plant breeding. Nat. Acad. Sci. Publ. 982, 1963. — HENRY, B. W.: Disease and insects in the southwide pine seed source study plantations during the first five years. South. Conf. on Forest Tree Impr. Proc. 5: 12—17, 1959. — HOLST, M.: Growth of Norway spruce (*Picea abies* [L.] KARST.) provenances in eastern North America. Canada Dept. of Forestry Publ. 1022, 15 pp., 1963. — IRGENS-MOLLER, H.: Genotypic variation in photoperiodic response of Douglas-fir seedlings. Forest Sci 8: 360–62 (1962). — JOHNSSON, H.: Utvecklingen i 15- ariga försöksodlingan av tall i relation till proveniens och odlingsort. Svenska Skogsv. Fören. Tidskr. 53: 58–88 (1955). — LANGLET, O.: Studier över tallens fisiologiska variabilitet och des samband med klimatet. Meddel. Statens Skogsförsöksanst. 29: 219 –470 (1936). — LANGLET, O.: The Norway spruce provenance experiments at Dönjelt and Hjuleberg. Stockholm, 8 pp., Mimeo., 1963. — MATZINGER, D. F.: Experimental estimates of genetic parameters and their applications in self-fertilizing plants, p. 253–279. *In* W. D. HANSON and H. F. ROBINSON, (ed.), Statistical genetics and plant breeding. Nat. Acad. Sci. Publ. 982, 1963. — MIROV, N. T., DUFFIELD, J. W., and LIDDICOET, A. R.: Altitudinal races of *Pinus ponderosa* — a 12-year progress report. J. Forestry 50: 825—831 (1952).— PERRY, T. O.: Racial variation in the day and night temperature requirements of red maple and loblolly pine. Forest Sci. 8: 336–344 (1962). — RUDOLF, P. O.: Winter damage and seed source of planted pines in northern Minnesota. Minn. Acad. Sci. Proc. 17: 74—79, 1949. — RUDOLPH, T. D.: Lammas growth and prolepsis in jack pine in the Lake States. Forest Sci. Monog. 6., 70 p., 1964. — RYCROFT, H. B., and WICHT, C. L.: Field trials of geographical races of *Pinus pinaster* in South Africa. Pretoria, Dept. of Forestry. Brit. Empire Forestry Conf. 12 pp., 1947. — SANTAMOUR, F. S., JR.: Seasonal growth in white pine seedlings from different provenances. Northeast. Forest Expt. Sta., Forest Res. Note 105., 4 pp., 1960. — SCHREINER, E. J., LITTLEFIELD, E. W., and ELIASON, E. J.: Results of 1938 IUFRO Scotch pine provenance test in New York. Northeast. Forest Expt. Sta. Pap. 166, 23 pp., 1962. — SLUDER, E. R.: A white pine provenance study in the southern Appalachians. Southeastern Forest Expt. Sta. Res. Pap. SE-2, 16 pp., 1963. — SNYDER, E. R., and ALLEN, R. M.: Sampling, nursery, and year-replication effects in a longleaf pine progeny test, p. 26–27. Proc. Forest Genet. Workshop, Macon, Georgia. Oct. 1962. Southern Forest Tree Impr. Com. Publ. 22, 1963. — WAKELEY, P. C.: Results of the southwide pine seed source study through 1960–1961. South. Conf. on Forest Tree Impr. Proc. 6: 10–24, 1961. — WIEDEMANN, E.: Die Versuche über den Einfluß der Herkunft des Kiefernsamens aus der preußischen forstlichen Versuchsanstalt. Z. Forst- u. Jagdw. 62: 498–522, 809–836 (1930). — WRIGHT, J. W., and BALDWIN, H. J.: The 1938 International Union Scotch pine provenance test in New Hampshire. Silvae Genetica 6: 2–14 (1957). — WRIGHT, J. W., and BULL, W. IRA: Geographie Variation in Scotch pine. Silvae Genetica 12: 1–25 (1963). — WRIGHT, J. W., LEMMIEN, W. L., and BRIGHT, J.: Geographic variation in eastern white pine — 6-year results. Quart. Bull., Mich. Agr. Exptl. Sta., East Lansing, 45: 691–697 (1963).

Assessment of Stem Form in Clones and Progenies of Larch

By H. KEIDING and H. C. OLSEN

Arboretum Hørsholm, and Forest Research Institute, Springforbi, Denmark

(Received for publication December 20, 1964)

Introduction

As part of a general assessment of clone collections and progeny trials in larch it was desired to study the variation and inheritance of stem form. Beside vigour, straightness of stem plays an important part in the evaluation of parent trees for breeding. Various methods for measuring and scoring stem form have been suggested by different workers, especially in connection with provenance trials. These methods may roughly be divided into 3 groups. Firstly evaluation based solely on measurements: PERRY (14), GENYS (4) and SHELBOURNE (15). Secondly evaluation based solely on scoring: GØHRN (5), LANGNER (9), LITTLEFIELD and ELIASON (11), and SØEGAARD (16) and thirdly an evaluation based on a mixture of measurements and scoring: FISCHER (3).

Stem form is usually assessed by three kinds of deviations from the straight: Crooks (sinuosity), basal sweep and lean. In general it is believed that crookedness is to a considerable extent genetically determined and that basal sweep and lean are mainly the result of factors such as wind and site.

In the current investigations of larch our aim was to find a practical method of assessment, which at one and the same time gave us a sufficiently detailed picture of the variation in stem form, and made it possible to sort out the least desirable parents from the point of view of crookedness. Various means of measuring crooks and basal sweeps have been contemplated but no satisfactory method was found, which would enable us to measure a large number of trees within a reasonable time.

