990	253.9	11.8
SBf	- 79.8	15.06	19	106.4	9.1	9.80	64	83	0.992	66.6	9.5
SBf	- 94.6	20.87	48			13.37	1369	83	0.991	69.9	10.0
SBf	43.9			192.1	35	8.03	39	83	0.990	73.7	10.6
STf	-216.0	47.64	14			64.93	1753	83	0.991	299.9	10.5
STf	296.5					69.99	7991	83	0.990	322.5	11.3
STf	-181.7	34.19	4.94	246.2	2.46	56.67	107	83	0.992	297.2	10.4
STf	99.0			440.8	11	52.65	98	83	0.991	304.5	10.7
Tf	154.1			852.5	21	55.39	57	83	0.990	419.3	11.1
Tf	536.1					88.91	6091	83	0.987	469.3	12.4
Tf	213.9	-7.28	0.11	894.0	16	54.53	49	83	0.990	421.6	11.2
Ld	61.7	-5.94	11	100.7	353			83	0.948	36.2	22.1
Ld	5.6			84.29	1288			83	0.941	38.4	23.4
Ld	60.6	-6.51	12	117.5	38	-0.61	0.84	83	0.949	36.2	22.1
Ld	7.1			80.48	22	0.15	0.05	83	0.941	38.6	23.5
BRd	158.1	-17.38	32	194.2	430			83	0.948	63.3	23.5
BRd	- 6.0			146.3	1038			83	0.927	74.3	27.6
BRd	160.3	-16.19	24	158.9	23	1.29	1.22	83	0.949	63.2	23.5
BRd	27.4			66.68	4.47	3.19	6.5	83	0.933	71.9	26.7
SWd	82.4					24.78	6305	83	0.987	128.6	13.1
SWd	- 6.6	8.39	1.60	-2.87	0.00	24.00	103	83	0.988	128.4	13.0
SWd	62.3			44.90	0.63	23.02	105	83	0.987	128.9	13.1
SBd	-20.0	5.59	9.9	42.40	5.47	5.16	66	83	0.990	34.3	10.4
SBd	-25.9	7.91	27			6.58	1305	83	0.989	35.2	10.7

TABLE 4 (continued)

Dependent Variables - Weight Comp. (grams)	Independent variables and their significance: Regression coefficients and F-ratios							N	R^2 or r^2	SE of Est.	
		X_1=H		$X_2=D^2$		$X_3=D^2H$					
	a	b_1	Fx_1	b_2	Fx_2	b_3	Fx_3			grams	Percent of mean
SBd	59.2					7.42	5683	83	0.986	40.6	12.3
SBd	25.9			74.24	22	4.50	51	83	0.989	36.2	11.0
STd	-32.1	16.14	6.0			30.49	1492	83	0.989	152.7	11.6
STd	141.6					32.20	7105	83	0.989	157.4	12.0
STd	-26.6	13.98	3.10	39.55	0.24	29.16	106	83	0.989	153.4	11.7
STd	88.2			119.2	3.05	27.52	103	83	0.989	155.4	11.8
Td	122.8			266.3	7.4	30.86	63	83	0.986	222.7	12.7
Td	242.1					41.34	5416	83	0.985	231.4	13.2
Td	194.3	-8.72	0.57	315.9	7.2	29.84	52	83	0.987	223.3	12.8
	Based on data from Area 1 and Area 2 plus 3										
Ld	82.7	-8.61	36	128.7	223	-1.24	40	132	0.939	54.3	25.3
Ld	88.0	-5.99	15	79.24	380			132	0.920	61.9	28.9
Ld	24.6			65.00	1324			132	0.910	65.1	30.4
Ld	0.8			96.22	160	-9.90	18	132	0.921	61.3	28.6
BRd	255.0	-26.25	63	172.7	75	1.66	13	132	0.951	125.8	29.7
BRd	247.9	-29.76	81	239.1	765			132	0.946	131.7	31.0
BRd	-67.1			168.3	1345			132	0.912	167.4	39.5
BRd	5.2			73.58	15	2.72	26	132	0.927	153.1	36.1
STd	-355.6	48.02	52			27.49	3206	132	0.991	323.6	12.7
STd	259.0					30.51	10800	132	0.988	382.3	15.0
STd	-319.4	39.77	22	79.83	2.44	25.83	490	132	0.992	321.8	12.6
STd	59.1			230.06	29	24.23	405	132	0.990	347.2	13.6
Td	65.1			399.87	77	26.06	420	132	0.993	366.5	11.5
Td	412.6					36.97	10862	132	0.988	462.0	14.5
Td	18.3	4.91	0.26	381.31	43	26.25	388	132	0.993	367.5	11.5

Significance levels: 5 per cent $F_{1,80} = 3.96$ $F_{1,129} = 6.96$

1 per cent $F_{1,80} = 3.92$ $F_{1,129} = 6.84$

Symbolically:

$$\Sigma a_i = a_T \qquad \text{and} \qquad \Sigma b_{ij} = b_{Tj}$$

where i is the i-th component
T the total, and
j the j-th variable

Best weight estimates can be obtained by regressions having all three independent terms H, D^2 and D^2H, although the inclusion of H as a third variable has generally very little influence in decreasing the error of the estimates. Tables 5 to 12 present dry component weight estimates in Metric and in English system units in terms of diameter and height, calculated by repeatedly solving appropriate regression equations. These tables may be used for quick estimation of component weight.

Table 4 indicates that stem components, based on fresh or dry measurements, can be estimated more accurately than crown components as their standard errors of estimate are much smaller. The error of estimates for the step-wise inclusion of H, D^2 and D^2H were of the same order of magnitude within each kind of component. They were smaller for dry weights than for fresh weights.

TABLE 5. Leaf dry weights (kg.) of aspen trees expressed in terms of D (cm.) and H (m.).

D \ H	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0
1.0	0.04	0.02	-0.									
1.2	0.05	0.02	-0.0									
1.4	0.06	0.03	0.00									
1.6	0.07	0.04	0.01	-								
1.8	0.09	0.06	0.03	-0.								
2.0	0.10	0.07	0.04	0.01								
2.2	0.12	0.09	0.05	0.02	-							
2.4	0.13	0.10	0.07	0.04	0.							
2.6	0.15	0.12	0.09	0.06	0.0							
2.8	0.17	0.14	0.11	0.07	0.04							
3.0	0.19	0.16	0.13	0.09	0.06	0.						
3.2	0.22	0.18	0.15	0.11	0.08	0.0						
3.4	0.24	0.21	0.17	0.14	0.10	0.06						
3.6	27	0.23	0.20	0.16	0.12	0.09	0					
3.8	0	0.26	0.22	0.18	0.15	0.11	0.0					
4.0		0.29	0.25	0.21	0.17	0.13	0.10					
4.2		0.32	0.28	0.24	0.20	0.16	0.12					
4.4		35	0.31	0.27	0.23	0.19	0.15	0.				
4.6		8	0.34	0.30	0.26	0.21	0.17	0.1				
4.8			0.37	0.33	0.29	0.24	0.20	0.16				
5.0			0.41	0.36	0.32	0.27	0.23	0.19	0.			
5.2			44	0.40	0.35	0.31	0.26	0.21	0.1			
5.4			8	0.43	0.39	0.34	0.29	0.25	0.20			
5.6				0.47	0.42	0.37	0.32	0.28	0.23	0		
5.8				0.51	0.46	0.41	0.36	0.31	0.26	0.		
6.0				55	0.50	0.44	0.39	0.34	0.29	0.24		
6.2				9	0.54	0.48	0.43	0.38	0.33	0.27		
6.4					0.58	0.52	0.47	0.41	0.36	0.31	0.	
6.6					0.62	0.56	0.51	0.45	0.40	0.34	0.2	
6.8					66	0.60	0.55	0.49	0.43	0.37	0.32	
7.0					71	0.65	0.59	0.53	0.47	0.41	0.35	0.
7.2						0.69	0.63	0.57	0.51	0.45	0.39	0.3
7.4						0.74	0.67	0.61	0.55	0.49	0.42	0.36
7.6						78	0.72	0.65	0.59	0.52	0.46	0.40
7.8						93	0.76	0.70	0.63	0.56	0.50	0.43
8.0							0.81	0.74	0.67	0.61	0.54	0.47
8.2							0.86	0.79	0.72	0.65	0.58	0.51
8.4							.91	0.84	0.76	0.69	0.62	0.55
8.6							96	0.89	0.81	0.74	0.66	0.59
8.8								0.93	0.86	0.78	0.70	0.63
9.0								0.99	0.91	0.83	0.75	0.67
9.2								1.04	0.96	0.87	0.79	0.71
9.4								09	1.01	0.92	0.84	0.76
9.6								5	1.06	0.97	0.89	0.80
9.8									1.11	1.02	0.93	0.85
10.0									1.17	1.07	0.98	0.89
10.2									22	1.13	1.03	0.94
10.4									8	1.18	1.08	0.99
10.6										1.24	1.14	1.04
10.8										1.29	1.19	1.09
11.0										35	1.24	1.14

TABLE 6. Branch dry weights (kg.) of aspen trees expressed in terms of D (cm.) and H (m.).

