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Seed weight of larch from different provenances (*Larix decidua* Mill.)

Frövikt hos lärk av olika provenienser

by

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Seed weight of larch from different provenances (*Larix decidua* Mill.)

European larch (*Larix decidua* Mill.) from different geographical regions of its natural range of distribution varies in seed weight. BOUVAREL & LEMOINE (1958) found that the thousand grain weight of pure seed (*cf.* BALDWIN 1942) in the various regions is very characteristic; for Polish and Sudetian larch they give values of 3.32—3.91 grams, for Eastern Alpine 4.21—6.33 grams and for Western Alpine larch 8.47—11.37 grams. These differences in seed weight are rather distinct, despite the fact that they have been found—as far as can be judged from the publication—for samples containing an unknown number of empty seeds. The empty seeds, which usually have about 70 per cent of the weight of filled seeds, can influence the thousand grain weight differently, depending upon the extent to which they occur in the samples (*cf.* LINNEMANN & al. 1956). Therefore, for comparative analyses of thousand grain weight (shortened to TGW in the text), it is desirable to use the weight of either empty or filled seeds only. However, it is rather difficult to separate empty and filled seeds of larch, owing to the small difference in their weight. In any case, the separation cannot be carried out with a seed blower, as is possible for Scots pine and Norway spruce, which have a relationship of about 1: 3 in the weight of empty and filled seeds (SIMAK 1953; VINCENT 1965). For commercial separation of larch seed, special equipment has been constructed (MESSER 1956 a; VINCENT 1965). A simple method of separating empty and filled seeds is by floating them in water; the latter sink earlier (SIMANCIK 1962 and 1965). For research purposes, the empty and filled seeds can be distinguished from each other by sectioning (MESSER 1956 b). However, this method is very time-consuming, and the seeds are lost. Empty and filled seeds can be precisely distinguished with the help of x-ray radiography (SIMAK & GUSTAFSSON 1953). HEIKEN & SØEGAARD (1962) have used this method for the determination of TGW of larch seeds from 43 provenances. As the empty and filled seeds are the same size, it is also possible to use the volume or the length of pure seed as a criterion for the comparative study of provenances. In this way, THULIN & MILLER (1964) analysed 26 provenances of *Larix decidua* and found that those from lower altitudes had seeds with smaller volume (and lower TGW) than the ones from higher elevations. Similar results were also obtained by GENYS (1960) who analysed the weight of pure seed of 33 provenances. He wrote: "At present this variation must be regarded as phenotypic. As far as known, there have been no critical experiments showing that high elevation sources produce larger seeds, if grown at low elevations." The variation in the length of larch seed from different sources has been studied by SINDELAR (1965).

In the present investigation the various difficulties in the determination of the TGW have been removed, keeping in view the experience of the authors cited above. The analyses were carried out on a large material, the origin of which had been properly checked. TGW variations were studied from genetical as well as from practical aspects. The results are presented under the following headings:

1. TGW of filled, empty and insect-attacked seeds.
2. TGW of filled seeds from autochthonous stands.
3. TGW of filled seeds of individuals from different stands.
4. TGW of filled and empty seeds in introduced provenances with known origin.

Material

Seed samples for investigation were obtained through forest institutes in the countries where larch grows. Consequently, the description of material may be considered as dependable. The origin of the provenances has also been checked from the literature, as far as possible. Important details about the material studied are given in Tables 1 and 3.

The seed collected during 1957—60 served for the laying out of provenance trials in Sweden from 1960 to 1962.

Methods and Definitions

In each provenance 200—400 seeds were studied. This number was found to be adequate, because the separation of seeds into empty, filled and insect-attacked groups had been carried out accurately by x-ray radiography (Fig. 1).

(a) *Filled seeds* are those which contain both embryo and endosperm, visible on the radiograph. The investigation showed that all seed, irrespective of origin, belonged to classes III A and IV A, according to the classification for Scots pine (MÜLLER-OLSEN & SIMAK 1954). Such seeds have well-developed endosperm and the embryo fills the embryo cavity length from 75 to 100 per cent.

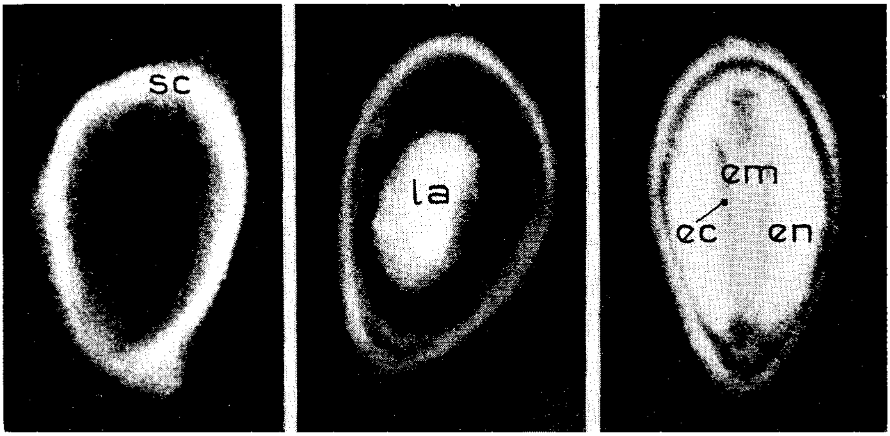

Fig. 1. Radiographs of empty, insect-attacked and filled seeds of *Larix decidua*. em = embryo, en = endosperm, sc = seed coat, ec = embryo cavity, la = larva.

(b) *Empty seeds* have neither embryo nor endosperm. The radiograph shows the seed coat only (class 0 in Scots pine).

(c) *Insect-attacked* seeds contain insect-larvae in them, visible on a radiograph.

(d) *Determination of* TGW: The empty, filled and insect-attacked seeds of all the samples were dewinged uniformly before weighing. Dewinging was carried out in such a way that nothing except that portion of the wing which is directly attached to the seed remained with it. Seeds were weighed with an analytical balance accurate to 10^{-4} grams.

(e) *Provenance* denotes the locality of larch from which the seed for analysis has been collected. Provenances can be autochthonous, introduced or unknown.

(f) *Autochthonous provenance* denotes that locality where the larch in question is indigenous.

(g) *Introduced provenance* is a foreign provenance introduced to a particular area.

(h) *TGW-frame* of a region is demarcated by the minimum and the maximum TGW values of the analysed autochthonous provenances belonging to the region in question *(cf.* Table 2).

Results

The autochthonous stands investigated here are divided into seven geographical regions (1—7, Table 1 and Fig. 2). Of these, Nos 1—4 are