We therefore decided to classify the material into 5 groups, each group being defined and illustrated by type trees. The distribution of trees in the 5 classes was registered for each clone or progeny. These distributions were compared and formed the basis for grading the material.

Material

Stem form was scored in two clone collections of Japanese larch (*Larix leptolepis*) and in one of European larch (*Larix* decidua). Further scoring was done in a progeny trial of Hybrid larch from controlled crossings between parents from the clone collections.

The clones were all grafted in 1953 and were thus 10 years old at the time of assessment. They represent a selection of plus trees made by Dr. C. SYRACH LARSEN (V-numbers) and by H. BARNER (K-numbers). One of the clone collections of Japanese larch and that of European larch are situated in the same experimental field at the State Forest Plant Breeding Station at Humlebaek. The soil here is of a rather heavy, clayish nature. The second clone collection of Japanese larch and the progeny trial of the hybrids are a few kilometers apart at Viborg State Forest district in the central part of Jutland. The soil here is lighter and more sandy and the climate of a more continental type with heavier frosts and stronger winds than that of Humlebaek. The two clone collections of Japanese larch are duplicates.

The lay-outs of the clone collections and the progeny trial are as follows: –

Clone collections:

1. Humlebaek, Birkemarken: Randomized block design with 3 replications and 4 trees per plot. Number of clones is for Japanese larch, 32, and for European larch, 27. Planting distance: 3 X 3 m.
2. Viborg district: Randomized block design with 2 replications and 6 trees per plot. 33 clones and planting distance, 3 X 3 m.

Progeny trial, Viborg district:

Randomized block design with 3 replications and 50 trees per plot. 39 progenies of which 5 are replicated twice only. The progenies consist of two groups of halfsibs of 19 and

20 progenies respectively. The experiment was planted in 1957 with 2 year old plants. Trees were thus 8 years old at the time of assessment. Planting distance: 3×1.3 m.

Method

The 5 classes mentioned above are illustrated in *figures 1–5*. In defining the classes we have attempted to cover the range of variation commonly observed in larch. The classes represent an increasing degree of crookedness from the absolutely straight to severe crooks. They are defined as follows:

Class 1: Straight.
Class 2: Crooks small, 1–2 in number.
Class 3: Crooks small, 3 or more in number.
Class 4: Crooks pronounced, 1–2 in number.
Class 5: Crooks pronounced, 3 or more in number.

Apart from basal sweeps the whole stem has been assessed. In support of the photographs of the type trees the following rules were used for the distinction between straight, small crooks and pronounced crooks:

Straight: Absolutely straight without any crooks.

Small crooks: If the crooks do not traverse a line from the base to the top of the tree the crooks are definitely small and they are believed to be of minor importance to the quality of the stem.

Pronounced crooks: If the crooks are visible in a stem with a diameter of 10 cm or more at breast height the crookedness is severe and will probably reduce the quality of the stem considerably.

A crook is defined as the distance from the top of one curve to the next on the same side of the tree.

Basal sweep is, in accordance with GENYS (4), the J-shaped lower part of the tree. Basal sweeps are recorded separately as will be seen in the form at *figure 6*.

It will be noted from the classification and the supporting rules that the greatest importance is attached to the distinction between small and pronounced crooks, i. e. between classes 2–3 and 4–5.

A form for the assessment in the field is shown in *figure 6*. Each tree is in turn registered in one or possibly two of the classes and basal sweeps or breaks are noted. In the clone collections all the grafts were secored, while in the progeny trial only 10 trees per plot or 30 trees per progeny

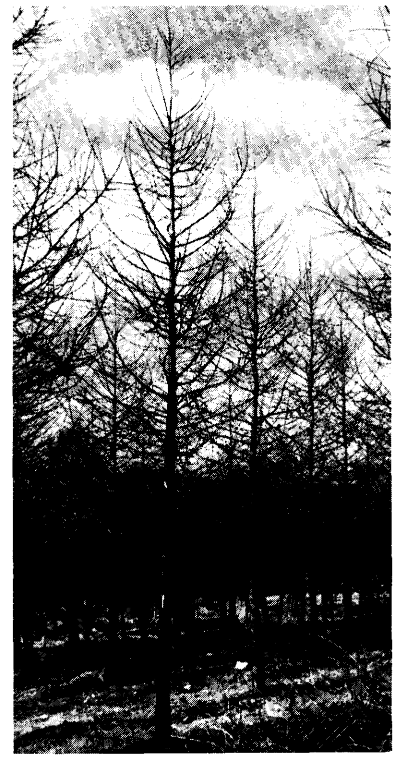

Fig. 2. — Scoring: Class 1: 1/4. Class 2: 3/4. Hybrid larch, S. 2986, 9 years old.

Fig. 1. — Scoring: Class 1: 1. Japanese larch, K. 51, 11 years old.

Fig. 3. — Scoring: Class 3: 1. Hybrid larch, S. 2987, 9 years old.

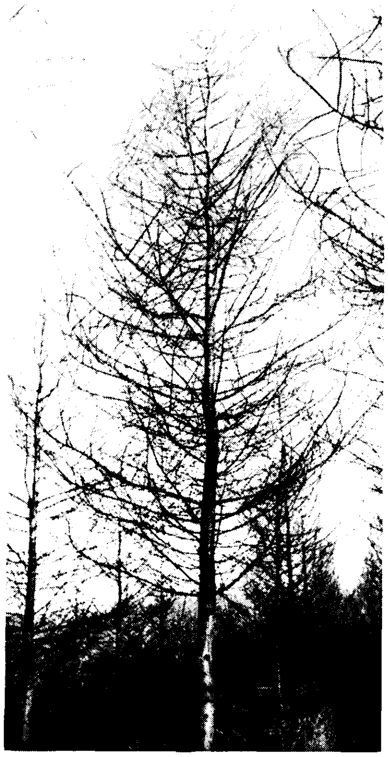

Fig. 4. — Scoring: Class 3: 3/4. Class 4: 1/4. Hybrid larch, S. 2988, 9 years old.