D \ H	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0
1.0	0.11	0.03	-0.0									
1.2	0.12	0.04	-0.0									
1.4	0.14	0.05	-0.03									
1.6	0.16	0.07	-0.01	-0.								
1.8	0.17	0.09	0.01	-0.0								
2.0	0.20	0.11	0.03	-0.05								
2.2	0.22	0.14	0.06	-0.02	-							
2.4	0.25	0.17	0.08	0.00	-0.							
2.6	0.28	0.19	0.11	0.03	-0.05							
2.8	0.31	0.23	0.15	0.07	-0.01	-						
3.0	0.34	0.26	0.18	0.10	0.02	-0.						
3.2	0.37	0.30	0.22	0.14	0.06	-0.0						
3.4	0.41	0.34	0.26	0.18	0.11	0.03						
3.6	.45	0.38	0.30	0.23	0.15	0.08	0.					
3.8	9	0.42	0.35	0.27	0.20	0.12	0.0					
4.0		0.47	0.39	0.32	0.25	0.17	0.10					
4.2		0.51	0.44	0.37	0.30	0.22	0.16					
4.4		.56	0.49	0.42	0.35	0.28	0.22	0.				
4.6		2	0.55	0.48	0.41	0.34	0.28	0.21				
4.8			0.61	0.54	0.47	0.41	0.34	0.27				
5.0			0.66	0.60	0.53	0.47	0.40	0.34	0.			
5.2			.73	0.66	0.60	0.54	0.47	0.41	0.3			
5.4			79	0.73	0.67	0.61	0.54	0.48	0.42			
5.6				0.80	0.74	0.68	0.62	0.56	0.50	0.		
5.8				0.87	0.81	0.75	0.69	0.64	0.58	0.5		
6.0				.94	0.88	0.83	0.77	0.72	0.66	0.61		
6.2				02	0.96	0.91	0.85	0.80	0.75	0.69		
6.4					1.04	0.99	0.94	0.89	0.84	0.78	0.	
6.6					1.12	1.08	1.03	0.98	0.93	0.88	0.83	
6.8					.21	1.16	1.12	1.07	1.02	0.97	0.93	
7.0					30	1.25	1.21	1.16	1.12	1.07	1.03	0.
7.2						1.35	1.30	1.26	1.22	1.18	1.13	1.0
7.4						1.44	1.40	1.36	1.32	1.28	1.24	1.20
7.6						.54	1.50	1.46	1.43	1.39	1.35	1.32
7.8						64	1.61	1.57	1.54	1.50	1.47	1.43
8.0							1.71	1.68	1.65	1.62	1.58	1.55
8.2							1.82	1.79	1.76	1.73	1.70	1.67
8.4							.93	1.90	1.88	1.85	1.83	1.80
8.6							05	2.02	2.00	1.97	1.95	1.93
8.8								2.14	2.12	2.10	2.08	2.06
9.0								2.26	2.25	2.23	2.21	2.19
9.2								2.39	2.37	2.36	2.34	2.33
9.4								52	2.50	2.49	2.48	2.47
9.6								5	2.64	2.63	2.62	2.61
9.8									2.78	2.77	2.77	2.76
10.0									2.91	2.91	2.91	2.91
10.2									06	3.06	3.06	3.06
10.4									0	3.21	3.21	3.22
10.6										3.36	3.37	3.38
10.8										3.51	3.53	3.54
11.0										67	3.69	3.70

TABLE 7. Stem dry weights (kg.) of aspen trees expressed in terms of D (cm.) and H (m.).

D \ H	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0
1.0	-0.02	0.12	0.27									
1.2	-0.00	0.15	0.30									
1.4	0.02	0.17	0.33									
1.6	0.04	0.20	0.37	0.								
1.8	0.07	0.24	0.41	0.5								
2.0	0.10	0.28	0.46	0.65								
2.2	0.13	0.32	0.52	0.71	0							
2.4	0.16	0.37	0.58	0.78	0.							
2.6	0.20	0.42	0.64	0.86	1.08							
2.8	0.24	0.48	0.71	0.94	1.18							
3.0	0.29	0.54	0.79	1.04	1.28	1.						
3.2	0.34	0.60	0.87	1.13	1.40	1.66						
3.4	39	0.67	0.95	1.24	1.52	1.80						
3.6	4	0.74	1.04	1.34	1.65	1.95	2.					
3.8		0.82	1.14	1.46	1.78	2.10	2.4					
4.0		0.90	1.24	1.58	1.92	2.26	2.60					
4.2		.99	1.35	1.71	2.07	2.43	2.80					
4.4		7	1.46	1.84	2.23	2.61	3.00	3.				
4.6			1.58	1.98	2.39	2.80	3.21	3.62				
4.8			1.70	2.13	2.56	3.00	3.43	3.86				
5.0			.83	2.28	2.74	3.20	3.66	4.12	4.			
5.2			96	2.44	2.93	3.41	3.90	4.39	4.87			
5.4				2.61	3.12	3.64	4.15	4.66	5.18			
5.6				2.78	3.32	3.87	4.41	4.95	5.49	6.		
5.8				.96	3.53	4.10	4.68	5.25	5.82	6.3		
6.0				14	3.75	4.35	4.95	5.56	6.16	6.76		
6.2				3	3.97	4.60	5.24	5.87	6.51	7.15	7	
6.4					4.20	4.87	5.54	6.20	6.87	7.54	8.	
6.6					4.44	5.14	5.84	6.54	7.25	7.95	8.65	
6.8					68	5.42	6.16	6.89	7.63	8.37	9.11	
7.0					3	5.71	6.48	7.25	8.03	8.80	9.58	10.
7.2						6.00	6.81	7.62	8.44	9.25	10.06	10.87
7.4						6.31	7.16	8.01	8.86	9.71	10.56	11.40
7.6						.62	7.51	8.40	9.29	10.18	11.07	11.95
7.8						4	7.87	8.80	9.73	10.66	11.59	12.52
8.0							8.24	9.21	10.18	11.15	12.13	13.10
8.2							8.62	9.64	10.65	11.66	12.68	13.69
8.4							.01	10.07	11.13	12.18	13.24	14.30
8.6							41	10.51	11.62	12.72	13.82	14.92
8.8								10.97	12.12	13.26	14.41	15.56
9.0								11.43	12.63	13.82	15.02	16.21
9.2								.91	13.15	14.39	15.63	16.88
9.4								39	13.68	14.98	16.27	17.56
9.6								9	14.23	15.57	16.91	18.25
9.8									14.79	16.18	17.57	18.96
10.0									5.36	16.80	18.25	19.69
10.2									.94	17.44	18.93	20.43
10.4									3	18.08	19.63	21.18
10.6										18.74	20.35	21.95
10.8										19.41	21.07	22.74
11.0										.10	21.82	23.54

TABLE 8. Total dry weights (kg.) of aspen trees expressed in terms of D (cm.) and H (m.).

D \ H	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0
1.0	0.14	0.17	0.2									
1.2	0.17	0.21	0.24									
1.4	0.22	0.26	0.30									
1.6	0.27	0.32	0.37	0.								
1.8	0.33	0.39	0.45	0.5								
2.0	0.39	0.46	0.53	0.60								
2.2	0.47	0.55	0.63	0.71	[illegible]							
2.4	0.54	0.64	0.73	0.82	0.							
2.6	0.63	0.74	0.84	0.95	1.06							
2.8	0.72	0.84	0.96	1.09	1.21							
3.0	0.82	0.96	1.10	1.23	1.37	1.						
3.2	0.93	1.08	1.23	1.39	1.54	1.6						
3.4	04	1.21	1.38	1.55	1.72	1.89						
3.6	5	1.35	1.54	1.73	1.92	2.11	2.					
3.8		1.50	1.71	1.92	2.12	2.33	2.5					
4.0		1.65	1.88	2.11	2.34	2.57	2.80					
4.2		82	2.07	2.32	2.57	2.82	3.07					
4.4		9	2.26	2.54	2.81	3.08	3.36	3.				
4.6			2.46	2.76	3.06	3.36	3.66	3.96				
4.8			2.67	3.00	3.32	3.65	3.97	4.29				
5.0			.90	3.25	3.59	3.94	4.29	4.64	4.			
5.2			2	3.50	3.88	4.26	4.63	5.01	5.3			
5.4				3.77	4.17	4.58	4.98	5.39	5.80			
5.6				4.05	4.48	4.91	5.35	5.78	6.22	6.		
5.8				.33	4.80	5.26	5.73	6.19	6.66	7.1		
6.0				63	5.13	5.62	6.12	6.62	7.11	7.61		
6.2					5.47	5.99	6.52	7.05	7.58	8.11	8	
6.4					5.82	6.38	6.94	7.51	8.07	8.63	9.	
6.6					.18	6.78	7.37	7.97	8.57	9.17	9.76	
6.8					55	7.18	7.82	8.45	9.08	9.72	10.35	1.
7.0					4	7.61	8.28	8.95	9.62	10.29	10.96	11.
7.2						8.04	8.75	9.46	10.16	10.87	11.58	12.25
7.4						8.48	9.23	9.98	10.73	11.47	12.22	12.97
7.6						94	9.73	10.52	11.30	12.09	12.88	13.66
7.8						1	10.24	11.07	11.90	12.72	13.55	14.38
8.0							10.76	11.63	12.51	13.38	14.25	15.12
8.2							1.30	12.22	13.13	14.04	14.96	15.87
8.4							.85	12.81	13.77	14.73	15.68	16.64
8.6							2	13.42	14.42	15.43	16.43	17.43
8.8								14.04	15.09	16.14	17.19	18.24
9.0								14.68	15.78	16.88	17.97	19.07
9.2								.33	16.48	17.63	18.77	19.92
9.4								00	17.20	18.39	19.59	20.78
9.6								8	17.93	19.17	20.42	21.67
9.8									18.68	19.97	21.27	22.57
10.0									9.44	20.79	22.14	23.49
10.2									22	21.62	23.03	24.43
10.4									1	22.47	23.93	25.39
10.6										23.33	24.85	26.37
10.8										24.22	25.79	27.36
11.0										.11	26.75	28.38

TABLE 9. Leaf dry weights (lb.) of aspen trees expressed in terms of D (in.) and H (ft.).