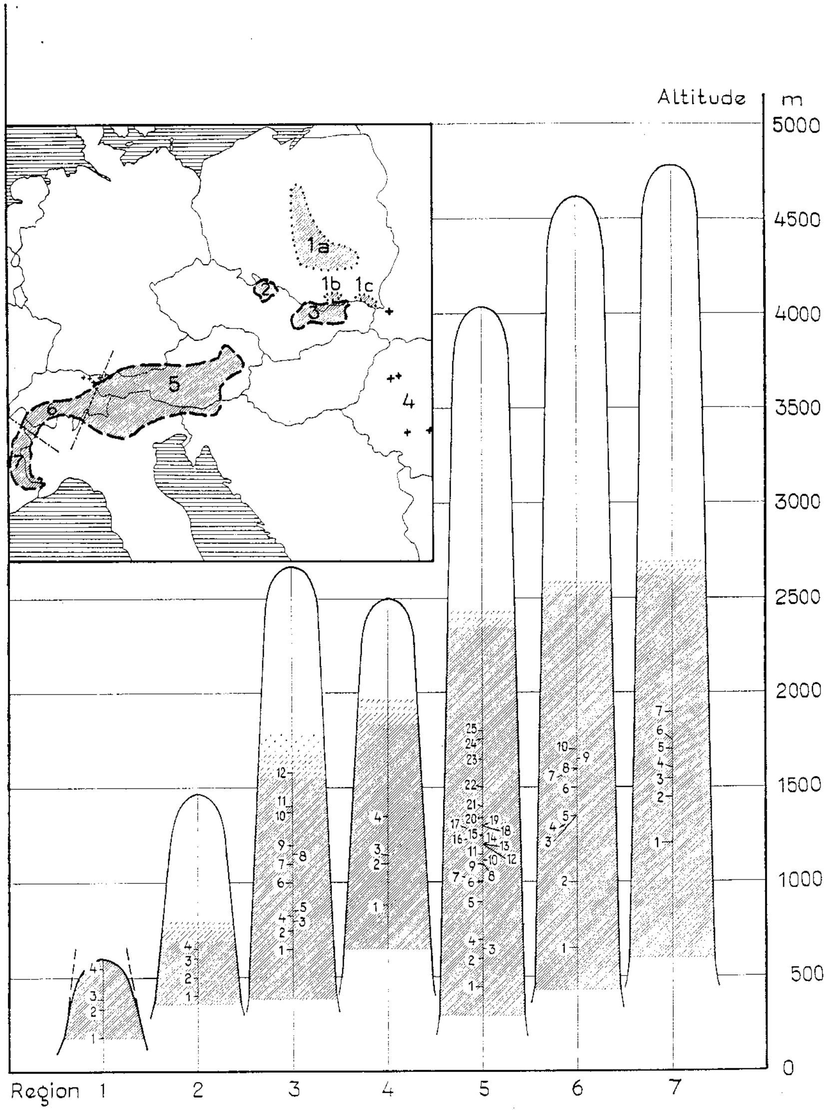

Fig. 2. Vertical and horizontal distribution of larch in its autochthonous area (shaded). + and . . . denote scattered occurrence. The height of each column denotes the maximum elevation of the mountain massif in the region in question.
The figures in white rings give the serial numbers of provenances, in order to altitude (*cf.* Table 1).

isolated regions (Polish, Sudetian, Slovakian and Rumanian), and Nos 5—7 (Eastern, Central and Western Alps) form a connected area of Alpine larch. The boundary between the Eastern and the Central Alpine regions is marked by the line going through Lake Como, Splügenpass, Hinter Rhein, and the Bodensee. Between the Central and Western Alpine regions the borderline passes through the river Dora Baltea, St. Bernardo and the Rhône. The average altitude of regions Nos 1—7 increases from east to west (excluding Rumanian larch).

The distribution of larch for the regions (Fig. 2) is based on the following literature:

Region 1. SZAFER (1913); MAUVE (1932); BALUT (1962); KUCABA (1966).
2. KRAUSS & RIEDEL (1936); RUBNER (1943); SIMAN (1943); SINDELAR (1959); NOZICKA (1962).
3. FEKETE & BLATTNY (1913); SIMAN (1943); RUBNER (1951); KNAZOVICKY (1954); SIMAK (1958 and 1961); BLATTNY & STASTNY (1959); STASTNY (1959).
4. FEKETE & BLATTNY (1913); GRINTESCU (1931).
5. TSCHERMAK (1935); MORANDINI (1956 and 1959).
6. BÜHLER (1886); HESS (1942); SIMAK (1960).
7. FOURCHY (1952); BOUVAREL (1959).

1. TGW of filled, empty and insect-attacked seeds

The differences in the weight of filled and empty seeds of a sample are shown in Table 1. When the weight of empty seeds is expressed as a percentage of that of filled seeds in a sample, the following average values are obtained for the different regions:

1. 67.7 per cent	5. 73.7 per cent
2. 70.8 »	6. 75.5 »
3. 67.3 »	7. 75.6 »
4. 69.1 »	

It seems from the above values that larches of Alpine origin tend to have relatively heavier empty seeds than those from the other regions.

Seeds containing insect-larvae were chiefly found in larches originating from low altitudes (*cf.* Table 1). On the average, the weight of such seeds was 74.4 per cent of that of filled ones. The corresponding value for empty seeds of these samples was 69.2 per cent.

The seed sample of each provenance was studied in detail radiographically and the amount of empty and insect-attacked seeds estimated. For filled seeds, the occurrence of different degrees of embryo development was noted. These results will be published in another paper.

Table 1. Information about the autochthonous stands and their seeds.

Notes: 1. In a provenance number the first figure always denotes the geographical region. The other two figures give the serial number of the provenance.
2. Asterisks mark those samples in which insect larvae have been found.
3. The figures in brackets after the locality name give the number at which the provenance in question is registered in the International Larch Provenance Expt. 1958/59.

Provenance No.	Locality	Longitude E.	Latitude N.	Altitude in metres	TGW in grams filled 1	TGW in grams empty 2	ratio $^2/_1$%
	1. Polish region						
101*	Grojec	20°50′	51°50′	180	4.25	2.79	65.6
102*	Blizyn	20°40′	50°50′	330	3.78	2.71	71.7
103	Skarzysko	20°55′	51°10′	380	3.86	2.51	65.0
104	Pieniny	20°30′	49°30′	550	4.91	3.37	68.6
	2. Sudetian region						
201	Dubicko (39)	16°58′	49°50′	400	4.60	3.24	70.4
202*	Bruntal	17°30′	50°00′	500	4.02	2.88	71.6
203*	Karlovice	17°40′	50°50′	600	3.73	2.63	70.5
204*	Krnov	17°40′	50°05′	650	4.24	2.99	70.5
	3. Slovakian region						
301*	Sabinov	21°06′	49°03′	650	4.99	3.23	64.7
302	Chmelienec (66)	20°00′	49°00′	750	6.10	3.56	58.4
303*	Ipoltica (51)	20°00′	49°00′	800	6.32	3.73	59.0
304	Brezovicka (59)	20°50′	49°07′	830	4.40	3.09	70.2
305*	Stare Hory (67)	19°08′	48°51′	850	5.13	3.50	68.2
306	Podbanske	19°56′	49°10′	1 000	5.17	3.43	66.3
307	Cierny Vah	20°00′	49°00′	1 100	6.74	4.77	70.8
308	Muran	20°05′	48°42′	1 150	6.24	3.77	60.4
309	Smokovec (53)	19°30′	49°09′	1 200	4.51	3.43	76.1
310*	St. Pleso (52)	20°05′	49°07′	1 370	4.96	3.54	71.4
311	Liptovska Teplicka (68)	20°06′	48°55′	1 400	4.81	3.30	68.6
312	»Tanap»	20°12′	49°08′	1 580	4.92	3.59	73.0
	4. Rumanian region						
401	Ksiky	25°40′	46°40′	880	5.58	4.19	75.1
402	Coltul Rosu	23°20′	46°20′	1 100	4.46	2.87	64.3
403	Belis	23°05′	46°40′	1 140	6.58	4.47	67.9
404	Lunca	25°40′	46°40′	1 350	6.01	4.15	69.1

2. *TGW of filled seeds from autochthonous stands*

The TGWs of provenances belonging to one geographical region are placed in TGW-frames in Fig. 3 (*cf.* Methods and Definitions). The lowest weight of filled seed—3.73 grams—was found in Sudetian larch (203-Karlovice), and the highest—10.81 grams—in Western Alpine larch (704-Ristola).

There may be considerable variation in TGW within a geographical region (Table 2). For example, in region 5, the TGW varies from 5.44 to