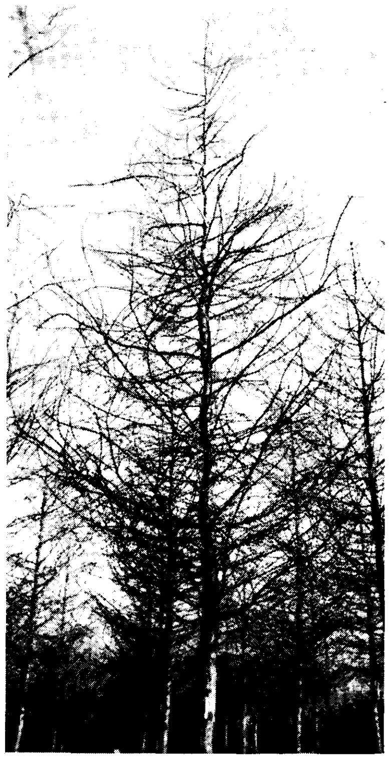

Fig. 5. — Scoring: Class 5: 1. Hybrid larch, S. 2962, 9 years old.

were registered. Normally it is fairly easy to place a tree in one class or another. If however doubt arises the tree may be registered with a fraction in both classes say ¼ and ¾. The sum of trees distributed over different classes should always equal the number of trees scored.

Basal sweeps and breaks, although recorded, are not treated in the following discussion.

Results

Variation between clones: An illustration of the variation between clones is best seen in *table 1*, where the clones from the three clone collections are arranged in order of merit. The succession from the top to the bottom of the table represents an increasing degree of crookedness. As a criterion for the ranking the percentage of trees in the merged classes 4 and 5 had priority. The clones having no trees in the classes 4 and 5 were arranged by decreasing percentage in class 1. It is obvious from this table that the clones in all 3 clone collections show a wide range of crookedness. There seems to be little doubt that real differences between genotypes exist but it has not been possible to apply a Chi-square test as the expected frequencies are less than 5 in some classes.

Variation within clones: As might have been expected most clones show comparatively little variation between the 12 grafts scored. This is demonstrated by the histograms in *figure 7*. Normally the stem form varies between two or

Species: *Hybrid Larch, No. 656* Plot no: *122, 172*
Locality: *Ulvedal, Viborg district* Date: *5-3-1964*

	tree no.:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20						sum I	sum II
straight						1/4														1/4							*0,50*	
small crooks	1—2		/	/	/	3/4	/	/				/		/		/	/	/	/	3/4	/						*13.50*	
	2—more								/	/	/		/		/												*5,00*	
pronounced crooks	1—2	/																									*1,00*	
	3—more																										—	

no. of trees registered: 20,00

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20						sum	%
basal sweep	slight																											
	pronounced																											
number of breaks		/					/									/											*3*	

Fig. 6. — Scoring of stem crookedness.

Table 1. — Clones arranged in order of merit based on the percentage assignment of trees to classes.

Japanese Larch Stendalgard						Japanese Larch Birkemarken						European Larch Birkemarken					
Clone	class					Clone	class					Clone	class				
	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
K. 51	50	50	0	0	0	K. 36	65	35	0	0	0	V. 618	25	75	0	0	0
K. 44*	20	71	9	0	0	K. 46	60	40	0	0	0	V. 622	6	69	25	0	0
K. 36	16	42	42	0	0	K. 51	42	58	0	0	0	K.1 92*	5	68	27	0	0
V. 634	15	27	58	0	0	K. 43	33	67	0	0	0	V. 981	4	88	8	0	0
V. 633	7	85	8	0	0	V. 631	15	77	8	0	0	V. 1860	0	92	8	0	0
V. 1859	2	48	50	0	0	K. 52	12	25	63	0	0	V. 621**	0	90	10	0	0
K. 52	0	100	0	0	0	K. 37	8	84	8	0	0	V. 983	0	8	92	0	0
K. 39	0	8	90	0	2	V. 634	6	77	17	0	0	Vø. 4	0	33	65	0	2
K. 49	0	33	65	0	2	K. 50	4	21	75	0	0	K. 194	0	8	88	0	4
K. 53	0	96	0	0	4	K. 44*	2	89	9	0	0	V. 44*	0	0	95	0	5
K. 37*	0	18	77	0	5	V. 975	2	31	67	0	0	K. 191**	0	60	30	10	0
V. 631	6	42	42	10	0	K. 49	2	15	83	0	0	V. 982	0	0	90	0	10
K. 45	0	25	65	8	2	K. 41	2	6	92	0	0	K. 189**	0	20	68	0	12
K. 55	0	88	0	0	12	V. 633*	0	73	27	0	0	V. 617	8	33	45	8	6
K. 50**	0	0	85	10	5	K. 39	0	67	33	0	0	V. 980	0	0	86	8	6
K. 41	0	8	77	8	7	K. 47	0	58	42	0	0	Vø. 55*	0	0	80	9	11
K. 43	2	64	15	17	2	K. 38	0	0	96	4	0	V. 418	0	8	71	8	13
K. 56	0	33	48	17	2	K. 55	0	0	96	4	0	V. 977*	0	0	76	8	16
K. 46*	30	34	9	27	0	K. 53	0	25	65	8	2	K. 193*	0	9	64	18	9
V. 1376*	0	9	62	27	2	V. 632	0	8	80	8	4	Vø. 58**	0	11	61	11	17
V. 975	0	0	71	25	4	K. 48	0	8	79	0	13	V. 984	0	0	71	25	4
V. 1378**	3	57	10	27	3	K. 54	0	0	83	0	17	K. 195*	0	9	57	18	16
K. 58	0	0	67	0	33	V. 1859	6	67	5	19	0	K. 188**	0	10	48	40	2
K. 54	0	0	63	25	12	K. 40	0	0	81	8	11	Vø. 56	0	0	38	49	13
K. 40	0	0	62	25	13	V. 1858*	0	25	55	20	0	V. 620	0	0	29	17	54
V. 1858	0	33	25	42	0	V. 1376*	0	0	71	18	11	K. 190**	0	0	15	20	65
K. 47*	0	7	48	38	7	K. 45	0	8	63	17	12	V. 978	0	0	6	25	69
K. 42	0	8	42	25	25	K. 58	0	0	71	8	21						
V. 632*	0	0	45	55	0	V. 1378**	0	20	40	40	0						
K. 38	0	0	42	8	50	K. 42	15	2	27	56	0						
K. 48	0	0	40	33	27	V. 635	0	0	40	41	19						
K. 57	0	0	19	8	73	K. 57*	0	0	7	18	75						
V. 635	0	0	4	8	88												
Mean	4.6	29.9	40.6	13.4	11.5	Mean	8.6	30.8	46.4	8.4	5.8	Mean	1.8	25.6	50.1	10.1	12.4