D \ H	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0	44.0
0.4	0.07	-0.01								
0.5	0.10	0.02	-							
0.6	0.12	0.04	-0.							
0.7	0.16	0.08	-0.00							
0.8	0.20	0.12	0.03	-						
0.9	0.24	0.16	0.07	-0.						
1.0	0.29	0.21	0.12	0.03						
1.1	0.35	0.26	0.17	0.08	-					
1.2	0.41	0.32	0.22	0.13	0.					
1.3	0.47	0.38	0.28	0.19	0.10					
1.4	0.54	0.45	0.35	0.25	0.15					
1.5	0.62	0.52	0.42	0.32	0.22	0.				
1.6	.70	0.60	0.49	0.39	0.29	0.18				
1.7	79	0.68	0.57	0.47	0.36	0.25	0.			
1.8		0.77	0.66	0.55	0.43	0.32	0.2			
1.9		0.86	0.75	0.63	0.51	0.40	0.28			
2.0		.96	0.84	0.72	0.60	0.48	0.36	0		
2.1		06	0.94	0.81	0.69	0.57	0.44	0.3		
2.2			1.04	0.91	0.78	0.65	0.53	0.40		
2.3			1.15	1.02	0.88	0.75	0.61	0.48	0.	
2.4			.26	1.12	0.98	0.85	0.71	0.57	0.4	
2.5			38	1.24	1.09	0.95	0.80	0.66	0.51	
2.6				1.35	1.20	1.05	0.90	0.75	0.60	0.
2.7				1.47	1.32	1.16	1.01	0.85	0.70	0.5
2.8				.60	1.44	1.28	1.12	0.95	0.79	0.63
2.9				73	1.56	1.40	1.23	1.06	0.89	0.72
3.0					1.69	1.52	1.34	1.17	0.99	0.82
3.1					1.83	1.64	1.46	1.28	1.10	0.92
3.2					.96	1.77	1.59	1.40	1.21	1.02
3.3					10	1.91	1.71	1.52	1.32	1.13
3.4						2.05	1.85	1.64	1.44	1.24
3.5						2.19	1.98	1.77	1.56	1.35
3.6						.34	2.12	1.90	1.69	1.47
3.7						9	2.26	2.04	1.81	1.59
3.8							2.41	2.18	1.94	1.71
3.9							2.56	2.32	2.08	1.84
4.0							.72	2.47	2.22	1.97
4.1							38	2.62	2.36	2.10
4.2								2.77	2.50	2.23
4.3								2.93	2.65	2.37
4.4								.09	2.80	2.52

TABLE 10. Branch dry weights (lb.) of aspen trees expressed in terms of D (in.) and H (ft.).

D \ H	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0	44.0
0.4	0.16	-0.06								
0.5	0.20	-0.03	-.							
0.6	0.25	0.02	-0..							
0.7	0.30	0.08	-0.15							
0.8	0.36	0.14	-0.08	-.						
0.9	0.43	0.21	-0.01	-0..						
1.0	0.51	0.29	0.08	-0.14						
1.1	0.60	0.38	0.17	-0.05	-.					
1.2	0.69	0.48	0.27	0.06	-0..					
1.3	0.79	0.59	0.38	0.17	-0.03					
1.4	0.90	0.70	0.50	0.29	0.09	-.				
1.5	1.02	0.82	0.62	0.43	0.23	0.0				
1.6	.15	0.95	0.76	0.57	0.37	0.18				
1.7	28	1.09	0.91	0.72	0.53	0.34	0			
1.8	3	1.24	1.06	0.88	0.69	0.51	0.			
1.9		1.40	1.22	1.04	0.86	0.69	0.51			
2.0		.57	1.39	1.22	1.05	0.87	0.70	0		
2.1		74	1.57	1.41	1.24	1.07	0.91	0.		
2.2		[illegible]	1.76	1.60	1.44	1.28	1.12	0.96		
2.3			1.96	1.81	1.65	1.50	1.34	1.19	1.	
2.4			.17	2.02	1.87	1.73	1.58	1.43	1.2	
2.5			38	2.24	2.10	1.96	1.82	1.68	1.54	
2.6			[illegible]	2.47	2.34	2.21	2.08	1.94	1.81	1.
2.7				2.71	2.59	2.46	2.34	2.21	2.09	1.9
2.8				.96	2.85	2.73	2.61	2.50	2.38	2.26
2.9				22	3.11	3.01	2.90	2.79	2.68	2.57
3.0				[illegible]	3.39	3.29	3.19	3.09	2.99	2.89
3.1					3.68	3.59	3.49	3.40	3.31	3.22
3.2					.97	3.89	3.81	3.73	3.65	3.56
3.3					28	4.20	4.13	4.06	3.99	3.92
3.4					[illegible]	4.53	4.47	4.40	4.34	4.28
3.5						4.86	4.81	4.76	4.70	4.65
3.6						.20	5.16	5.12	5.08	5.04
3.7						56	5.53	5.49	5.46	5.43
3.8						[illegible]	5.90	5.88	5.86	5.84
3.9							6.28	6.27	6.26	6.26
4.0							.68	6.68	6.68	6.68
4.1							08	7.09	7.11	7.12
4.2							[illegible]	7.52	7.55	7.57
4.3								7.95	7.99	8.03
4.4								.40	8.45	8.50

TABLE 11. Stem dry weights (lb.) of aspen trees expressed in terms of D (in.) and H (ft.).

D \ H	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0	44.0
0.4	0.10	0.49								
0.5	0.16	0.56								
0.6	0.22	0.66	1.							
0.7	0.31	0.77	1.23							
0.8	0.40	0.90	1.39							
0.9	0.51	1.04	1.58	2.						
1.0	0.63	1.21	1.79	2.36						
1.1	0.76	1.39	2.01	2.64						
1.2	0.91	1.59	2.26	2.94	3.					
1.3	1.06	1.80	2.54	3.27	4.01					
1.4	1.23	2.03	2.83	3.63	4.42					
1.5	1.42	2.28	3.14	4.01	4.87	5.				
1.6	1.61	2.55	3.48	4.42	5.35	6.2				
1.7	82	2.83	3.84	4.85	5.86	6.87				
1.8		3.13	4.22	5.31	6.40	7.49	8.			
1.9		3.45	4.62	5.80	6.97	8.14	9.31			
2.0		3.79	5.05	6.31	7.57	8.83	10.09	1		
2.1		14	5.49	6.85	8.20	9.56	10.91	12.		
2.2			5.96	7.41	8.87	10.32	11.77	13.23		
2.3			6.45	8.00	9.56	11.12	12.67	14.23	15.	
2.4			.96	8.62	10.29	11.95	13.61	15.27	16.9	
2.5			49	9.27	11.04	12.82	14.59	16.36	18.14	
2.6				9.94	11.83	13.72	15.61	17.50	19.39	21.
2.7				10.63	12.65	14.66	16.67	18.68	20.69	22.7
2.8				.36	13.49	15.63	17.77	19.90	22.04	24.18
2.9				11	14.37	16.64	18.91	21.17	23.44	25.71
3.0					15.28	17.68	20.09	22.49	24.89	27.29
3.1					16.22	18.76	21.30	23.84	26.38	28.92
3.2					.20	19.88	22.56	25.25	27.93	30.61
3.3					20	21.03	23.86	26.69	29.52	32.36
3.4						22.22	25.20	28.18	31.17	34.15
3.5						23.44	26.58	29.72	32.86	36.00
3.6						.70	28.00	31.30	34.60	37.91
3.7						99	29.46	32.93	36.39	39.86
3.8							30.96	34.60	38.24	41.87
3.9							32.49	36.31	40.12	43.94
4.0							.07	38.07	42.06	46.06
4.1							59	39.87	44.05	48.23
4.2								41.72	46.09	50.46
4.3								43.61	48.17	52.74
4.4								.55	50.31	55.07

TABLE 12. Total dry weights (lb.) of aspen trees expressed in terms of D (in.) and H (ft.).

D \ H	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0	44.0
0.4	0.34	0.42								
0.5	0.45	0.55								
0.6	0.60	0.72	0..							
0.7	0.77	0.92	1.08							
0.8	0.96	1.15	1.34							
0.9	1.18	1.41	1.64	1..						
1.0	1.43	1.71	1.98	2.25						
1.1	1.70	2.03	2.35	2.67						
1.2	2.00	2.38	2.76	3.13	3..					
1.3	2.33	2.76	3.20	3.63	4.07					
1.4	2.68	3.18	3.68	4.17	4.67	5				
1.5	3.06	3.62	4.19	4.75	5.32	5..				
1.6	3.46	4.10	4.74	5.37	6.01	6.64				
1.7	89	4.61	5.32	6.03	6.74	7.46	8			
1.8	5	5.14	5.94	6.73	7.52	8.32	9..			
1.9		5.71	6.59	7.47	8.35	9.23	10.11			
2.0		.31	7.28	8.25	9.22	10.19	11.16	12		
2.1		94	8.00	9.07	10.13	11.20	12.26	13.3.		
2.2			8.76	9.93	11.09	12.25	13.42	14.58		
2.3			9.56	10.83	12.09	13.36	14.63	15.90	17.	
2.4			.39	11.77	13.14	14.52	15.90	17.27	18.6.	
2.5			25	12.74	14.23	15.72	17.21	18.70	20.20	
2.6				13.76	15.37	16.98	18.59	20.20	21.80	23.
2.7				14.82	16.55	18.28	20.02	21.75	23.48	25.2.
2.8				.92	17.78	19.64	21.50	23.35	25.21	27.07
2.9				96	19.05	21.04	23.03	25.02	27.01	29.00
3.0					20.37	22.49	24.62	26.75	28.87	31.00
3.1					21.73	23.99	26.26	28.53	30.80	33.07
3.2					.13	25.54	27.96	30.37	32.79	35.20
3.3					58	27.14	29.71	32.27	34.84	37.40
3.4						28.79	31.51	34.23	36.95	39.67
3.5						30.49	33.37	36.25	39.13	42.01
3.6						.24	35.28	38.32	41.37	44.41
3.7						03	37.25	40.46	43.67	46.88
3.8							39.27	42.65	46.04	49.42
3.9							41.34	44.90	48.47	52.03
4.0							.47	47.21	50.96	54.71
4.1							55	49.58	53.52	57.45
4.2								52.01	56.14	60.26
4.3								54.49	58.82	63.14
4.4								.04	61.56	66.09

DISCUSSION AND CONCLUSION

The weights of all aerial tree components increased with tree size as expressed in D, H, or in terms of total weight. The relative distribution of components was generally the same for all tree sizes although weak--yet statistically significant--trends were revealed indicating decrease in relative amount of leaves and stem bark and increase in relative amounts of branches and stem wood with increasing tree size. It would be reasonable to expect more definite trends in component distribution if a greater range of tree sizes and ages were sampled. In the present investigations, however, only juvenile stands under 25 years of age were included, with essentially similar growing status and little differentiation of individuals into tree classes. Conclusive results on component distribution patterns have been reported for other species (Ovington 1956, Ovington and Madgewick 1958, 1959, Tadaki et al. 1962, Tadaki 1966, Satoo 1962, and Johnstone 1967.

