X-ray photography employed in germination analysis of Scots Pine *(Pinus silvestris L.)*

Röntgenfotografering vid grobarhetsanalyser av tall (Pinus silvestris L.)

by

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The subject of investigation

Previous communications (SIMAK and GUSTAFSSON 1953 a and b) have demonstrated the possibility of defining the embryonic and endospermic qualities of various kinds of seed by means of X-ray photography. The following problem was the chief object of the present investigation:

What connexion exists between the embryonic and endospermic qualities of seeds of Scots pine *(Pinus silvestris L.)*—determined through X-ray photography—and the actual germinative power of the same seeds in Jacobsen's germinator?

Parallel to this main problem, it was considered desirable to ascertain whether the vigour of pine seed could be adequately determined by means of X-ray photography.

The investigation deals with seed of Scots pine exclusively. The collection of cones took place in late autumn 1953.

The seed-material

The collection of cones was effected according to directions issued through the Board of Crown Lands and Forests. Follows a translation of the instructions given to the collectors:

"The collection is limited to cones of Scots pine.

Cones may be collected from standing as well as from felled trees. In the latter case the tree must not have been felled before October 15th 1953.

If more than one sample of cones is dispatched in the same consignment, the cones from each tree must be packed separately. *It is of the utmost importance that the different samples are kept apart.*

Minimum number of cones per tree: 100.

It is essential that the cones are protected against moisture and that great care is taken with the packing.

Please fill in the form overleaf—altitude and latitude of the locality—as carefully as possible and enclose it with the cone-sample in question.

The collection has to take place between November 1st and 10th, and the sender is requested to forward the sample(s) as express goods to: The State Forest Research Institute, Stockholm N."

The total number of cone-samples received were 240. For the experiment were selected 89 samples from various localities over the whole country as well as from a variety of altitudes (Fig. 1 & table 1).