* 11 trees scored. ** 10 trees scored. In all the rest 12 trees have been scored.

Table 2. — Hybrid Larch progenies arranged in order of merit. Percentage assignment to quality classes.

European Larch V. 44 × Japanese Larch							Japanese Larch V. 634 × European Larch						
No.	Male parent	class					No.	Male parent	class				
		1	2	3	4	5			1	2	3	4	5
645	K. 39	2	16	80	0	2	636	V. 982	13	50	36	0	1
644	K. 38	0	3	94	3	0	634	V. 980	7	35	56	0	2
648	K. 43	0	23	74	0	3	628	K. 200	2	17	79	2	0
660	V. 634	0	13	84	0	3	631	V. 977	2	25	71	0	2
657	K. 187	3	24	68	3	2	633	V. 979	4	46	47	3	0
656	K. 186	2	49	44	3	2	635	V. 981	4	37	56	0	3
658*	V. 631	0	25	70	5	0	629*	K. 202	5	55	36	0	4
643	K. 37	0	7	87	3	3	632	V. 978	7	79	7	7	0
651	K. 56	2	19	70	7	2	625	K. 196	0	20	72	3	5
646	K. 40	0	16	74	1	9	627	K. 198	0	9	82	3	6
642	K. 36	2	30	57	3	8	637	V. 983	0	23	67	10	0
659	V. 632	0	17	68	10	5	623	K. 194	0	10	77	10	3
654*	K. 184	0	5	77	10	8	624	K. 195	0	10	77	10	3
649	K. 50	0	0	81	13	6	622	K. 192	5	18	61	10	6
647	K. 41	1	10	62	20	7	626	K. 197	0	33	49	8	10
655*	K. 185	0	0	71	15	14	621	K. 190	0	10	70	7	13
653	K. 58	0	0	69	17	14	620	K. 189	1	6	72	10	11
652	K. 57	0	0	66	17	17	630	V. 44	0	18	59	17	6
650	K. 54	0	10	52	27	11	638*	V. 984	0	15	56	10	19
661	V. 975	0	0	52	17	31							
Mean		0.6	13.3	70.0	8.7	7.4	Mean		2.6	27.2	59.5	5.8	4.9

* 20 trees scored. In all the rest 30 trees have been scored.

three classes with the majority of trees concentrated in one of the classes. Some clones however have a more even distribution to the different classes and examples are K. 42, 46, 47 and K. 48. They seem to be less stable or perhaps more easily influenced by smaller changes in environment such as site, stock/scion relationship, or more or less successfull grafting. This quality of some clones is also apparent when comparisons are made between the grafts of one clone on two different sites.