Provenance No.	Locality	Longitude E.	Latitude N.	Altitude in metres	TGW in grams filled 1	empty 2	ratio ²/₁%
	5. Eastern Alps region						
501	Wienerwald	16°00′	48°10′	450	5.44	3.81	70.0
502	Tenna (18)	11°17′	46°01′	600	6.37	4.96	77.9
503*	Cavedine	11°00′	46°00′	650	6.45	4.89	75.8
504*	Vigolo Vataro	11°26′	46°12′	700	6.89	4.97	72.1
505	Blühnbachtal	13°10′	47°30′	900	6.56	5.48	83.5
506	Stilfser Tal	10°25′	46°32′	1 000	6.54	4.54	69.4
507	Sterzing (12)	11°25′	46°52′	1 000	5.89	4.14	70.3
508	Schönwies (2)	10°40′	47°10′	1 100	6.98	5.91	84.7
509	Bruneck (15)	11°55′	46°45′	1 100	6.97	4.18	60.0
510	Radovna	13°58′	46°25′	1 120	7.38	5.56	75.3
511	Domat Ems	9°25′	46°50′	1 150	6.60	4.92	74.6
512	Stilfser Joch	10°25′	46°32′	1 200	6.77	5.11	75.5
513	Semmering (8)	15°50′	47°40′	1 200	5.64	3.73	66.1
514*	Urslja gora	14°58′	46°29′	1 200	6.35	4.12	64.9
515	St. Lambrecht	14°15′	47°07′	1 250	5.81	4.08	70.2
516*	St. Lambrecht	14°15′	47°07′	1 250	6.09	4.56	74.9
517	Cavalese	11°26′	46°18′	1 250	7.24	5.16	71.3
518	Mezahlje	13°59′	46°26′	1 300	7.38	5.15	69.8
519	Savognin	9°36′	46°36′	1 300	6.32	4.52	71.5
520	Churwalden	9°35′	46°45′	1 340	6.53	5.03	77.0
521	Pergine (19)	11°15′	46°04′	1 400	7.00	5.77	82.4
522	Längenfeld	11°00′	47°05′	1 500	6.81	4.90	72.0
523	Domat Ems	9°25′	46°50′	1 650	6.81	5.72	84.0
524	Tschierw	10°22′	46°37′	1 760	7.92	6.20	78.3
525	Tschierw	10°22′	46°37′	1 800	7.82	5.56	71.1
	6. Central Alps region						
601	Calanda	9°25′	46°55′	650	7.17	4.78	66.7
602	Trins	9°20′	46°50′	1 000	8.17	6.15	75.3
603	Martisberg	8°05′	46°20′	1 350	7.56	5.35	70.8
604	Grengiols	8°05′	46°20′	1 350	7.71	5.54	71.9
605	Martigny	7°05′	46°05′	1 350	8.58	6.45	75.2
606	Saxon	7°10′	46°10′	1 500	9.34	7.15	76.6
607	St. Maria	8°47′	46°35′	1 600	7.62	6.22	80.2
608	Trins	9°20′	46°50′	1 600	7.76	6.22	80.2
609	Martisberg	8°05′	46°20′	1 650	7.93	5.92	74.7
610	Saxon	7°10′	46°10′	1 700	7.62	6.37	83.6
	7. Western Alps region						
701	Chamonix (60)	6°50′	45°55′	1 210	8.73	6.07	69.5
702	Aiguilles (23)	6°52′	44°45′	1 450	10.51	8.64	82.2
703	St. Vincent	6°25′	44°25′	1 550	10.18	7.52	73.9
704	Ristola (22)	6°58′	44°45′	1 600	10.81	7.63	70.6
705	St. Pierre	6°40′	44°52′	1 700	10.24	7.59	74.1
706	Pragelato	6°57′	44°57′	1 750	10.42	8.28	79.5
707	Pragelato (21)	6°58′	44°57′	1 900	9.54	7.55	79.1

7.92 grams. Polish and Sudetian larches which overlap with each other in this respect, have a very narrow variation (3.78—4.91 and 3.73—4.60 grams respectively). The degree of TGW variation also depends upon the ecological homogeneity of the geographical region concerned.

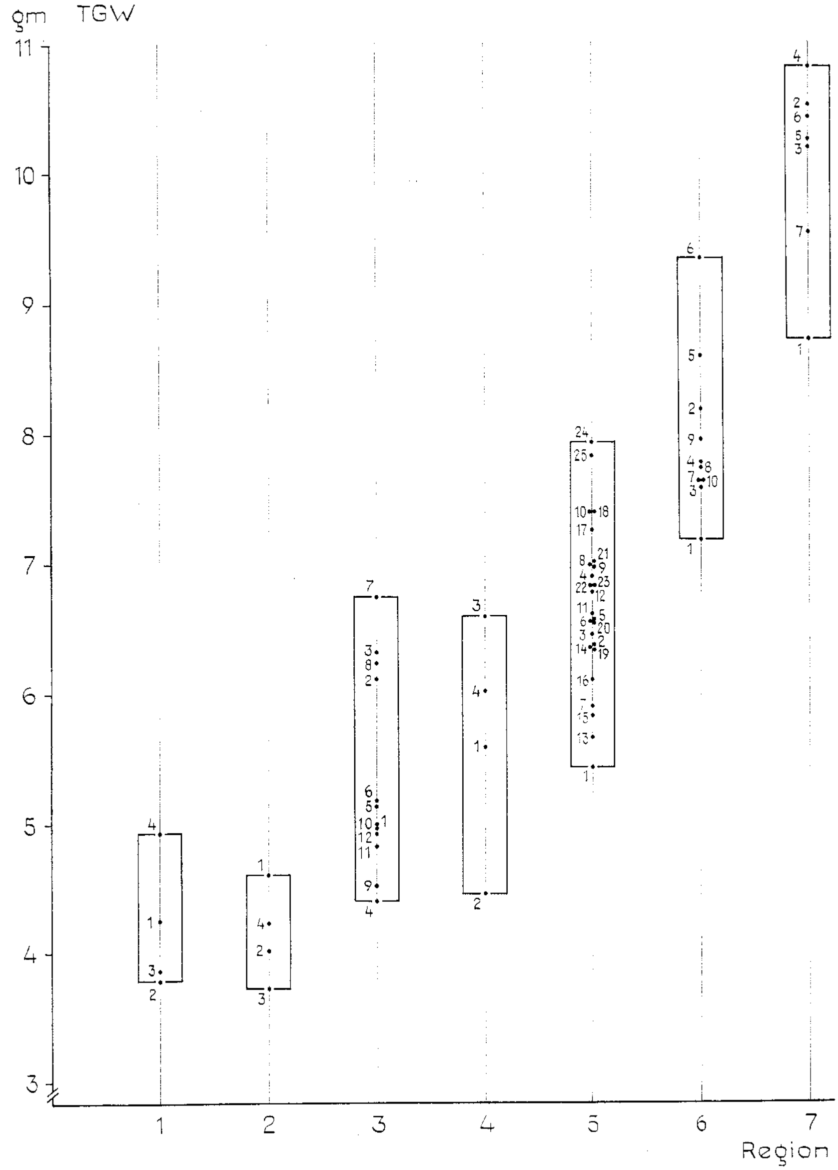

Fig. 3. TGW variation of filled seeds within and between geographical regions of autochthonous larch.

In region 7, for instance, the six provenances Nos 702—707 (Dauphin-Piemont) have a higher TGW than provenance No 701 (Ht. Savoie), which can probably be ascribed to the ecological differences between

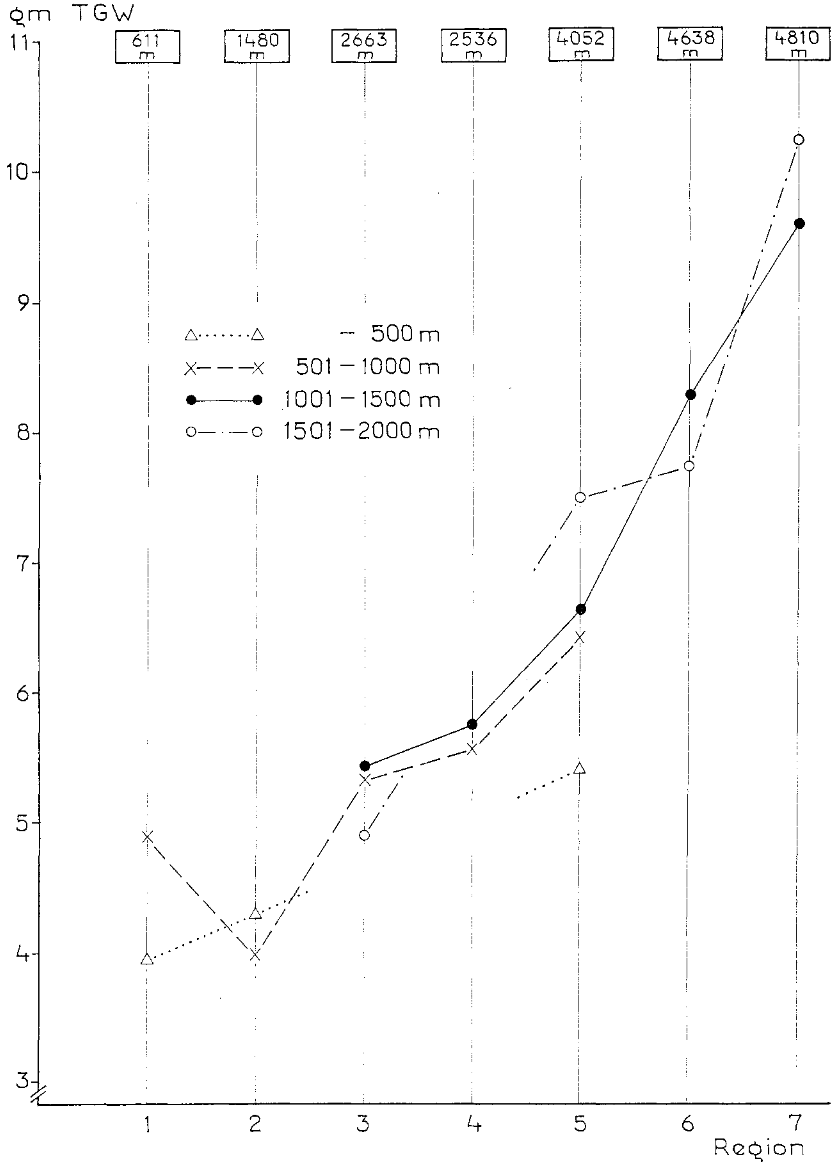

Fig. 4. Average TGW of filled seeds for iso-altitude belts: up to 500 m, 501—1000 m, 1001—1500 m, 1501—2000 m in regions 1—7. In the frames at the top of the figure is given the maximum elevation of the mountain massif (metres) for the region in question.