Results showed that D, or more precisely D^2, is the most important single variable for estimating tree component weights. Estimating accuracy may be improved for stem components by using the combined variable term D^2H. This is because D and H are the two most important, and also the most easily and accurately measurable, stem parameters determining stem component weights.

Generally, stem components can be estimated more accurately than crown components from D and H (i.e. D^2H); this is indicated by the relevant standard errors of the estimates. The point was demonstrated for several coniferous and deciduous species in Japan (Kira and Shidei 1967). The Japanese workers pointed out that regressions of stem weight over D^2H seem to be nearly identical for a number of tree species, even for those in different species groups, viz., softwoods or hardwoods. This suggests a similarity of stem dry matter density and stem form for these species.

The difficulty in estimating crown components arises from the lack of easily measurable and definable linear crown parameters. Diameter and height used in this study are stem parameters, and only indirect estimators of crown dimensions. Although crown width and crown length would probably remove some of the variation in crown component weight estimates, they are more cumbersome to measure and are themselves quite variable.

The apparent anomaly of a negative height term in the branch and leaf weight multiple regressions is simple to explain. For instance, while a dominant tree in a 10-year-old stand and an intermediate tree in a 20-year-old stand or a similar site may have the same breast height diameter, the 10-year-old dominant would be much shorter than the 20-year-old intermediate. The faster growing dominant would likely have a greater amount of leaves and possibly branches than the older, intermediate tree which is slowly being eliminated from the stand. This elimination process is manifested by the dying of lower branches, proportionally smaller amount of leaves, and a decline in growth rate.

The relative magnitude of the standard error of the estimates, as expressed in per cent of the mean of the independent variable, was about the same for similar components regardless of whether they were fresh or dry. This suggests a relatively constant moisture content for the sample; or at least component weight variations resulting from possible moisture content differences were negligible compared to inherent tree to tree variation. This agrees with other findings on moisture content variation in trembling aspen (Sonley 1956, Bendsten and Rees 1962) which indicated relatively stable moisture status at any given time (e.g. early spring, late spring, early summer, etc.), a distinct pattern of annual moisture content variation notwithstanding.

In conclusion, reliable estimates of aerial component weights for young aspen may be obtained for the Boreal Mixedwood Forests of Manitoba and Saskatchewan by using regression equations presented in this paper. D^2 and D^2H will account for over 90 percent of the variation in any tree component weight. Additional independent variables tested have no practical importance in improving the reliability of the estimate. When estimating component weights, the values of independent variables should be within the range of the data on which the equations were based. Additional data from a wider area would be required to establish conclusively the possible effect of differences arising from geographic location.

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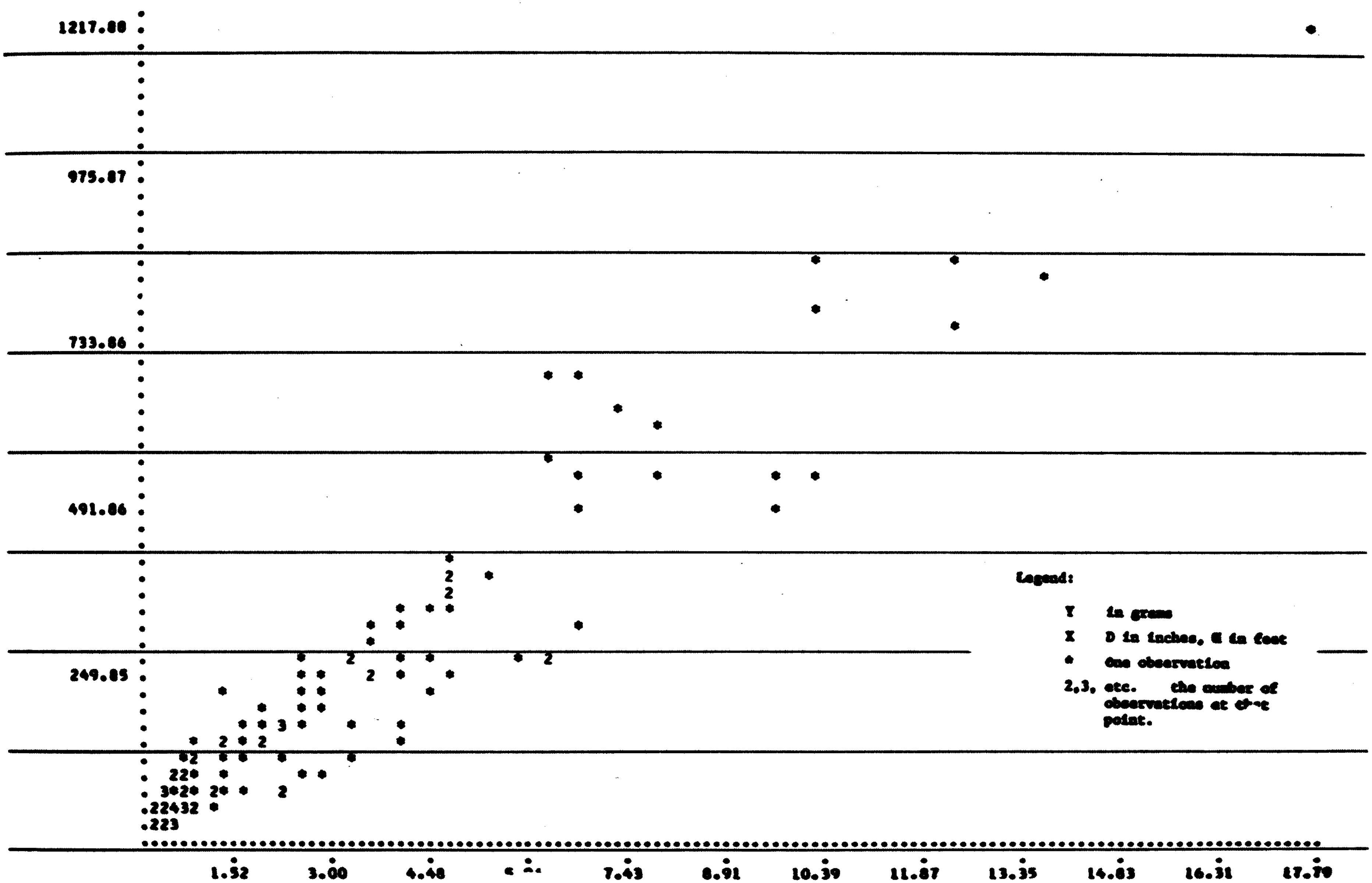
APPENDIX