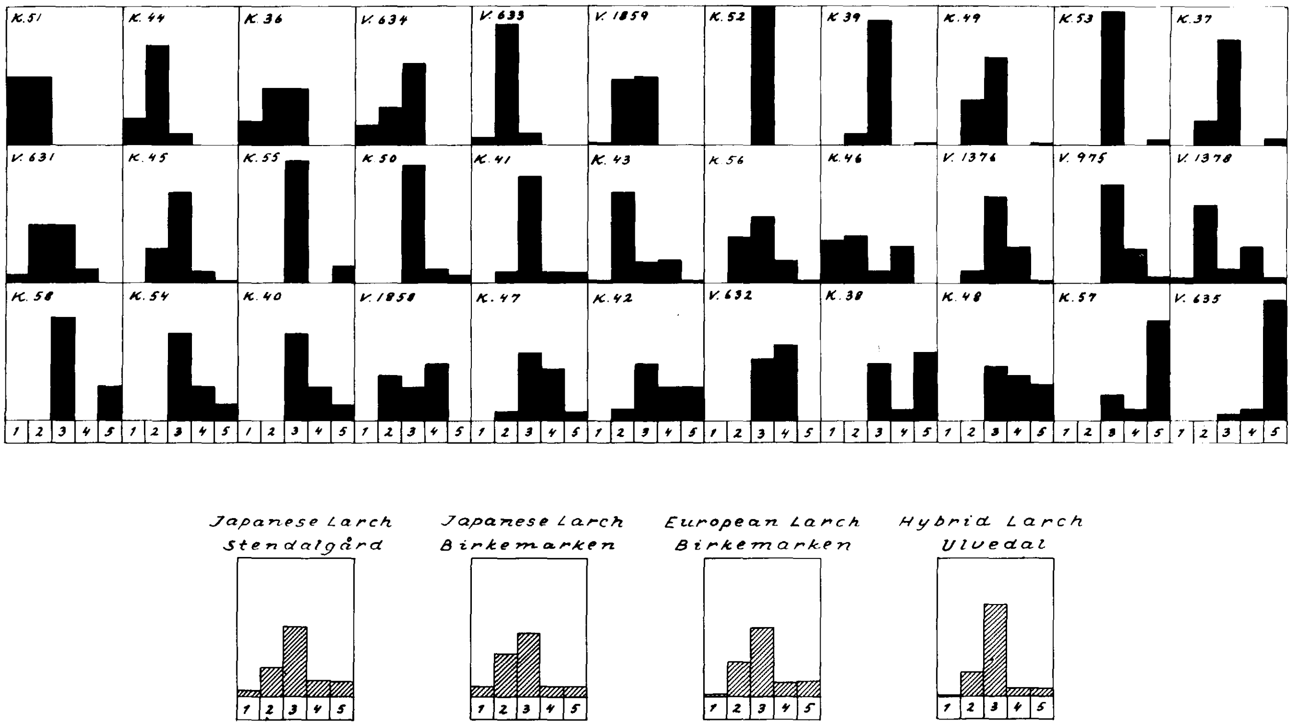

Fig. 7. — Histograms showing the percentage assignment to classes of individual clones of Japanese larch, Stendalgård. The 33 clones are arranged in order of merit from the top left to the bottom right. — The 4 shaded histograms below illustrate the mean distribution of the clone collections and the progeny trial. — The number 1—5 denote classes.

The influence of environment on stem form: As already mentioned there are two clone collections of Japanese larch, each having the same set of 32 clones, but located on different sites and under different climatic conditions. In order to find out how much the environment might influence the stem form the mean distributions for the two clone collections were compared. A Chi-square test of the two mean distributions showed a significant difference at the 95% level. A closer examination of each clone at the two sites revealed that almost all the clones at Stendalgård, Jutland were slightly more crooked than their counterparts at Birkemarken, Sjaelland and that 5 clones: V. 635, K. 36, K. 38, K. 47 and K. 48 differed markedly. However excluding V. 635 from the test (this clone being the most variable of the five) resulted in the Chi-square value = 7.60 which is less than the tabulated value 7.81 for 3 df. at P: 0.05. This shows that site effect, although present, has relatively little influence on stem form in the majority of the clones.

Further the clones at the two sites were ranked according to their degree of crookedness *(table 3)*. The coefficient of rank correlation was worked out for Stendalgård and Birkemarken and gave very good correlation between the two sites. The calculated figure for the coefficient of rank correlation was 4.536, which is highly significant. Apparently the environmental differences have influenced the relative merit of the clones very little.

From these observations it seems that comparison of clones in respect of stem form gives almost the same result at two different sites.

Variation between progenies of Hybrid Larch: Of the 39 progenies present in the experiment, 34 were replicated three times and from each progeny 30 trees were scored. The 10 trees per plot were taken as follows: Every alternate tree in row 2 and 4 was registered starting with tree No. 1 in row 2 and tree No. 2 in row 4. Each plot was ori-

Table 3. — Rank correlation between clones of Japanese Larch at two sites, Birkemarken and Stendalgård.

Clone	Rank Birkemarken	Rank Stendalgard	Rank difference
K. 36	1	3	2
K. 46	2	18	16
K. 51	3	1	−2
K. 43	4	17	13
V. 631	5	12	7
K. 52	6	7	1
K. 37	7	11	4
V. 634	8	4	−4
K. 50	9	15	6
K. 44	10	2	−8
V. 975	11	20	9
K. 49	12	9	−3
K. 41	13	16	3
V. 633	14	5	−9
K. 39	15	8	−7
K. 47	16	26	10
K. 38	17	29	12
K. 55	18	14	−4
K. 53	19	10	−9
V. 632	20	28	8
K. 48	21	30	9
K. 54	22	23	1
V. 1859	23	6	−17
K. 40	24	24	0
V. 1858	25	25	0
V. 1376	26	19	−7
K. 45	27	13	−14
K. 58	28	22	−6
V. 1378	29	21	−8
K. 42	30	27	−3
V. 635	31	32	1
K. 57	32	31	−1

Number of clones: 32

Sum of squared differences: 1976

Rank correlation coefficient: $R = 1 \div \frac{6 \times 1976}{32\,(1024 \div 1)} = 0.638^{+++}$

Student's $t = 0.638 \sqrt{\frac{30}{1 - 0.638^2}} = 0.449$ for df. = 32 — 2 = 30.

Table 4. — Chi-square test of the hybrids Jap. Larch V. 634 × Eur. Larch.*)

No.	class 1	2	3	4	5	Sum	Male parent
620	0.25	1.75	21.75	3.00	3.25	30	K. 189
621	—	3.00	21.00	2.00	4.00	30	K. 190
622	1.50	5.50	18.25	3.00	1.75	30	K. 192
623	—	3.00	23.00	3.00	1.00	30	K. 194
624	—	3.00	23.00	3.00	1.00	30	K. 195
630	—	5.50	17.75	5.00	1.75	30	V. 44
631	0.50	7.50	21.50	—	0.50	30	V. 977
632	—	2.00	24.00	2.00	2.00	30	V. 978
634	2.00	10.50	16.75	—	0.75	30	V. 980
635	1.25	11.00	16.75	—	1.00	30	V. 981
636	4.00	15.00	10.75	—	0.25	30	V. 982
637	—	7.00	20.00	3.00	—	30	V. 983
Total	9.50	74.75	234.50	24.00	17.25	360	
	84.25		275.75				

*) Only progenies in which 30 trees were scored have been tested.