these two areas (*cf.* BOUVAREL 1959). Among other factors, provenance No 701 lies 240 metres lower than the lowest provenance in the group Dauphin-Piemont.

Provenances which are located near each other but on opposite sides of the boundary line between two geographical regions, usually have similar TGWs. Examples of this are provenances 701-Chamonix and 605-Martigny, which are located only some ten kilometres from each other and which have TGW values of 8.73 and 8.58 grams, respectively. Of course, an artificial border line between two regions does not necessarily signify differences in biological and morphological characteristics of the larches situated on the two sides.

In Polish larch, the provenances 102-Blizyn, 101-Grojec and 103-Skarzysko form a group of classical stands from the central Polish mountains (Swietokrzyskie Mts. and their surroundings, the Łodz hills, the northern border of the Roztocze elevation; *cf.* BALUT 1962). Their TGW varies from 3.78—4.25 grams. The fourth investigated provenance, 104-Pieniny—identified as Polish larch by SZAFER (1913)—lies isolated and to the south of the above-mentioned groups *(cf.* 1 b in Fig. 2). Its TGW—4.91 grams—is relatively high as compared with that of other Polish larches, and agrees more or less with that of the neighbouring Slovakian larch in Tatra *(cf.* Fig. 3). Ecologically, too, Pieniny larch is a mountain type from higher elevations than that from Blizyn, Grojec and Skarzysko.

For Slovakian larch two provenance groups can be distinguished where TGW is concerned. The provenances Nos 302, 303, 307, 308 have TGWs over 6 grams, whereas the corresponding values for the other group (provenances Nos 301, 304, 305, 306, 309, 310, 311 and 312) are around 5 grams. The differences in this respect between the two groups are distinct.

When one compares the average altitude of the provenances with the average TGW in each region on the basis of the data given in Table 1, the following results are obtained:

Table 2. Relationship between TGW and average altitude of geographical regions.

Geographical region	No. of provenances	Average altitude in metres	TGW		
			Minimum	Maximum	Average
1 Polish	4	360	3.78	4.91	4.20
2 Sudetian	4	538	3.73	4.60	4.15
3 Slovakian	12	1057	4.40	6.74	5.36
4 Rumanian	4	1118	4.46	6.58	5.66
5 Eastern Alps	25	1167	5.44	7.92	6.66
6 Central Alps	10	1375	7.17	9.34	7.95
7 Western Alps	7	1580	8.73	10.81	10.06

The values given above show that there is a direct relationship between the average altitude of the regions and the average TGW of filled seeds.

3. TGW of filled seeds of individuals from different stands

For one provenance of Sudetian larch (Ruda n.M. Long. 18° 37′, lat. 51° 11′, alt. 500 m), seven provenances from Slovakia, Nos 302, 303, 304, 305, 309, 310, 311, and three provenances from the Eastern Alps, Nos 507, 508, 509, seeds from individual trees were obtained. On the basis of this material, the TGW variation among the individuals of a provenance and within the TGW-frame of a region can be studied.

From Fig. 5 it may be seen that the TGWs for some trees fall outside the corresponding TGW-frame. This is natural, because the TGW of a provenance has also an internal variation caused by the TGW values of its individual trees. In addition to this variation, which is mathematically explicable, it is necessary to take into account the other kinds of variation. The TGW values for five trees in the provenance Ruda n.M. are in this respect noteworthy. Three of the trees have very low TGWs, namely, 3.82, 4.04 and 4.09 grams, which correspond with the TGW-frame for Sudetian larch. The remaining two trees have unusually high TGWs, *i.e.* 7.27 and 7.28 grams, fitting more with the TGW-frame for region 5 or 6.

As pointed out earlier, the Slovakian larch has in its TGW-frame (Fig. 3) two distinct groups of provenances, one with a high and the other with a low TGW. These differences are also noticeable in Fig. 5. So, for example, eight trees from provenance 304-Brezovicka have TGWs between 4.45 and 5.19 grams, whereas seven trees of the provenance 302-Chmelienec, not far away, have a considerably higher TGW, namely, between 5.69 and 7.13 grams.

4. TGW of filled and empty seeds in introduced provenances with known origin

For this investigation, seeds of some provenances from experimental plots and planted stands in Czecho-Slovakia (CS), Denmark (DK), Germany (D), Poland (Pl) and Sweden (S) were obtained (*cf.* Table 3).

A comparison of TGW from the introduced provenances with the TGW-frame of their origin (Fig. 6) shows that only the values for provenances Pl-18-1 and CS-16-6 fall outside its frame.

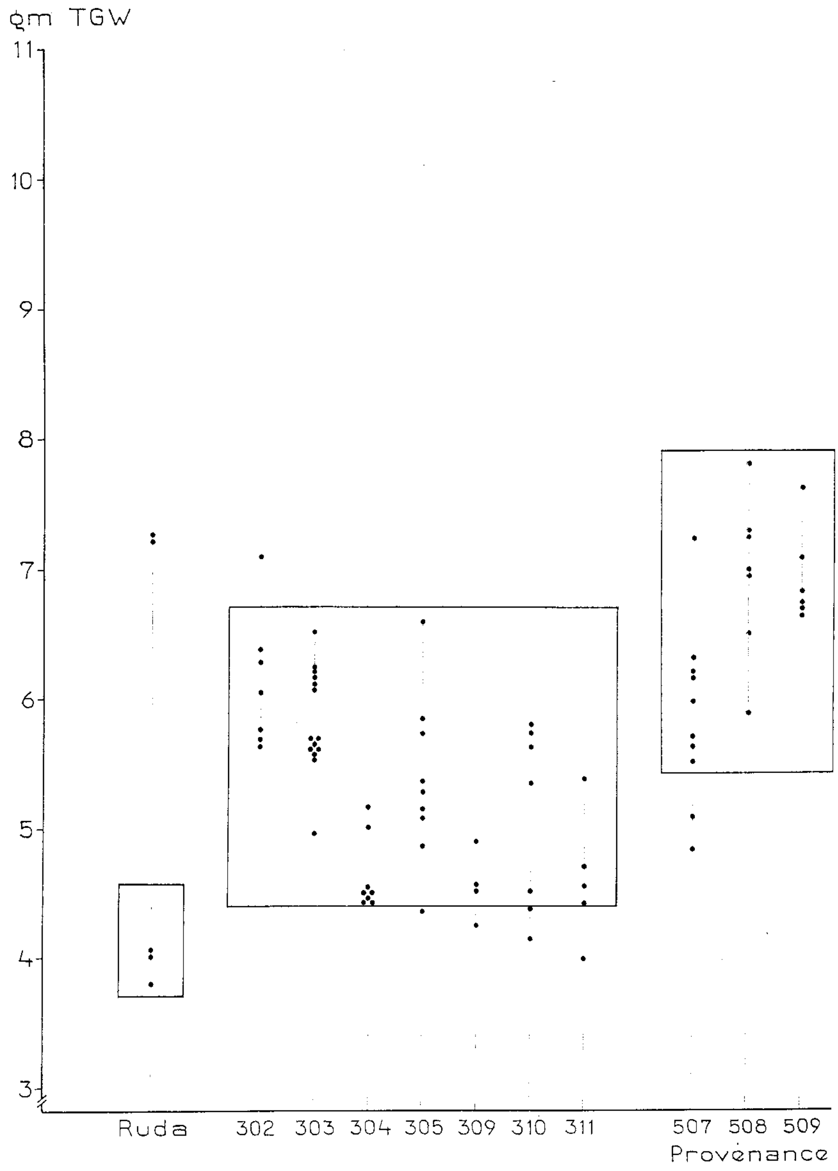

Fig. 5. TGW variation among the individuals within a provenance and within TGW-frame of a region. The mean TGW values for provenances in this figure need not agree with those of the corresponding provenances in Fig. 3, because both of them represent seed material from different samples.