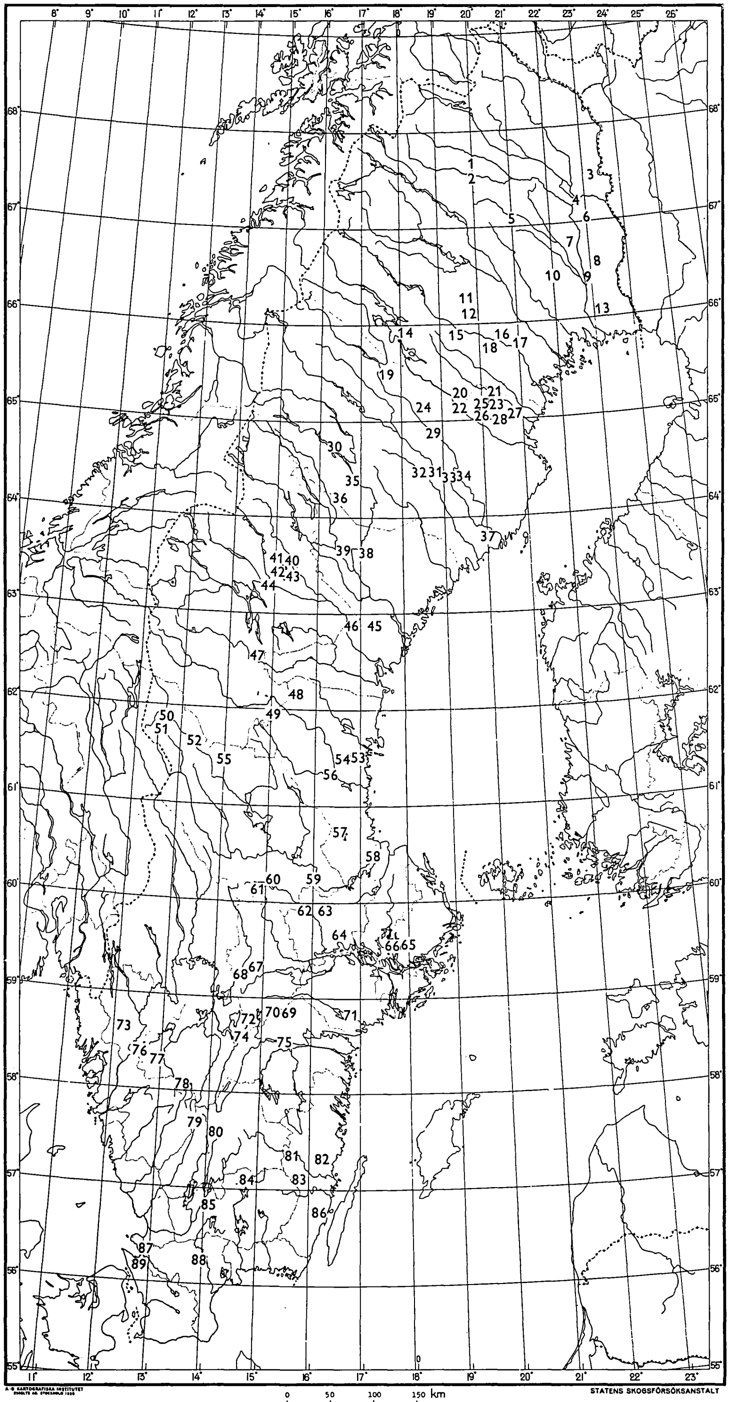


Fig. 1. The distribution of the analysed trees.

Växtplatser för de undersökta träden.

Tab. 1. Data of the seed-material

Tree No.	Altitude	Empty seeds per cent	Distribution of good seeds to embryo-classes (n = 200)				Germination percentage for good seeds		Deviation
			I	II	III	IV	Jacobsen	calculated	
1	269	4.5	—	5	13	182	99.5	97.0	+ 2.5
2	370	42.0	11	39	119	31	80.5	79.0	+ 1.5
3	280	8.0	4	25	64	107	76.5	87.0	— 10.5
4	175	9.0	4	4	9	183	96.5	95.5	+ 1.0
5	330	17.5	2	25	83	90	88.0	87.5	+ 0.5
6	200	9.5	3	2	18	177	97.5	96.0	+ 1.5
7	230	9.0	1	2	13	184	98.0	97.0	+ 1.0
8	125	13.0	4	0	2	194	97.0	97.0	± 0.0
9	110	6.5	—	—	5	195	99.0	98.5	+ 0.5
10	200	20.0	1	7	24	168	90.0	95.5	— 5.5
11	410	25.5	9	35	59	97	74.0	83.5	— 9.5
12	300	9.0	4	9	22	165	89.0	93.0	— 4.0
13	100	10.0	1	—	7	192	98.0	98.0	± 0.0
14	510	11.5	2	18	43	137	92.0	91.5	+ 0.5
15	337	4.5	2	2	24	172	98.0	96.0	+ 2.0
16	250	2.0	—	1	7	192	99.0	98.0	+ 1.0
17	150	20.0	4	2	4	190	95.0	96.0	— 1.0
18	255	9.0	2	14	72	112	81.0	90.5	— 9.5
19	470	54.0	10	26	95	69	83.0	82.5	+ 0.5
20	350	1.0	—	2	10	188	100.0	98.0	+ 2.0
21	220	15.5	3	2	12	183	98.5	96.5	+ 2.0
22	310	14.0	1	7	37	155	95.0	95.0	± 0.0
23	210	10.0	3	—	1	196	98.5	97.5	+ 1.0
24	325	3.0	—	2	7	191	98.5	98.0	+ 0.5
25	80	7.5	—	2	4	194	99.0	98.5	+ 0.5
26	230	22.5	5	6	12	177	94.5	94.5	± 0.0
27	60	13.5	1	—	1	198	99.5	99.0	+ 0.5
28	120	3.5	2	—	4	194	98.5	97.5	+ 1.0
29	260	7.5	—	2	24	174	92.5	97.0	— 4.5
30	285	33.0	—	3	25	172	97.5	96.5	+ 1.0
31	260	37.0	1	1	2	196	98.0	98.0	± 0.0
32	310	37.0	6	1	19	174	92.5	95.0	— 2.5
33	310	6.5	1	3	9	187	98.0	97.5	+ 0.5
34	225	33.0	4	1	11	184	97.5	96.0	+ 1.5
35	420	15.5	—	3	5	192	99.0	98.0	+ 1.0
36	350	7.0	1	1	7	191	98.5	97.5	+ 1.0
37	350	11.5	1	4	8	187	96.5	97.0	— 0.5
38	206	4.0	—	—	—	200	99.5	99.5	± 0.0
39	240	15.0	1	4	5	190	93.5	97.0	— 3.5
40	325	4.5	—	2	7	191	98.0	98.0	± 0.0
41	435	27.5	2	4	14	180	98.5	96.0	+ 2.5
42	330	6.0	—	3	6	191	98.5	97.5	+ 1.0
43	259	11.0	—	—	4	196	98.5	99.0	— 0.5
44	300	12.5	—	—	2	198	100.0	99.5	+ 0.5
45	550	20.0	4	6	39	151	93.0	93.5	— 0.5
46	400	15.5	1	5	19	175	96.0	95.5	+ 0.5
47	450	29.0	3	2	30	165	94.5	95.0	— 0.5
48	415	16.0	1	8	25	166	97.0	95.0	+ 2.0
49	510	41.0	1	24	41	134	95.0	90.5	+ 4.5
50	500	8.5	1	9	14	176	98.0	95.0	+ 3.0
Träd nr.	H. ö. h. m	Tomfrö %	I	II	III	IV	Jacobsen	beräknad	Avvikelse
			Fördelning av matat frö i embryoklasserna (n=200)				Grobarhetsprocent för matat frö		