Chi² = (total number)

$$\text{Chi}\sum\left(\frac{(\text{number of trees per class within each clone})^2}{(\text{number of trees per clone}) \times (\text{total number per class})} \div 1\right)$$

$= 360 \times (1.15651 - 1) = 56.34^{+++}$

Tabulated Chi² at P: 0.01 for 11 df. = 24.73

ginally planted in 5 rows of 10 trees. In some cases it was necessary to extend the scoring to row 5 when trees were missing in the other rows. In the actual scoring all 5 classes were used but in the comparison of the frequency distributions it was necessary to merge the classes into two groups comprising class 1 + 2 and class 3 + 4 + 5 respectively in order to get the expected frequency above 5. The Chi-square test of the 34 progenies has shown highly significant differences between their distributions. Both groups of halfsibs mentioned above were also subjected to Chi-square tests *(tables 4 and 5)*. Of the hybrids having V. 634 as common mother, 12 of the male parents were present in the clone collection of European larch. These 12 progenies were significantly different with a Chi-square of 56.43 (tabulated value 24.73 for 11 df. at P: 0.01) which indicate considerable differences in breeding value of the male parents. It appears that three progenies, Nos. 634, 635 and 636, all with Polish larch as males distinguish themselves in respect of better stemform. Similarly 15 progenies with the European larch, V. 44, as the common mother were

Table 5. — Chi-square test of the hybrids Eur. Larch V. 44 × Jap. Larch.*)

No.	class 1	2	3	4	5	Sum	Male parent
642	0.75	9.25	16.75	1.00	2.25	30	K. 36
643	—	2.00	26.00	1.00	1.00	30	K. 37
644	—	1.00	28.00	—	1.00	30	K. 38
645	0.50	4.75	24.00	—	0.75	30	K. 39
646	—	4.75	22.25	0.25	2.75	30	K. 40
647	0.25	3.00	18.75	6.00	2.00	30	K. 41
648	—	7.00	22.00	—	1.00	30	K. 43
649	—	—	24.25	4.00	1.75	30	K. 50
650	—	3.00	15.75	8.00	3.25	30	K. 54
651	0.50	5.75	21.00	2.00	0.75	30	K. 56
652	—	—	20.00	5.00	5.00	30	K. 57
653	—	—	20.75	5.00	4.25	30	K. 58
659	—	5.00	20.50	3.00	1.50	30	V. 632
660	—	4.00	25.00	—	1.00	30	V. 634
661	—	—	15.75	5.00	9.25	30	V. 975
	2.00	49.50	320.75	40.25	37 50	450	
	372.25		77.75				

*) Only progenies in which 30 trees were scored have been tested.

Chi² = $450 \times (1.14053 - 1) = 63.23^{+++}$ (see note under table 4)

Tabulated Ch² at P: 0.01 for 14 df. = 29.14

tested and significant differences found at P: 0.01 (Chi-square 63.23 against 29.14 for 14 df.). For the same reasons as mentioned above the classes 1, 2 and 3 as well as 4 and 5 were merged in this test.

Finally it is interesting to compare the average distribution of each of the 3 clone collections with that of the progeny trial. From the shaded histograms in *figure 7* it will be seen that the distribution of the hybrids is different from those of the clones. The former shows a greater uniformity expressed by the higher concentration of trees in class 3. It is probably the constitution of the progeny trial in two equal groups of halfsibs which is responsible for the smaller variation between the hybrids.

Variation within progenies: In contrast to the variation between progenies the trees within progenies in general vary more than the grafts within a clone. Most progenies are represented in 4 classes. Only 10 out of 39 progenies have trees registered in 3 classes and none in 2 or 1. For comparison the clone collection of Japanese larch at Stendalgård have 9 clones registered in 4 classes, 18 in 3, 5 in 2 classes and 1 in 1 class only.

Offspring in relation to clones: It has been demonstrated that a considerable variation in stem form exists between clones of both Japanese and European larch. Further it has been proved that offspring, having a sample of these clones as parents, belong to significantly different distributions. The scoring of clones gives us the genotypes of the selected individuals, or an approximation to the genotypes depending of how much we can reduce the environmental factors by the number of grafts and replications in the experimental design. The scoring of the progenies on the other hand may give the breeding value of the same clones provided the proper means of comparison are available. Although our chief concern is the breeding value, and in this context the breeding value in respect of stem form, it is of considerable interest to see whether the stem form of the clones are correlated with the stem form of their offspring. Often in the early stages of a breeding programme seed orchards have been established on basis of the parent trees' superior phenotypic value or perhaps on their good genotypic value judged from the clone collections.

Table 6. — Rank correlation beteween male parents of European Larch (clones) and offspring of Hybrid Larch (V. 634 × European Larch).

Male parent	Rank	Offspring	Rank	Rank difference
K. 192	1	622	9	−8
V. 981	2	635	4	−2
V. 983	3	637	6	−3
K. 194	4	623	7	−3
V. 44	5	630	12	−7
V. 982	6	636	1	5
K. 189	7	620	11	−4
V. 980	8	634	2	6
V. 977	9	631	3	6
V. 984	10	638	13	−3
K. 195	11	624	8	3
K. 190	12	621	10	2
V. 978	13	632	5	8

Number of clones: 13

Sum of squared differences: 334

Rank correlation coefficient: $R = 1 \div \frac{6 \times 334}{13\,(169 \div 1)} = -0.124$

Student's $t = -0.124 \sqrt{\frac{11}{1 - (-0.124)^2}} = -0.414$ for df. = 11.