In the provenance Blühnbachtal there are two TGW values for comparison, one—6.20 grams—(provenance D-04-5) after introduction to an altitude of 290 m in Germany (SCHOBER & FRÖHLICH 1967), and the

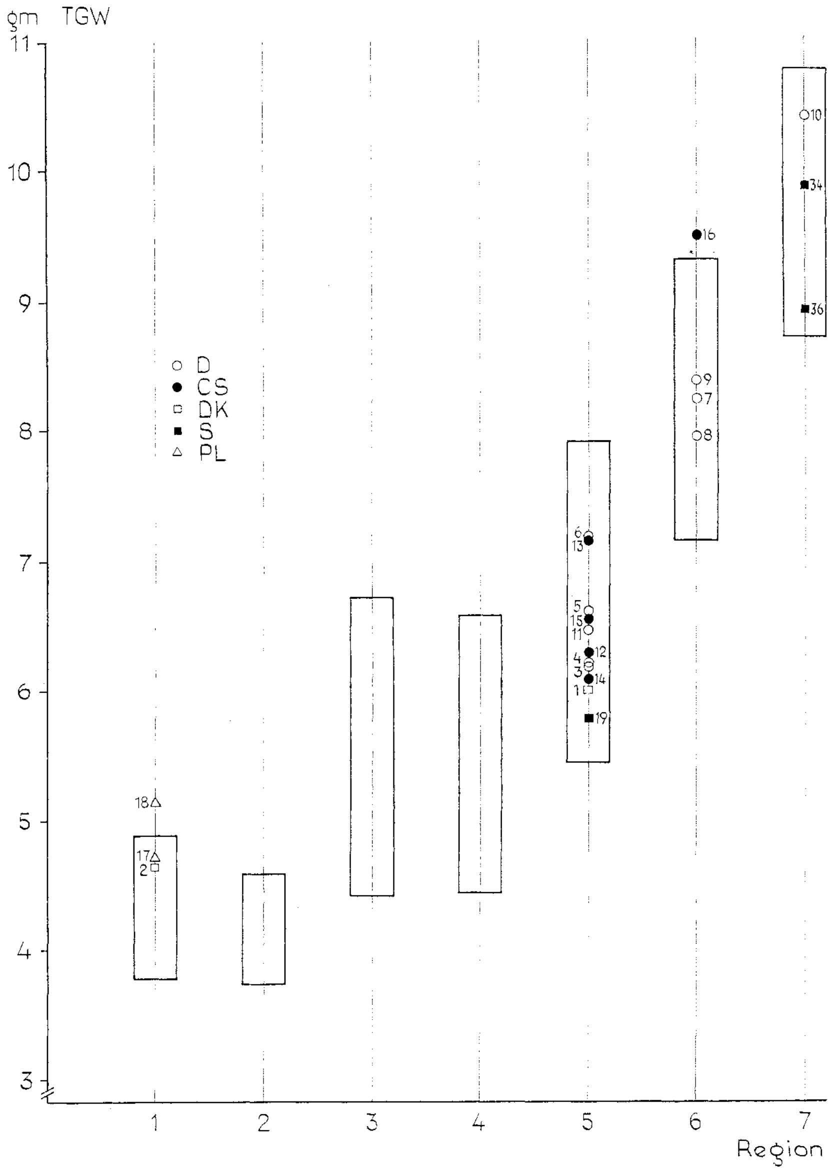

Fig. 6. TGW of filled seeds in provenances of known origin, but growing outside the area of natural distribution of larch, in comparison with the TGW-frames. In the frames only the serial numbers of provenances are given (*cf.* Table 3).

other—6.28 grams—(provenance CS-12-5) after introduction to an altitude of 950 m in Slovakia (STASTNY 1965). In spite of these environmental differences, the TGWs in both cases remained almost the same

Table 3. Provenances of known origin introduced into Czecho-Slovakia (CS), Denmark (DK), Germany (D) Poland (Pl) and Sweden (S).

In provenance number the letters denote the country into which the provenance in question has been introduced.
The following two figures give the serial number of provenances. The last number after the dash gives the region from which the provenance originated.

Prov. No.	Origin of provenances				Places of introduction					TGW of introduced prov.	
	Locality	Long. E.	Lat. N.	Alt. m	Locality	Long. E.	Lat. N.	Alt. m	Remarks	filled gm	empty gm
DK-01-5	»Tyrol»	—	—	—	Ganløse	12°15′	55°49′	50	Cult. stand	5.99	3.98
DK-02-1	Zagnansk	20°36′	50°52′	300	Nødebo	12°20′	56°00′	40	Grafts from a prov. trial	4.65	3.20
D-03-5	Wienerwald	15°55′	48°05′	400	Gahrenberg	9°35′	51°25′	290	Prov. trial	6.18	3.89
D-04-5	Blühnbach tal	13°05′	47°45′	600	»	»	»	»	»	6.20	4.04
D-05-5	»	13°05′	47°45′	800	»	»	»	»	»	6.62	4.44
D-06-5	»	13°05′	47°45′	1 000	»	»	»	»	»	7.18	4.64
D-07-6	Mt. Pahier	7°28′	46°15′	1 325	»	»	»	»	»	8.26	5.84
D-08-6	Eifischtal	7°35′	46°13′	1 400	»	»	»	»	»	7.97	5.19
D-09-6	St. Luc	7°35′	46°13′	1 630	»	»	»	»	»	8.40	6.21
D-10-7	Briançon	6°43′	44°56′	1 860	»	»	»	»	»	10.42	7.71
D-11-5	»Tyrol»	—	—	—	Schlitz	9°35′	50°40′	350	Cult. stand	6.47	5.26
CS-12-5	Blühnbach	13°10′	47°30′	600	Podbanske	19°56′	49°10′	950	Prov. trial 1944	6.28	5.01
CS-13-5	Lamerau	13°15′	47°35′	700	»	»	»	»	»	7.17	6.20
CS-14-5	Murau Paal			1 700	»	»	»	»	»	6.09	4.53
CS-15-5	Steinach Gries			1 900	»	»	»	»	»	6.55	4.92
CS-16-6	Lötschenthal	7°45′	46°20′	1 500	»	»	»	»	»	9.51	6.65
Pl-17-1	Lysa Gora	20°50′	50°50′	~400	Kartuzy-Kielpino	18°10′	54°20′	~200	Regeneration fr. cult. stands	4.70	3.31
Pl-18-1	»	20°50′	50°50′	~400	Kartuzy-Bilowo	18°10′	54°20′	~200	»	5.14	3.28
S-19-5	»Schlitz»	9°35′	50°40′	350	Bogesund	18°00′	59°24′	30	Exp. plot	5.79	3.10
S-20-5	Agord	12°05′	46°17′	580	Bogesund	18°00′	59°24′	30	Grafts	—	4.60
S-21-5	Pergine	11°15′	46°04′	800	»	»	»	»	»	—	5.61
S-22-5	Pontebba	13°18′	46°30′	1 000	»	»	»	»	»	—	5.15
S-23-5	Luttach	11°55′	46°55′	1 100	»	»	»	»	»	—	5.95
S-24-5	Segonzano	11°15′	46°12′	1 100	»	»	»	»	»	—	5.78
S-25-5	Saures	12°42′	46°25′	1 300	»	»	»	»	»	—	4.49
S-26-5	Vallada	11°55′	46°20′	1 320	»	»	»	»	»	—	4.48
S-27-5	Sexten	12°22′	46°45′	1 360	»	»	»	»	»	—	5.98
S-28-5	Pocol	12°08′	46°32′	1 530	»	»	»	»	»	—	4.88
S-29-5	Valent	10°35′	46°45′	1 550	»	»	»	»	»	—	6.25
S-30-5	Schmals	10°50′	46°45′	1 550	»	»	»	»	»	—	5.58
S-31-5	Eisack	11°35′	46°58′	1 700	»	»	»	»	»	—	5.60
S-32-5	Pretau	12°07′	47°05′	1 770	»	»	»	»	»	—	6.04
S-33-7	Ormea	7°54′	44°10′	1 400	»	»	»	»	»	—	7.74
S-34-7	Cesan	6°45′	44°46′	1 600	»	»	»	»	»	9.84	8.01
S-35-7	Noasca	7°20′	45°27′	2 000	»	»	»	»	»	—	7.19
S-36-7	Pragelato	6°58′	44°57′	2 000	»	»	»	»	»	8.95	6.98
S-37-GB	Scottish	?	?	?	Vingåker	15°55′	59°03′	40	Cult. stand	4.54	3.05
S-38-GB	larch	»	»	»	Lissjö	16°04′	59°41′	65	»	6.32	4.97
S-39-GB	according to	»	»	»	Maltesholm	13°58′	55°54′	110	»	4.88	3.56
S-40-GB	Schotte	»	»	»	Edsgatan	13°30′	59°23′	50	»	5.46	3.86
S-41-GB	(1917)	»	»	»	Ekkepigen	13°59′	58°11′	145	»	5.40	3.66
S-42-GB		»	»	»	Skabersjö	13°08′	55°32′	40	»	6.48	4.66