Tree No.	Altitude	Empty seeds per cent	Distribution of good seeds to embryo-classes ($n = 200$)				Germinationpercentage for good seeds		Deviation
			I	II	III	IV	Jacobsen	calculated	
51	672	11.5	—	23	81	89	92.5	85.5	+ 7.0
52	480	11.5	7	4	9	182	95.0	95.0	± 0.0
53	230	18.5	5	2	2	196	99.5	98.5	+ 1.0
54	80	13.5	—	1	6	193	99.5	98.5	+ 1.0
55	370	10.0	4	1	3	192	97.5	96.5	+ 1.0
56	330	49.0	—	—	2	198	100.0	99.0	+ 1.0
57	160	15.5	—	1	1	198	100.0	99.5	+ 0.5
58	40	10.0	—	—	1	199	100.0	99.5	+ 0.5
59	100	4.0	—	1	2	197	98.0	99.0	— 1.0
60	390	4.0	—	1	18	181	98.5	97.5	+ 1.0
61	280	11.0	3	3	11	183	94.0	96.5	— 2.5
62	250	28.5	2	—	10	188	98.0	97.5	+ 0.5
63	71	10.0	—	—	—	200	99.5	99.5	± 0.0
64	35	28.5	5	—	12	183	94.5	96.0	— 1.5
65	60	17.5	—	—	8	192	98.5	98.5	± 0.0
66	25	17.5	1	1	2	196	98.5	98.0	+ 0.5
67	195	3.5	—	1	—	199	100.0	99.5	+ 0.5
68	86	5.0	—	—	1	199	100.0	99.5	+ 0.5
69	103	3.5	—	—	—	200	100.0	99.5	+ 0.5
70	190	4.5	—	—	6	194	99.0	98.5	+ 0.5
71	25	2.5	—	—	1	199	99.5	99.5	± 0.0
72	176	30.0	1	4	14	181	97.5	96.5	+ 1.0
73	180	20.5	—	1	8	191	98.5	98.5	± 0.0
74	131	10.0	1	1	1	197	98.5	98.0	+ 0.5
75	100	11.0	—	1	5	194	99.5	98.0	+ 1.5
76	135	1.0	—	—	—	200	99.5	99.5	± 0.0
77	80	21.5	—	—	3	197	100.0	99.0	+ 1.0
78	170	7.5	—	2	1	197	98.0	98.5	— 0.5
79	300	4.5	—	1	1	198	100.0	99.0	+ 1.0
80	250	7.0	—	—	2	198	99.5	99.5	± 0.0
81	325	27.5	—	1	10	189	98.5	98.5	± 0.0
82	50	6.5	—	1	5	194	99.5	98.5	+ 1.0
83	74	1.5	—	—	5	195	99.5	98.5	+ 1.0
84	250	11.5	—	—	—	200	100.0	99.5	+ 0.5
85	170	13.5	—	1	1	198	99.5	99.0	+ 0.5
86	32	8.0	—	1	1	198	99.0	99.0	± 0.0
87	200	33.5	—	1	3	196	98.5	98.5	± 0.0
88	105	18.5	—	—	3	197	96.0	99.0	— 3.0
89	5	4.5	1	—	1	198	96.5	98.5	— 2.0
Träd nr.	H. ö. h. m	Tomfrö	I	II	III	IV	Jacobsen	beräknad	Avvikelse
			Fördelning av matat frö i embryoklasserna ($n = 200$)				Grobarhetsprocent för matat frö		