Tabulated $|t| = 2.201$ for P: 0.05.

Table 7. — Rank correlation between male parents of Japanese Larch (clones) and offspring of Hybrid Larch (V. 44 × Japanese Larch).

Male parent	Rank	Offspring	Rank	Rank difference
K. 36	1	642	9	−8
V. 634	2	660	4	−2
K. 39	3	645	1	2
K. 37	4	643	6	−2
V. 631	5	658	5	0
K. 50	6	649	11	−5
K. 41	7	647	12	−5
K. 43	8	648	3	5
K. 56	9	651	7	2
V. 975	10	661	16	−6
K. 58	11	653	13	−2
K. 54	12	650	15	−3
K. 40	13	646	8	5
V. 632	14	659	10	4
K. 38	15	644	2	13
K. 57	16	652	14	2

Number of clones: 16

Sum of squared differences: 418

Rank correlation coefficient: $R = 1 \div \frac{6 \times 418}{16\ (256 \div 1)} = 0.385$

Student's $t = 0.385 \sqrt{\frac{14}{1 - 0.385^2}} = 1.56$ for df. = 14.

Tabulated $|t| = 2.160$ for P: 0.05.

From the current investigations it was possible to compare the stem form of some clones with the stem form of those progenies in which the clones acted as male parents. The rank correlation coefficient between clones and their progenies was calculated in two cases: (1) Between 13 clones of European larch and their progenies (halfsibs with Japanese larch V. 634 as common mother) and (2) between 16 clones and their progenies (halfsibs with European larch V. 44 as common mother) (See *tables 6 and 7*). Neither of the two correlation coefficients were significant, indicating that no relation between the ranks of clones and their offsprings in respect of stem form could be proved. In the group of V. 634 × European larch, three clones, V. 977, 978 and 980 impressed their offspring with a much better stem form than might have been expected from the clone collection while two clones, V. 192 and V. 44, were a good deal below expectation. In the other group of V. 44 × Japanese larch, K. 38 gave rise to a much better progeny than expected and K. 36 and V. 975 a good deal below expectation.

These discrepancies in the ranking of clones and offspring should not be ignored. It is confirmed by the observations of the Japanese clone V. 975, which gives a much more crooked offspring than its genotype would indicate. Being included in several seed orchards it now must be removed or the seed orchards be given up.

Discussion

In describing our material of clones and progenies we have found a division into 5 classes convenient. In our experience it covers the range of variation of stem form reasonably well and it helps us in grading the material without specifying the value of the individual classes. It will be noted that all description is essentially a registration of single trees into classes, and as distinct from other methods of scoring stem form except Søegaard's (16), comparisons and tests are between frequency distributions. Admittedly our material did not suffice for a complete application of the scoring system, because the number of trees of the individual clones and progenies often was too small.

As will be appreciated from the preceding sections the expected frequencies were in some cases insufficient (less than 5) to allow for a Chi-square test. Where the tests have been applied it was necessary to merge neighbouring classes to obtain expexted frequencies of at least 5.

Therefore in new descriptions it seems reasonable to score about 40—50 trees and perhaps subdivide class 3 (small crooks, 3 or more in number) into two classes thus working with 6 classes in all.

The scoring of clones and progenies with subsequent gradings and tests has emphasized the different genetical values which might be deduced from the two kinds of material. The classification of clones in order of increasing crookedness may help to evaluate the *genotypic value* of the selected material. A similar classification of progenies gives us a possibility to assess the *breeding value* of the parents, which in our example are some of the clones in the clone collections. Some indication of the risk involved in concluding from the clone performance to the breeding value of the clones is given in the two rank correlation tests between the male parents and their offspring.

The scoring and assessment of clones have their greatest interest for the study of the variation of the selected material. If we had intended to establish plantations with vegetatively propagated material the results from the clone collections might have been applied directly. This is not likely to be done in larch but may be contemplated for other species such as beech, oak and teak. The wide range of variation between clones has already been mentioned. It may seem a little surprising that we find clones with very pronounced crooks in our selected material as the criterion for selection was among other things, straightness of stem. In our opinion it shows how difficult it may be to assess stem form in older trees of larch. This species seems to have a great ability to "straighten" out crooks which does not mean that the wood has the same quality as in trees with originally straight stems. Scoring of stem form thus seems dependant on the age of the trees. The evaluation might therefore best be carried out when crookedness is at its worst, that is, between the 5th and the 20th year.

The assessment of stem form in progeny trials as distinct from clone collections may give us an estimate of the breeding value, which is fundamental for progress in the breeding work. With one female and many male partners, as in the progeny trials treated here, we get at the most the relative merit of the male parents. We have no possibility of separating special and general combining abilities, and in working out the breeding values, that of the female partner has to be fixed arbitrarily. For a reliable estimate of the breeding value very much depends therefore on the planning of crossing series and subsequent experimental lay-outs. The recommendations of H. Johnsson, Sweden (8) for parallel crossings and triangular crossing-series should be noted.

Finally it has to be stressed that the ultimate screening of the material is based on a combined evaluation of growth rate and stem form. The order of merit may therefore be different from that of stem form only.

Acknowledgement

The classification of stem form has its origin in the description of plus trees but was modified for the scoring of clones and seedlings. For this and for later suggestions and discussions about the present system we are greatly indebted to Mr. H. Barner, the leader of the State Forest Plant Breeding and Seed Extracting Station at Humblebaek. Further we wish to thank Mr. K. Bryndum for help in working out tables and figures.