as that of the autochthonous stand—6.56 grams—(provenance No. 505, Table 1).

Of interest is the TGW of provenance DK-02-1 (Table 3) of Polish origin from Zagnansk, which was planted in 1933 on a plot in Nødebo in Denmark (*cf.* Gøhrn 1956). In 1951 some individuals of this provenance were grafted for a seed orchard, also situated in Denmark. TGW determinations on the seed from these grafts prove its Polish origin (*cf.* Fig. 6), in spite of the climatic influence (introduction to Denmark) and physiological influence (grafting).

On the seed of grafts from 17 provenances S-20-5 to S-36-7, belonging to regions 5 and 7, the influence of three different modificative factors on the TGW can be studied: (1) Introduction to Sweden. (2) Grafting, and (3) Inbreeding. All seeds obtained from these grafts are products of artificial inbreeding, and consequently, very few filled seeds were obtained. Only some trees in two provenances, namely S-34-7 and S-36-7, had relatively high self-fertility and, therefore, enough filled seeds were available for estimation of their TGW. For the remaining 15 samples, the TGW of empty seeds had to be used for comparison, and for this purpose special TGW-frames, based on the weight of empty seeds from autochthonous provenances, were prepared. Table 1 shows that the TGW-frame for empty seeds in region 5 ranges from 3.73 to 6.20 grams and in region 7 from 6.07 to 8.64 grams. The values in Table 3 show that only one sample, namely S-29-5, has a slightly higher TGW than that permitted by the frame.

No less interesting is provenance DK-01-5, growing in Ganløse, Denmark. It is considered to be the 5th or the 6th generation of Tyrolian larch introduced into Denmark in 1760—1777 (*cf.* Holten 1944). This larch, after growing for 200 years in Denmark, still produces seed the TGW of which is characteristic for larch from Tyrol.

The Tyrolian relationship is also shown by the TGW of larch seed from Schlitz (provenance D-11-5), the origin of which has been determined by several authors from historical documents (Immel 1933; Schober 1935 a, b). Provenance S-19-5 is the progeny of Schlitz which was planted in 1959 in an experimental plot near Stockholm. The TGW of this larch introduced to Sweden is lower than that of the mother stand in Schlitz (5.79 and 6.47 grams respectively). However, the seed from Stockholm locality was collected in June 1966, *i.e.* at a time when most of the last year's seeds—and probably the heaviest—had been shed by the cones. In spite of this, the TGW value (5.79 grams) still lies within the TGW-frame for region 5. Similarly, the value for Schlitz larch (6.0

grams) in the diagram by HEIKEN & SØEGAARD (1962), based on filled seed selected by x-ray radiography, also falls within the frame.

The larch from Kartuzy in the North of Poland (Pl-17-1 and Pl-18-1) should originate from Lysa Gora, where the centre of the natural distribution of Polish larch is situated. It is said that larch seed was brought and sown in Kartuzy by monks from a monastery situated at Gory Swiatokrizske (Lysa Gora). These monks had walked the long distance to receive absolution. One of the tested samples (Pl-17-1) fits well into the frame for Polish larch. The second one (Pl-18-1), however, lies slightly higher than the maximum value of the TGW-frame.

A special group of larches in Table 3 (S-37-GB to S-42-GB) is formed by the TGW values of some Swedish stands which SCHOTTE (1917) postulated to be of Scottish origin. But Scottish larch is also introduced chiefly from the Alps (OPPERMANN 1923) or from Sudeten (RUBNER 1953). A critical survey of the origin of Scottish larch has also been given by ROBAK (1946). Consequently, heterogeneity in the characteristics of Scottish larch may be expected. For instance, EDWARDS (1953) found "very wide differences between cones of different Scottish larches" and he thinks that "it seems unlikely that even an elaborate investigation would reveal any cone characteristics typical of Scottish larch".

The TGW variation for the Scottish larch stands in Sweden agrees with this view (Table 3). But this variation would also fit well in the TGW-frame of regions 3 and 4, with which the regions of Sudetian and Alpine larches overlap. However, historically there are no documents available to show that in the last century regions 3 and 4 exported seed to Britain (MACDONALD & al. 1957).

Discussion

In this paper the results for Thousand Grain Weight (TGW) of filled seed from 66 autochthonous and 42 introduced provenances of European larch *(Larix decidua* Mill.) have been put forward. The TGW in the literature is often given in the form of tables, without much comment, even though TGW deserves as much attention as other characters studied in provenance experiments. The relationships between TGW and the origin of provenances can be of interest from practical as well as from genetical point of view, as has been shown in this paper.

The area of distribution of European larch is divided into seven geographical regions. The demarcation of regions was based on the amount and distribution of seed material available. Therefore, this division should not be considered as a general biological classification of *Larix decidua*. A larger material might allow a more detailed division to be made; for instance the biological aspects of the classification of the Alpine larch, which according to WETTSTEIN (1946) and RUBNER (1954), has formed different ecotypes during the postglacial period, might also be included.

Two important requirements for the study of TGW relationships are that the TGW is determined by a correct method, and that the selection of the material in respect of the origin is done accurately.

The TGW values of larch seed given in most of the publications cannot usually be used for detailed studies. First, because in most cases, these denote the weight of pure seed (filled and empty seeds together), and secondly, since the dewinging of seed was not uniform. Both inadequacies in the procedure cause irregularities in the TGW values. The radiographic inspection of seed and uniform dewinging, as in the present investigation, are the first steps towards the standardised determination of TGW.

To give correct information about the origin of the investigated material is important, even if it is often not an easy task. This is because foreign larches have also been introduced into the area of natural distribution of larch, which lies in ten countries (France, Italy, Switzerland, Germany, Austria, Yugoslavia, Rumania, Czecho-Slovakia, Poland and USSR, *cf.* Fig. 2), and it is a problem today to identify their origin. Moreover, not only is it difficult to obtain seed material for experimental purposes from some of these countries, but also the information supplied about the material is often inadequate, etc. A better cooperation in this respect among the various forest research institutions is needed.

For checking the autochthonity of material a certain amount of information is available in the literature, but even here there are difficulties. A typical example of this is the provenance Ruda (Fig. 5), the seeds of which are said to be of autochthonous Sudetian larch. However, the big differences in TGW for the individuals give the impression that the origin is not so certain. DOMIN (1930), KLIKA (1930), and HRUBY & GOTTHARD (1934) consider that these stands are autochthonous. DOMIN (1930) even introduces a new botanical name—*Larix sudetica*—on the basis of the study of larch in just these stands. This new species should, among other characters, have cones up to 5 cm in length, which has also been confirmed by KLIKA (1930). HRUBY & GOTTHARD (1934) carried out a detailed analysis of characters, including cone size in the Polish, the Alpine and the Sudetian larches. The material for the last-named larch was collected in just these Ruda stands. They found that the Sudetian larch had the biggest cones (average length 33 mm) of the three larches named above. Moreover, the Sudetian larch possesses the largest variability in the investigated characters of cones and needles.