Data plottings

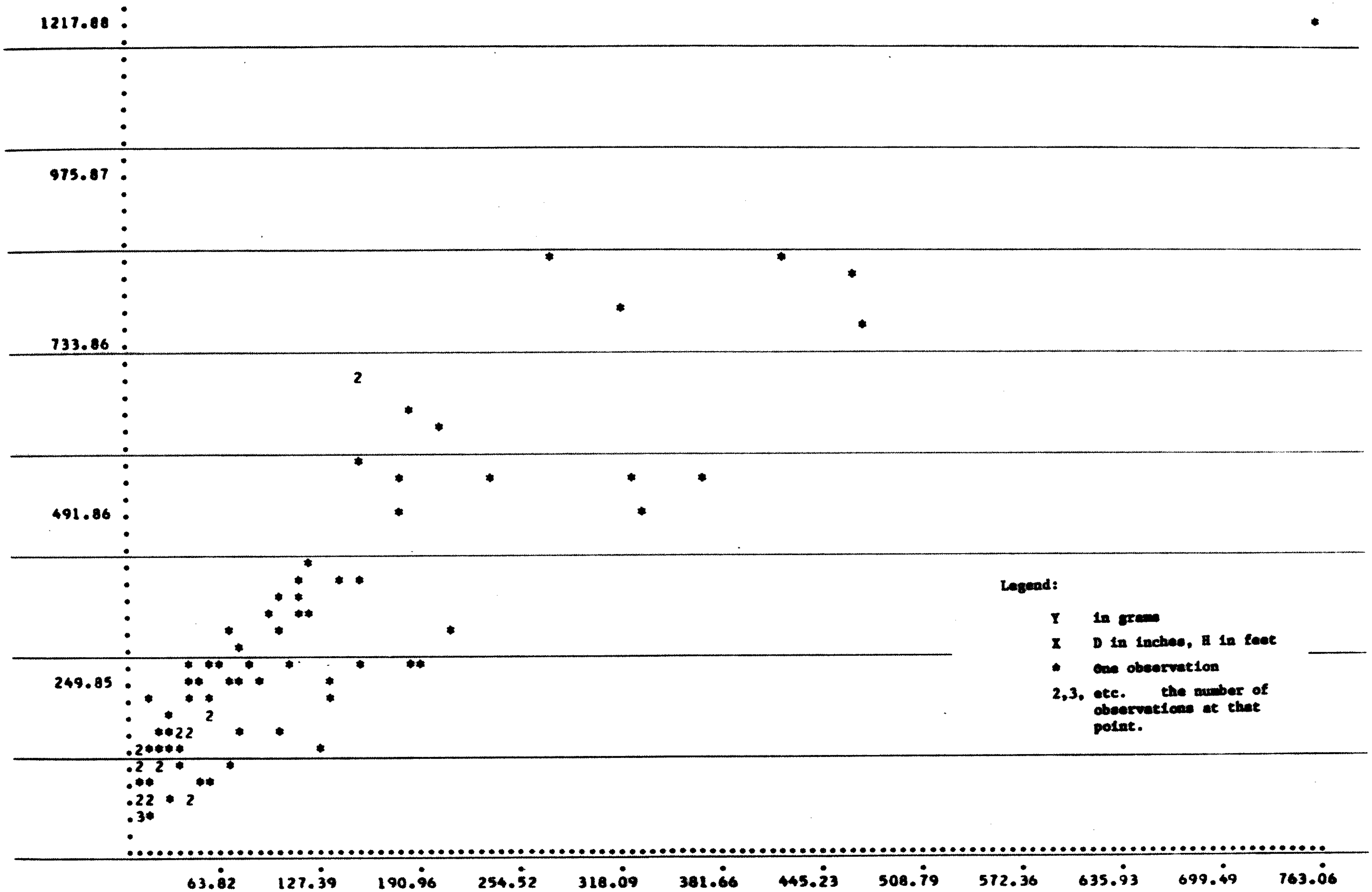
1. Leaf weight (Y) over D^2 (X).
2. Leaf weight (Y) over D^2H (X).
3. Branch weight (Y) over D^2 (X).
4. Branch weight (Y) over D^2H (X).
5. Stem total (wood plus bark) weight (Y) over D^2 (X).
6. Stem total (wood plus bark) weight (Y) over D^2H (X).
7. Total aerial component weight (Y) over D^2 (X).
8. Total aerial component weight (Y) over D^2H (X).
9. Leaf weight (Y) over total aerial component weight (X).
10. Branch weight (Y) over total aerial component weight (X).
11. Stem total (wood plus bark) weight (Y) over total aerial component weight (X).

1. LEAF WEIGHT (Y) OVER D^2 (X)



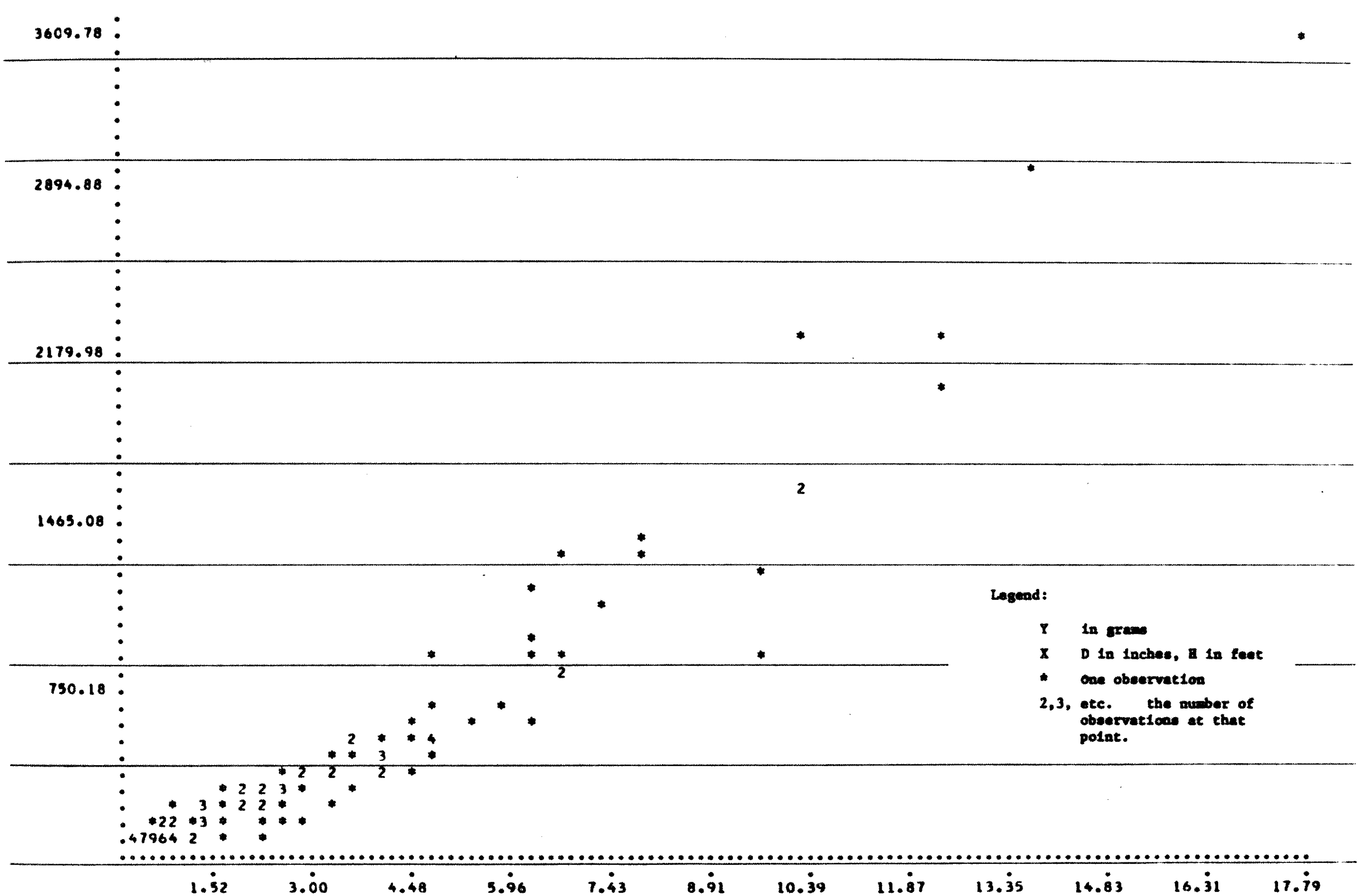
NUMBER OF OBSERVATIONS= 132
SCALE Y= 24.201 SCALE X= 0.148

2. LEAF WEIGHT (Y) OVER D^2H (X)



NUMBER OF OBSERVATIONS= 132
SCALE Y= 24.201 SCALE X= 6.357

3. BRANCH WEIGHT (Y) OVER D^2 (X)



NUMBER OF OBSERVATIONS= 132
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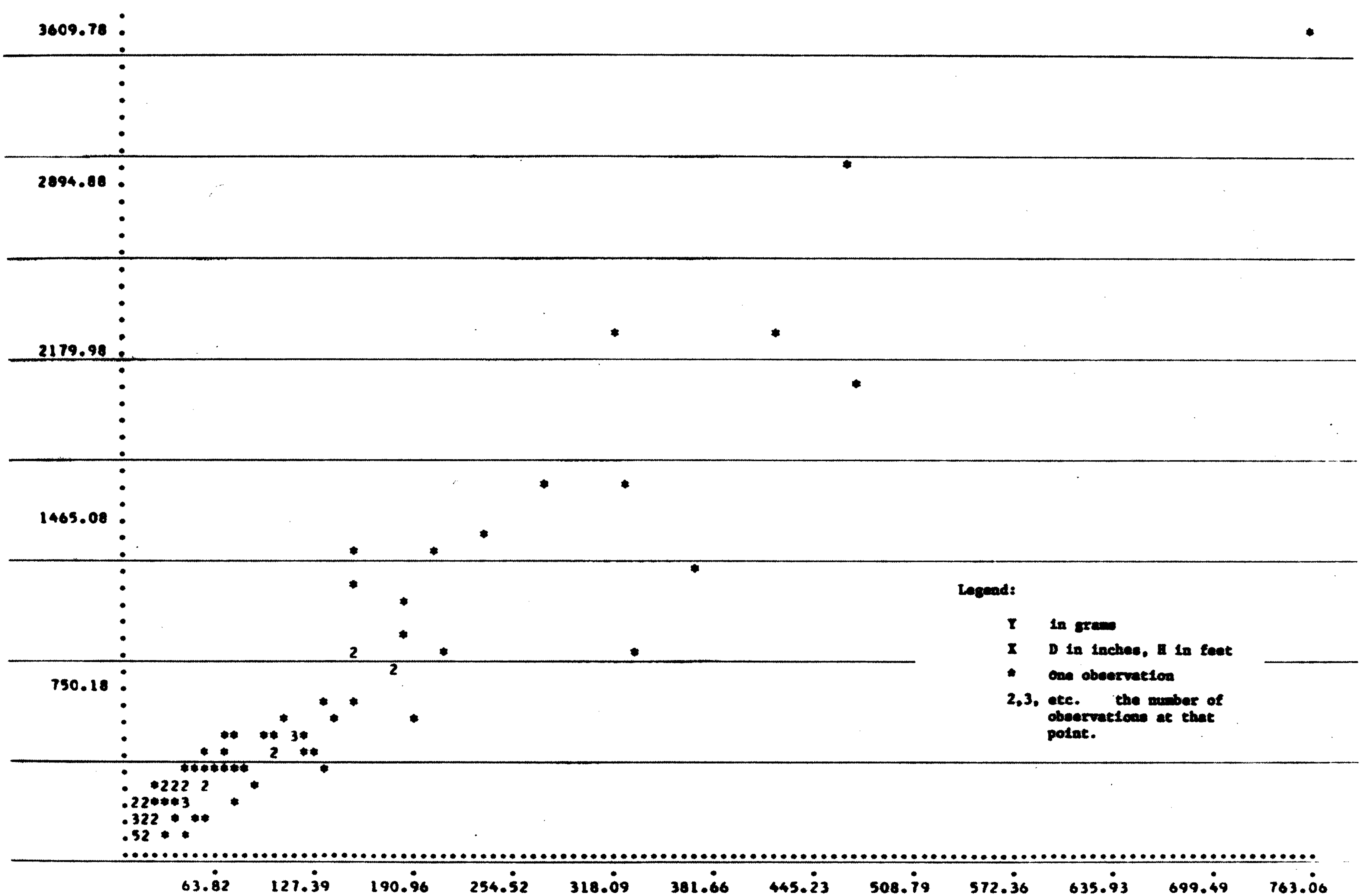
4. BRANCH WEIGHT (Y) OVER D^2H (X)