Summary

The need of a practical method for scoring and assessing stem form has long been felt. As actual measurements are found to be both difficult and time consuming to carry out, especially in extensive progeny or provenance trials, a system of scoring the material by means of 5 classes has been used. The classes are defined and illustrated by type trees. The scoring is a registration of the frequency with which the trees occur in the different classes. Without specifying the value of the individual classes the probability that the progenies or clones belong to the same distribution has been tested by Chi-square tests.

Three clone collections, two of Japanese and one of European larch, and a progeny trial of Hybrid larch have been subjected to the scoring. A demonstration of the variation between and within both clones and progenies is given in various tables and figures. In the case of the progenies significant differences in assignment to classes were proved by Chi-square tests thus reflecting differences in breeding value of the male parents. Rank correlation between clones and offsprings was tested in two instances, where the clones acted as males for a common female. No correlation was found in either test, indicating the risk of deducing breeding value from the performance of the clones.

The influence of site on stem form has been investigated for two clone collections of Japanese larch. A small effect of site was registered for a majority of clones while a few seemed more strongly influenced. The ranks of the clones at the two sites however were higly correlated.

Finally the genetic values which might be deduced from clone collections and progeny trials are discussed.

Résumé

Titre de l'article: *Mesure de la forme de la tige dans des clones et des descendances de mélèze.*

On a éprouvé depuis longtemps le besoin d'une méthode pratique d'évaluation et de mesure de la forme de la tige. Les méthodes actuelles sont difficiles à mettre en oeuvre et demandent beaucoup de temps, spécialement dans les grandes plantations comparatives de descendances ou de provenances; on a donc employé un système d'évaluation du matériel en utilisant cinq classes. Les classes sont définies et illustrées par des arbres-types. L'évaluation constitue une mesure de la fréquence des arbres dans les diverses classes. Sans tenir compte de la valeur de chaque classe, on a testé par le test de Chi-carré la probabilité pour que les descendances ou clones appartiennent à la même distribution.

On a soumis à cette méthode trois collections de clones (deux de mélèze du Japon et une de mélèze d'Europe) et un test de descendances de mélèze hybride. Les tables et les figures montrent la variation à l'intérieur et entre les clones et descendances. On a trouvé entre les descendances des différences significatives quant à la proportion des diverses classes (différences vérifiées par un test de Chi-carré), ce qui prouve l'existence de différences dans les aptitudes héréditaires (breeding value) des parents mâles. Des corrélations de rang entre clones et descendances ont été établies dans deux cas, les clones étant pris comme parents mâles pour un parent femelle commun. On n'a trouvé aucune corrélation, ce qui indique qu'il y a un risque à déduire l'aptitude héréditaire de la performance des clones.

L'influence de la station sur la forme de la tige a été étudiée pour deux collections de clones de mélèzes du Japon. Cette influence se manifeste assez légèrement pour la majorité des clones et plus fortement pour un petit nombre d'entre eux. Les classements des clones dans les deux stations sont cependant liés par une corrélation très forte.

On discute enfin les paramètres génétiques qui peuvent être déduits des collections de clones et des tests de descendances.

References

(1) Ehrenberg, Carin E.: Genetic variation in progeny tests of Scots pine (*Pinus silvestris* L.). Studia Forest. Suec., Nr. 10, 1963. — (2) Falconer, D. S.: Introduction to quantitative genetics. New York, 1961. — (3) Fischer, F.: Ergebnisse eines Versuches über die Vererbbarkeit der Wuchsform bei Lärche, mit einem Beitrag zur Methodik der Erfassung der Formmerkmale. Internat. Kongr. IUFRO, Roma, 1953, p. 437. — (4) Genys, J. B.: Geografic variation in European larch. Fox Trust Fund For. Res., Bull. No. 13, New Hampshire Forestry and Recreation Comm., 1960. — (5) Goddard, R. R., and Strickland, R. K.: Crooked stem form in loblolly pine. Silvae Genetica 13, 155—157 (1964). — (6) Gøhrn, V.: Proveniensforsøg med laerk. Det Forstl. Forsøgsv. 23, 1956. — (7) Jeffers, J. N. R.: Experimental design and analysis in forest research. IUFRO, 1959. (Uppsala, 1960.) — (8) Johnsson, H.: Riktlinjer för "korsningsförädlingen". Interdepartmental comm. — (9) Langner, W.: Kreuzungsversuche mit *Larix europaea*, D. C. und *Larix leptolepis*, Gord. Z. Forstgenetik 1, 13 (1951—52). — (10) Larsen, C. Syrach: Genetics in silviculture. Edinburgh, 1956. — (11) Littlefield, E. W., and Eliason, E. J.: Report on an experimental plantation of several species of larch in New York. Z. Forstgenetik 5, 166—169 (1956). — (12) Moroney, M. J.: Facts from figures. Pelican Books (1958). — (13) Pearson, E. S., and Hartley, H. O.: Biometrika tables for statisticians. Cambridge Univ. Press (1962). — (14) Perry, T. O.: The inheritance of crooked stem form in loblolly pine (*Pinus taeda* L.). J. Forestry 58, 943—947 (1960). — (15) Shelbourne, C. J. A.: Growth rates, stem form and branching characteristics of five provenances of *Pinus khasya* grown under plantation conditions in N. Rhodesia. Commonw. Forestry Rev. 42 (4), No. 114 (1963). — (16) Søegaard, B.: Fem søskendebestøvninger i europaeisk laerk. (Controlled pollination of five sister trees of European larch.) Det Forstl. Forsøgsv. 21, 1954.