Many authors have objected to the character "big cone size" for Sudetian larch. RUBNER & SVOBODA (1944), on the basis of an analysis of 33 autochthonous larch provenances, found the average cone length to be 21.6 mm (16.0—30.3 mm). They question the autochthonity of the material used by HRUBY & GOTTHARD (1934) and write as follows: ". . das Material *Larix sudetica* (ist) wahrscheinlich eine Mischung von Zapfen aus heimischen und fremden Lärchen." SIMAN (1943) also considers that the larch with big cones denoted by DOMIN as *Larix sudetica* is not autochthonous. KLIKA (1930), while he assumes that the larch in Ruda is Sudetian, writes that there are big differences among the individuals of the stand. In autumn, some of the trees are still green, whereas the others are yellow and shedding their needles. Thus he acknowledges the heterogeneity of the stands. The introduction of Alpine larch into region 2 and its hybridisation with the Sudetian larch has been assumed, for instance, by DOMIN (1939) and SIMAN (1944). Also RUBNER (1943) describes and shows on a map the localities with doubtful and foreign larches in the Sudetian region. One must therefore take into account that some of the larches denoted as Sudetian may be of foreign origin. Evidence for this is found in England (personal observation), where the "Sudetian larch" gives very variable results on experimental plots (SIMAK 1955 a). EDWARDS (1962 p. 168) also writes: "Confusion has been caused by imports of larch labelled 'Sudeten' but collected in Silesia and other places, as some of these have resembled Alpine larch in their behaviour. Genuine Sudeten larch is difficult to obtain, as stands are mixed even in the Sudetenland."

In the literature one finds TGW values for Sudetian larch which are higher than 6 grams. Because this figure, in most cases, refers to the weight of pure seed (empty and filled seeds) the TGW for the filled seeds must be higher. However, it is difficult in such cases to decide, whether it is a "false" Sudetian larch, or the seed has been insufficiently cleaned, etc. CIESLAR (1899) gives in his Table X, p. 28, TGW values of good seed—"Tausendkorngewicht guter (im Wasser gesunkener) Körner *g*"—for four trees of the Sudetian larch from Freudental as 5.094—7.032 grams. These values remind one of the TGW from the large-sized cones in Ruda. Also HEIKEN & SØEGAARD (1962) have determined the TGW of filled seed of Sudetian larch selected by x-ray radiography and obtained a rather high figure. But in this case, one can observe from the data given that most of the investigated stands lie outside the area of natural distribution of larch.

On the basis of the arguments for and against, the possibility is not excluded that the two trees in Ruda with high TGW (7.27 and 7.28 grams)—Fig. 5—are the progeny of an Alpine larch, or hybrids between Alpine and Sudetian larch, in which the high TGW has been preserved. However, it will be necessary to make the TGW-frames for Sudetian larch based on a large material before the identification can be done accurately with the help of TGW. It is also of principal importance that the origin of such doubtful stands as those in Ruda is established with certainty, because on this the definite size of TGW-frame for Sudetian larch depends. Mr SINDELAR (Prague) has informed me that he is writing a paper on the natural distribution of Sudetian larch. The problem of the origin of this larch discussed above can, therefore, be left open until then.

Some introduction of the Alpine larch to Slovakia (region 3) is mentioned by BARTAK (1929). RUBNER & SVOBODA (1944) analysed cones from slopes of the Nizke Tatry and Velka Fatra, *i.e.* within the area of natural distribution of Slovakian larch, and found that there were large variations in the shape and size of the cones. On the basis of these characters the above authors want to separate the autochthonous from the introduced larches in the stands in question. Even the analysis of TGW in Fig. 3 for region 3 shows two different groups of larches, one with a high and the other with a low value. According to SIMAN (1944) the areas around Cierny Vah (provenances Nos 302, 303 and 307, the group with high TGW) were planted with larch to obtain better sheltering of the pasture. It is possible that on this occasion a foreign larch could have been introduced into the area. This view is also shared by Mr STASTNY from Slovakia (personal communication). Although it may be too much to postulate, on the basis of TGW differences only, that the stands have been mixed, it is desirable to find a satisfactory explanation for this fact. If these stands are found, with absolute certainty, to be autochthonous, this will mean that TGW differences are an ecotypical character, which could be of great diagnostic value. All four provenances with high TGW (Nos 302, 303, 307 and 308) belong to the ecotype "subtatrensis" (SIMAN 1943). The provenances in the second group with low TGW (excluding two provenances, Nos 305 and 311), fall in the ecotypes "tatrensis" and "sarisensis" *(cf.* SIMAN 1943). However, it may be mentioned that in the area of provenance 305-St. Hory, many foreign larches have been introduced (SIMAN 1944; STASTNY 1954); thus the autochthonity of this provenance may be questionable.

The TGW values of the provenances which lie on the borders of the TGW-frames of a region must be checked. For instance, there is no definite proof for the autochthonity of provenance 304-Brezovicka (with the lowest TGW value in region 3). Similarly, care is also necessary over the Rumanian larch (Figs 3 and 6) for the origin of which no information is available. From the literature it is known that this larch is morphologically very variable, so that some taxonomists have identified it as *Larix decidua,* others as *Larix polonica* or *Larix sibirica* (GRINTESCU & ANTONESCU 1924). However, on the basis of karyological studies (SIMAK 1962 and 1964) the provenances 402-Coltul Rosu—and 403-Belis—belong to the group of European larch *(Larix decidua).*

Coming to the results of the present investigation, the first question is that of the weight relationship of filled, empty and insect-attacked seeds. The small differences in the weight of empty and filled seeds found here agree with the studies of several workers (MESSER 1958; DIECKERT 1962, VINCENT 1965). It is not known why the relative weight of empty seeds seems to increase with increasing altitude (page 7). It is necessary to have a larger material and to make comparative measurements *(e.g.* of the thickness of seed coat, etc.), in order to find the explanation. In this connection, it is of interest to note that according to NEGER (cit. WIBECK 1920), the testa of empty seeds has a different structure than that of the filled ones (also *cf.* Fig. 1). A similar observation was made by DOGRA (1966) in empty seeds of *Abies pindrow.*

The insect-attacked seeds are only slightly heavier than the empty ones. The occurrence of insect larvae, chiefly in seeds from lower elevations, indicates similar specific ecological adaptation of insects, as has been shown in seeds of *Picea abies* (SIMAK 1955 a). The small differences in the weight of empty, insect-attacked and filled seeds make seed cleaning difficult in practice.

Table 2 shows that provenances from regions with higher average elevation have also higher TGW. This may indicate that larch is well-adapted to high altitudes with severe climatic conditions, as far as seed development is concerned. Also, x-ray analyses of the filled larch seeds (SIMAK, unpublished) from high elevations did not show any noticeable differences in the embryo and endosperm development. As against this, Scots pine growing in high altitudes near the Arctic Circle shows poor seed development, although vegetatively, the trees flourish (SIMAK & GUSTAFSSON 1954). Such climatically modified TGW values, as in Scots pine and in Norway spruce (*cf.* ANDERSSON 1965), do not occur in larch seed.

The results in Table 2 and Figure 3 also show that the farther apart in average altitude two geographical regions lie, the more significantly their TGWs differ from each other. Consequently, the lowest and the highest values of TGW are found in regions 1 and 7, respectively. In neighbouring regions, chiefly in the Alps, the differences in TGW are gradual—they show a clinal variation.

Figure 4 deserves special attention. It shows that larches from the same altitude but belonging to different geographical regions have different TGW values. It seems that the higher the mountain massif in a region, the greater is the TGW for a particular altitude. Of course, the "mountain massif" which is considered responsible here for the TGW variation among the regions can be expressed by other factors, *e.g.* geographical position, continentality of the locality, etc. For instance, SINDELAR (1965 and 1966) has proved, that it is the latitude of the locality which influences cone size, seed size and seed weight of European larch far more than the altitude does. He found a negative correlation for latitude and a positive one for the altitude, expressed in partial regression.