NUMBER OF OBSERVATIONS= 132
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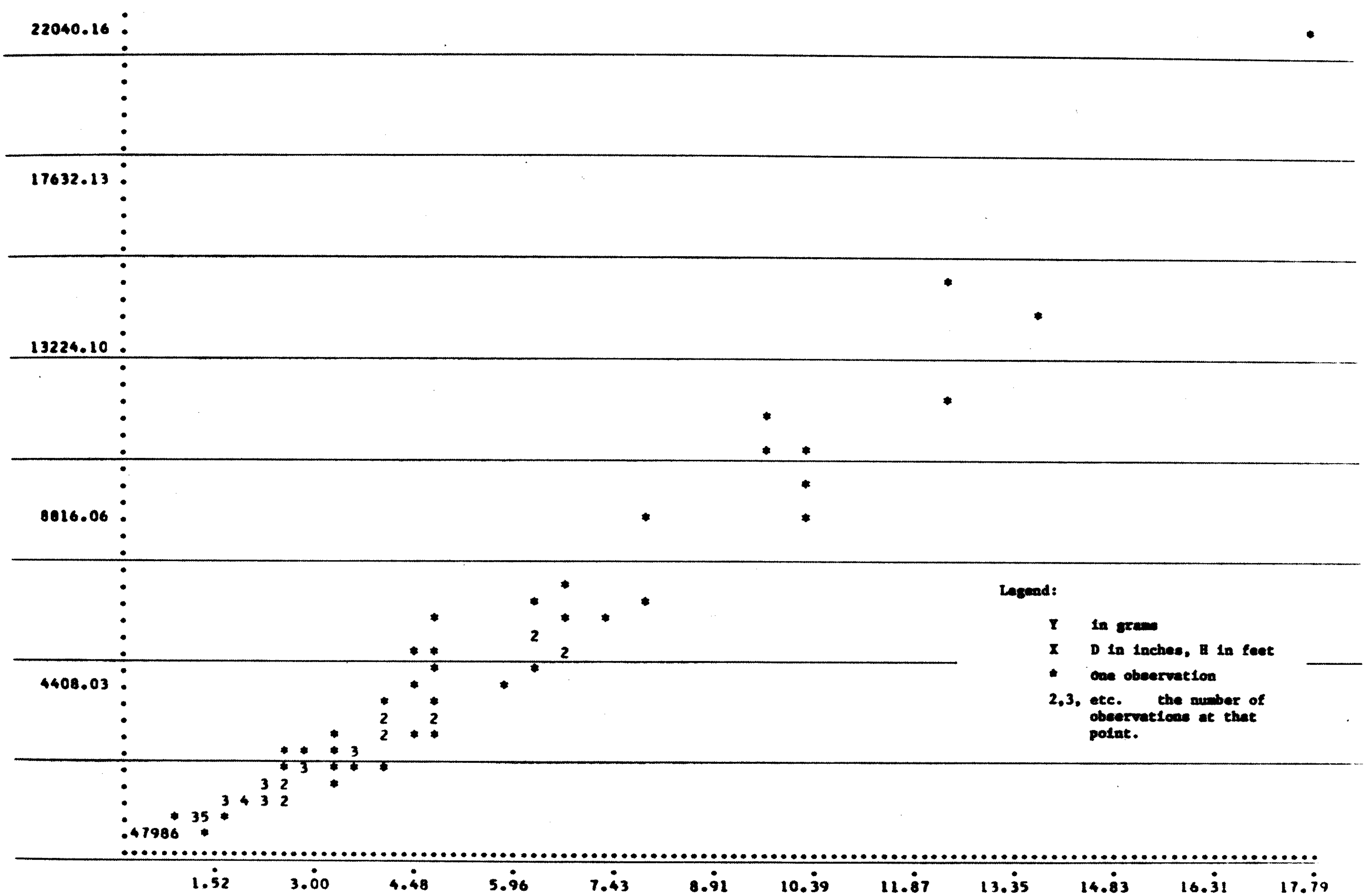
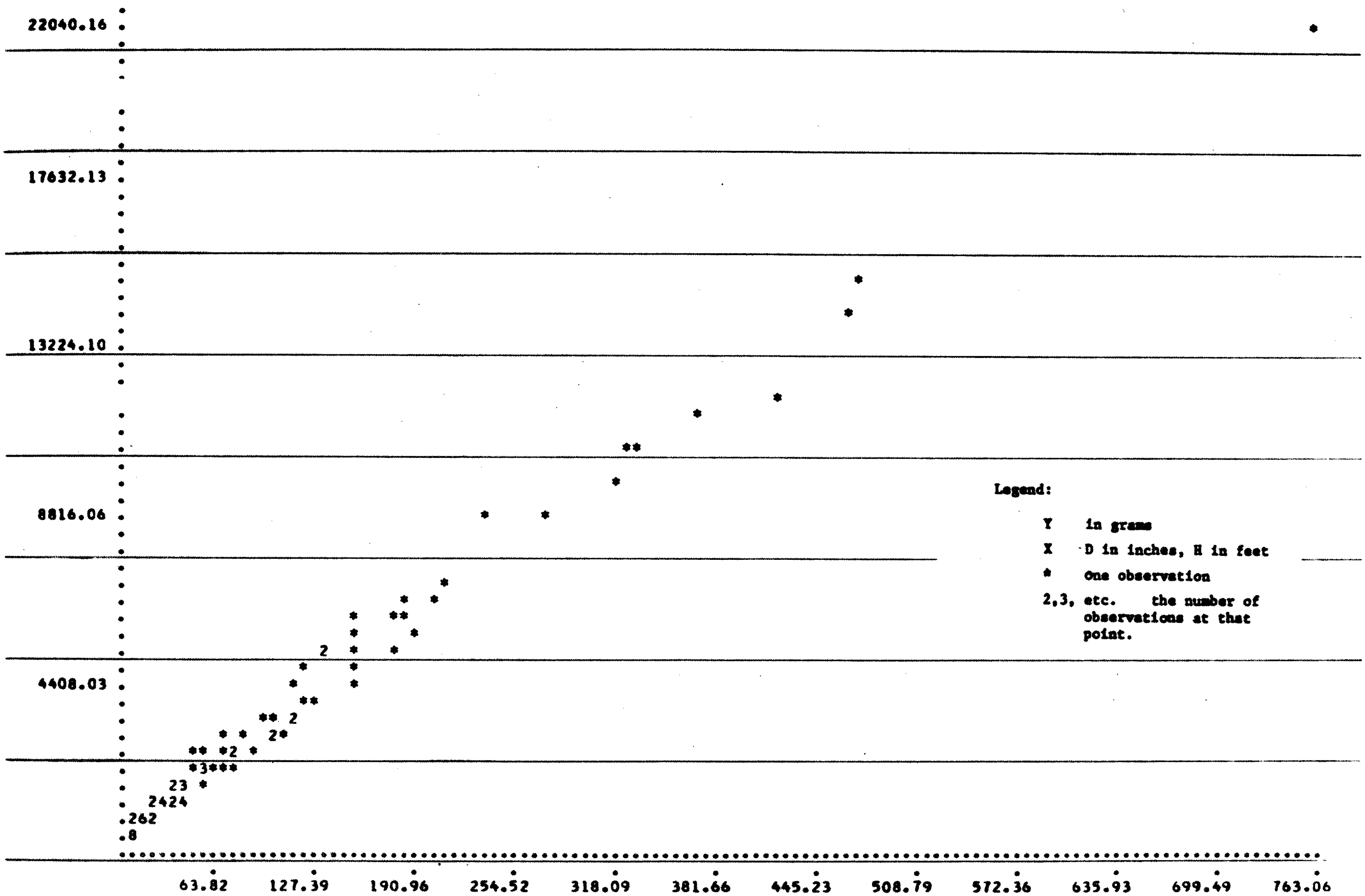
5. STEM TOTAL (WOOD PLUS BARK) WEIGHT (Y) OVER D^2 (X)