The shape, size and TGW of larch seed are rather constant for an individual tree. This is because the seed coat and endosperm—as in all gymnosperms—(SIMAK 1953 a) are exclusively produced by the mother tree. Only the embryo, which does not appreciably influence the weight, and not at all the external characters of the seed, is the result of the sexual union of the male and female gametes. Not only for individual trees, but also within a large population and in geographical regions, the TGW falls within a certain weight range, as is shown by Figure 3.

Of course, there are several external factors which can modify the TGW of a tree. For example, the position of a tree in a stand, the position of the cones in a tree crown, cone size, the position of the seed in a cone, climatic and edaphic factors, the age of the tree and the number of cones produced by a tree, etc. (VINCENT 1930; TYSZKIEWICZ 1931; MESSER 1956 b, 1958). But such a complex of modifying factors is included in the TGW range of a region, because the TGW-frames are constructed on the basis of the material obtained during several years and representing an average sample from many trees.

Evidence for the specificity and constancy of TGW is given by the studies described under heading 4. above. There it was shown by a number of examples that the TGW does not change appreciably, in spite of the influence of a complex of modificative factors. An example of this is provenance DK-02-1 (Table 3) which was introduced from

Poland into Denmark. It was sown there and the resulting plants were used for grafting. The seed from these grafts still have the TGW characteristic of Polish larch. It is known that the TGW of Scots pine seed would change considerably under such conditions (SIMAK & GUSTAFSSON 1954). The examples in Table 3, explained in detail under heading 4. above, show that the TGW of larch seed is genetically strongly fixed and only slightly modified by external factors. There is no evidence for RUBNER & SVOBODA (1944) to suppose that the seed size (and consequently also the TGW) is not usable as a characteristic for distinguishing larch from different regions, because of the influence of external factors.

Used in conjunction with other characters, *e.g.* size and shape of cones (RUBNER & SVOBODA 1944; SINDELAR 1966), number and shape of cone scales, number of needles on a brachiblast (HRUBY & GOTTHARD 1934), colour of flowers (DOMIN 1939; DIECKERT 1962), colour of wood (SVOBODA 1939), type of bark (KNAZOVICKY 1954) etc., TGW can serve as a diagnostic character for the identification of the origin of larch.

The seed investigated here was primarily collected for provenance experiments, and planted in different places in Sweden during the years 1960—62. The TGW studies were carried out only as a sideline. For a more detailed investigation of the TGW relationships, a larger material, well distributed over the various regions, would, of course, be necessary. If a sufficient number of provenances for each TGW-frame were available, it would be possible to calculate the statistical parameters for the frames, and the identification of the unknown provenances could be carried out with the usual statistical methods. However, the supply of adequate material from each region requires a closer cooperation among the forest research workers in the area of natural distribution of larch.

Summary

Samples of 66 autochthonous and 42 introduced provenances of *Larix decidua* were selected in respect of filled, empty and insect-attacked seeds with the help of x-ray radiography. Thousand Grain Weight (TGW) was determined for each of the above seed types within a sample. Seed was uniformly dewinged before weighing. Both these methodical aspects, namely, the exact determination of the seed quality and the uniform dewinging of the material, are basic requirements for obtaining correct TGW values.

In order to study the relationships between TGW and seed origin,

the localities of the autochthonous provenances were divided into seven geographical regions: 1. Polish, 2. Sudetian, 3. Slovakian, 4. Rumanian, 5. Eastern Alpine, 6. Central Alpine, and 7. Western Alpine. The first four regions lie isolated from one another, whereas the remaining three form a continuous area of the Alpine larch. The average altitude of the regions 1—7 increases from east to west (excluding Rumanian larch).

For TGW of larch, the following relationships have been found:

(1) TGW values of filled seed lie between 3.73—10.81 grams. There is a direct relationship between the TGW and the average altitude of a region. The differences among the regions are gradual, *i.e.* the greater the difference between the average altitudes of two geographical regions, the farther apart lie the TGW values. The TGW for a particular altitude was found to be greater the higher the mountain massif in a region.

(2) The TGW of empty seeds is about 70 per cent of that of filled ones. There was a tendency that with increasing altitude of the provenances, the relative weight of the empty seeds also increased.

(3) The TGW value of insect-attacked seeds was about 74.4 per cent of that of filled ones. The insect-attacked seeds occurred chiefly in the provenances from low elevations.

(4) The TGW values do not change even after the provenances have been introduced into other localities. Thus, TGW is genetically strongly fixed and only slightly modified by external factors.

The following conclusions can be drawn from the results:

The effectiveness of the various methods for separating the empty and the insect-attacked seeds from the filled ones can easily be checked by x-ray radiography. Of course, for practical purpose it is not necessary to remove empty seeds from the sample, if the density of sowing is estimated on the number of filled seeds.

In view of the fact that TGW values of larch seed from different geographical regions are constant and specific, they could be used as a criterion for the identification of the origin of larch. However, the TGW variation among the regions has a clinal character, which makes it difficult or impossible to determine the origin of provenance material lying on the boundary of two neighbouring regions. Chiefly in addition to other characters (*e.g.* form and size of cones, colour of flowers, etc.), TGW can be useful for the identification of the origin of larch. For carrying out the identification test with the help of TGW, it is necessary to construct a standard TGW-frame for each region, based on a large and autochthonous seed material.

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Sammanfattning

Frövikt hos lärk av olika provenienser (*Larix decidua* Mill.)

Lärkfrö från 66 autoktona och 42 introducerade provenienser har med röntgenografisk metod uppdelats i fyllda, tomma och insektsangripna frön. Tusenkornvikten (TGW) fastställdes för var och en av de ovannämnda frötyperna inom ett prov. Fröna avvingades likartat före vägningen. Båda dessa metodiska förfaranden, nämligen exakt bestämning av frökvaliteten och likartad avvingning av materialet, är nödvändiga för att erhålla korrekta TGW-värden.

Sambandet mellan TGW och fröets ursprung har studerats i följande sju geografiska regioner: 1. polsk; 2. sudetisk; 3. slovakisk; 4. rumänsk; 5. östalpin; 6. central-alpin; 7. väst-alpin. De fyra första regionerna ligger isolerade från varandra under det att de tre andra bildar en sammanhängande areal av alpin lärk. Medelaltituden i regionerna 1—7 ökar från öst till väst.

Beträffande TGW har följande samband framkommit:

(1) TGW-värdena för fyllt frö ligger mellan 3,73 och 10,81 gram. Ett klart positivt samband mellan TGW och medelaltituden i en region förefinnes. Skillnaderna mellan regionerna förlöper gradvist, dvs. ju större skillnaden i medelaltituden mellan två geografiska regioner är desto mera skiljs TGW-värdena åt. TGW-värdet för en viss höjd har befunnits vara större ju högre medelaltituden i regionen ifråga är.

(2) TGW hos tomma frön utgör ca 70 % av värdet för de fyllda fröna. Den relativa vikten av tomma frön tycks öka ju högre upp proveniensen är belägen.

(3) TGW-värdet hos insektsangripna frön utgjorde ca 75 % av de fyllda frönas TGW-värde. Insektsangripna frön förekom huvudsakligen i provenienserna från lägre nivåer.

(4) Proveniensernas introducering i andra mera avlägsna lokaler förändrar icke TGW-värdena. Alltså är TGW så starkt genetiskt fixerad att den endast obetydligt förändras genom miljöbyte.

Av resultaten kan följande slutsatser dragas:

Effektiviteten av olika metoder för skiljande av tomma och insektsangripna frön från fyllda kan lätt kontrolleras på röntgenografisk väg. Naturligtvis är det i praktiken inte nödvändigt att avlägsna tomma frön från provet; såddtätheten kan anpassas direkt efter den röntgenografiskt bestämda procenten fyllda frön.

Med hänsyn till att TGW-värdena för lärkfrö från olika geografiska regioner är specifika och konstanta, skulle de kunna utgöra ett kriterium vid identifieringen av lärkfröets härkomst. Emellertid är TGW-variationen mellan regionerna av klinal karaktär, vilket gör det svårt eller rent av omöjligt att på detta sätt fastställa proveniensernas ursprung, om de härstammar från närbelägna regioner. I sådana fall kan TGW användas tillsammans med andra egenskaper (t. ex. form och storlek hos kottarna, blomfärg etc.) för att underlätta identifieringen. För TGW-test är det naturligtvis nödvändigt att konstruera en standard »TGW-ram» för varje region, baserad på ett stort och autoktont frömaterial.