NUMBER OF OBSERVATIONS= 132
SCALE Y= 440.803 SCALE X= 0.148

6. STEM TOTAL (WOOD PLUS BARK) WEIGHT (Y) OVER D^2H (X)



NUMBER OF OBSERVATIONS= 132
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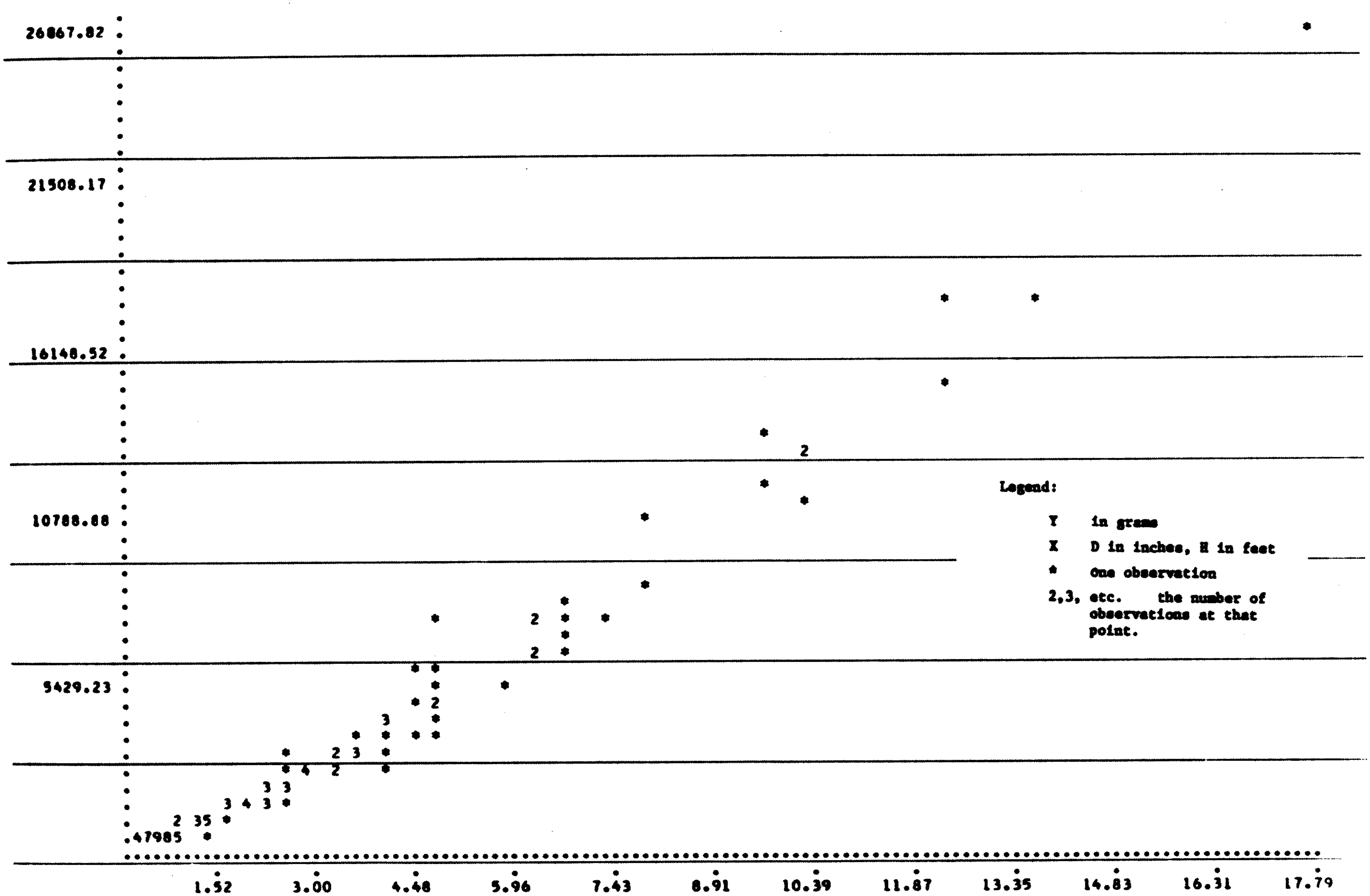
7. TOTAL AERIAL COMPONENT WEIGHT (Y) OVER D^2 (X)



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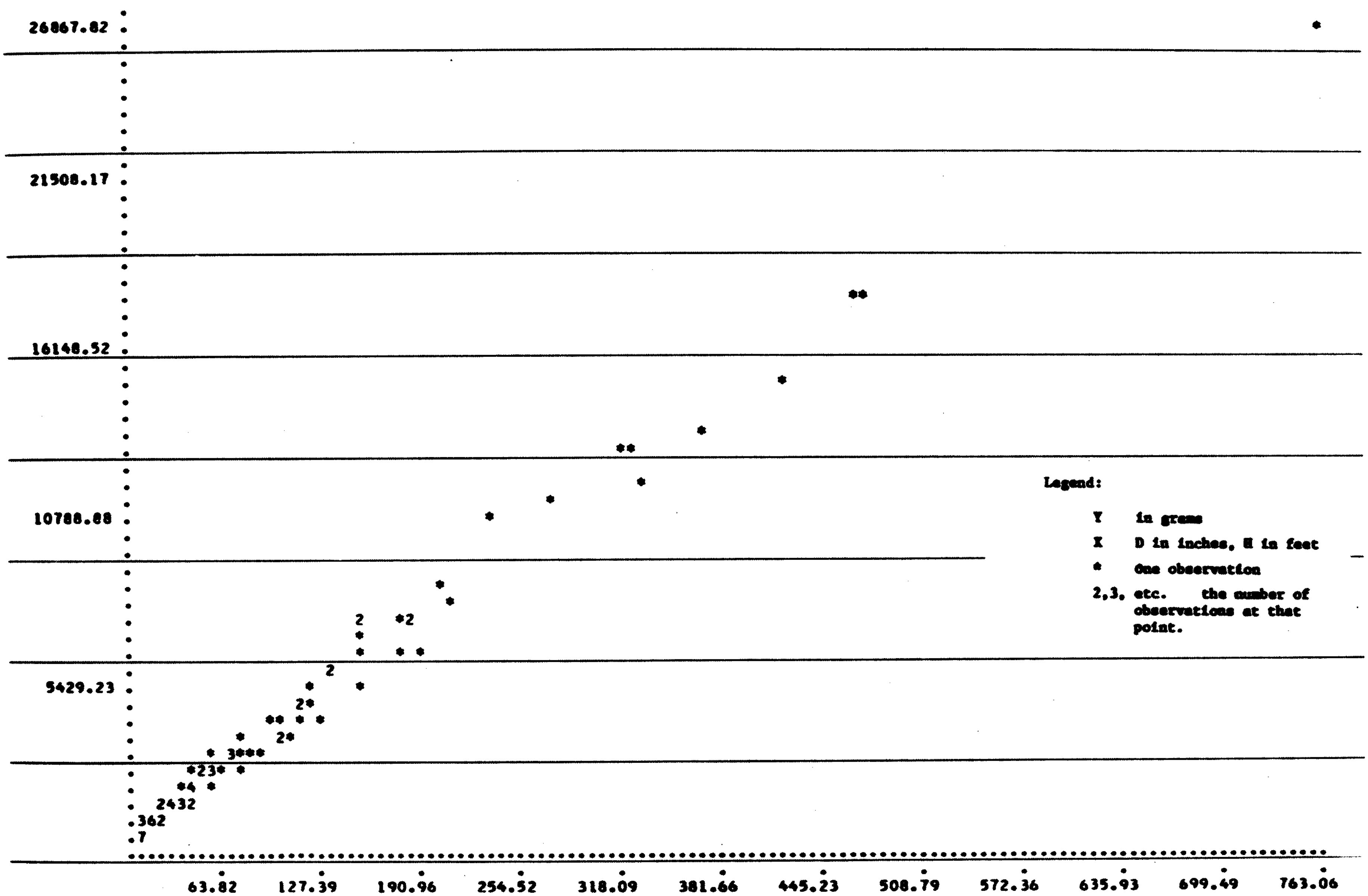
8. TOTAL AERIAL COMPONENT WEIGHT (Y) OVER D^2H (X)



NUMBER OF OBSERVATIONS= 132
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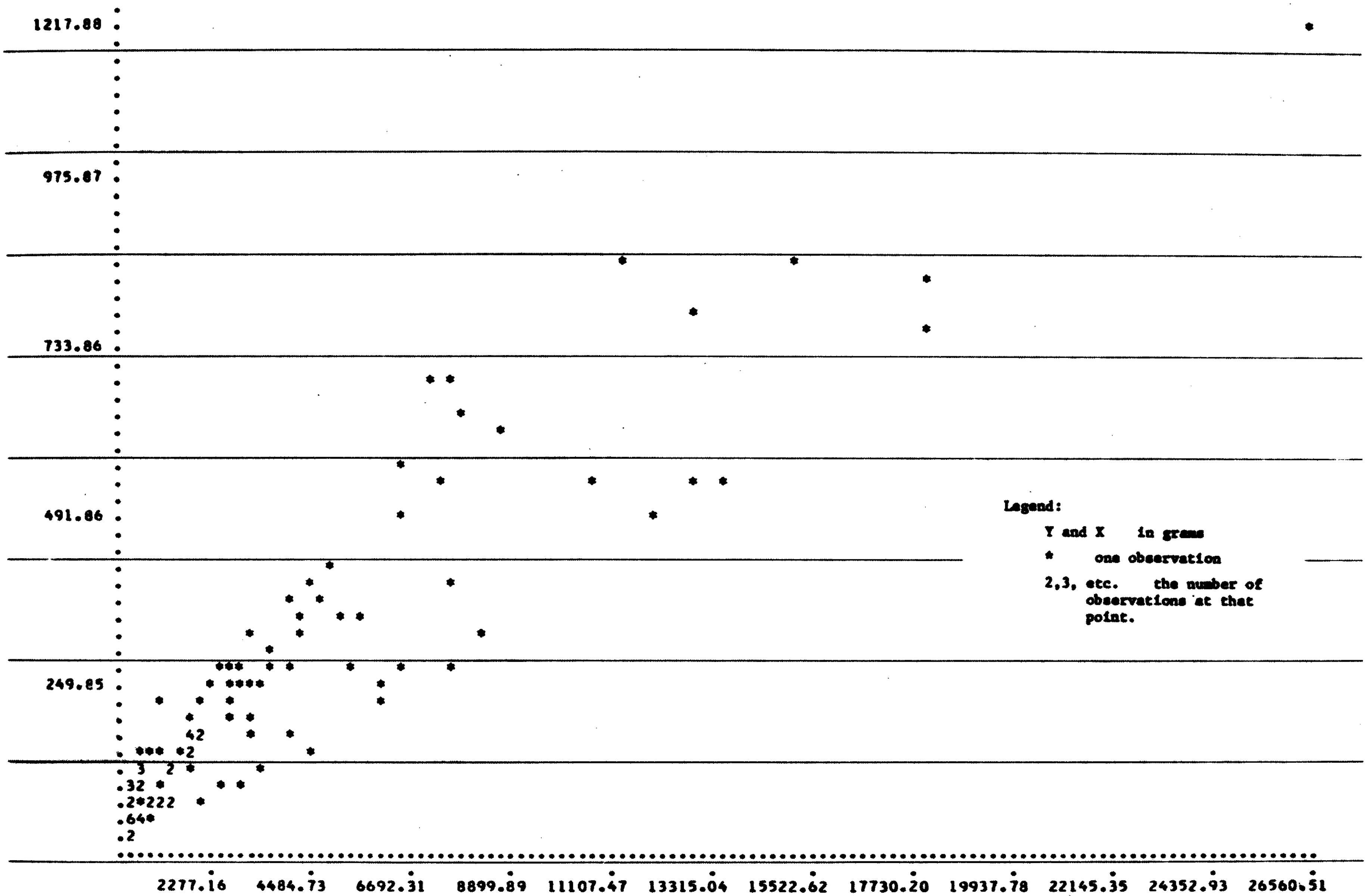
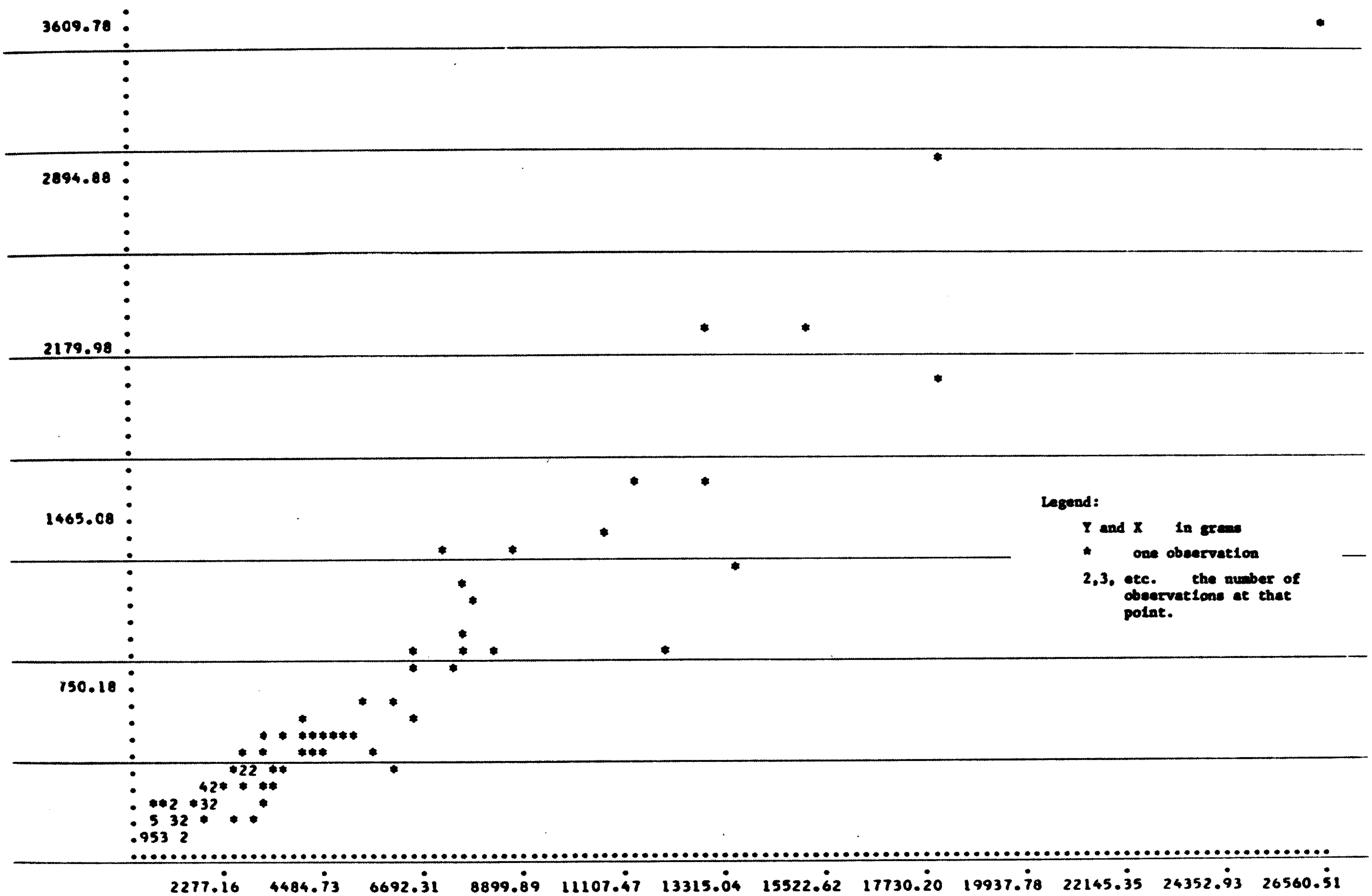
9. LEAF WEIGHT (Y) OVER TOTAL AERIAL COMPONENT WEIGHT (X)



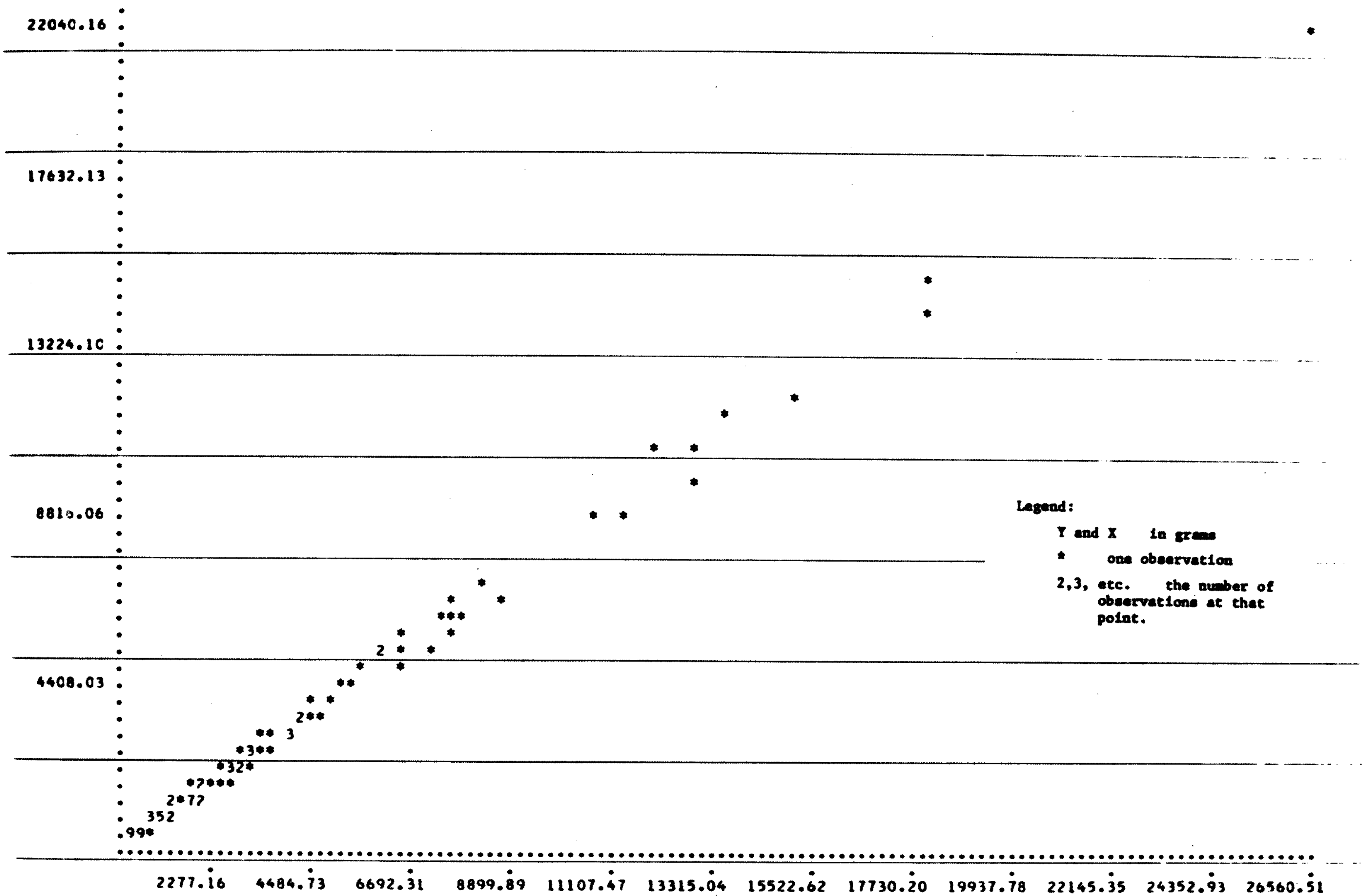
NUMBER OF OBSERVATIONS= 132
SCALE Y= 24.201 SCALE X= 220.758

10. BRANCH WEIGHT (Y) OVER TOTAL AERIAL COMPONENT WEIGHT (X)



NUMBER OF OBSERVATIONS= 132
SCALE Y= 71.490 SCALE X= 220.758

11. STEM TOTAL (WOOD PLUS BARK) WEIGHT (Y) OVER TOTAL AERIAL COMPONENT WEIGHT (X)



NUMBER OF OBSERVATIONS= 132
SCALE Y= 440.803 SCALE X= 220.758