Methods

The usual way of determining the germinative power of seeds, by means of the Jacobsen germinator, was employed in order to test the validity of X-ray photography in general practice. For a description of the germinator and its application to seed-analysis see Huss (1951).

The determination of the germinative capacity of seeds by the X-ray method is based on photography with rays of small penetrating power, the so-called Grenz-rays. The photographic negatives are examined, and the seeds classed according to their embryonic and endospermic properties. A comparison between the embryo- and endosperm-classes of the seeds and the subsequent germination of the self-same seeds in the germinator forms the basis of the present work. The technique of photography employed in the experiment has been described in two previous publications (SIMAK and GUSTAFSSON 1953 a, b), for which reason only the main points will be repeated here.

As will be known, X-rays exercise upon the cells of living organisms an effect which is partly physiological in character, partly genetical through its induction of chromosomal alterations. The risk of such internal changes sets a limit to the applicable dose of radiation. The limits vary from organism to organism. With the seeds of Scots pine the germinative power suffers an incipient reduction at a dose of 500 X-ray units *(r)* as shown in fig. 2 (SIMAK and GUSTAFSSON 1951 b). However, for the purpose of seed-photography, the dose is certainly much less than 50 r, thereby excluding the risk of heavily injuring the seed. In this experiment, the exposure is characterized by the following data: 10 kV, 18 mAs, $f = 25$ cm.

An X-ray apparatus for producing the necessary soft radiation has been described, together with film materials, etc., in the above mentioned papers. It was constructed by AB G. SCHÖNANDER, Stockholm, and purchased by

Difference in germination between X-rayed and non-X-rayed seed. Per cent.

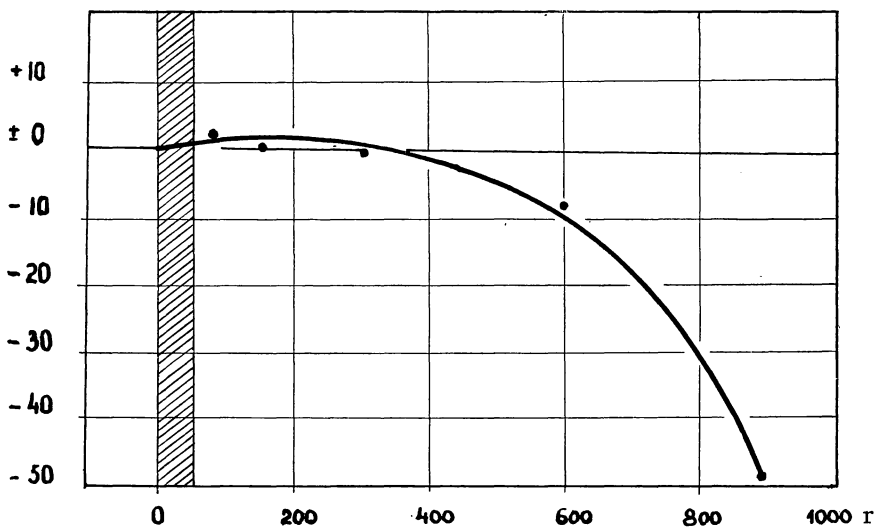


Fig. 2. The effect of X-irradiation (r) on the germination capacity (per cent) of Scots pine-seeds. The hatched column indicates the dose of irradiation (exaggerated!) used for photography.

Inverkan av röntgendos (r) på grobarheten (procent) hos tallfrö. Den streckade kolumnen anger det bestrålningsområde i vilket röntgenfotograferingen utföres.

financial support from the KNUT and ALICE WALLENBERG Foundation. The negatives were examined in appliances of very simple design.

If the photographic seed-analysis is to be carried out on a commercial scale with a simplified technique, the number of seed-samples that can be treated in an eight-hour day is calculated to average 100.

General outline of the procedure

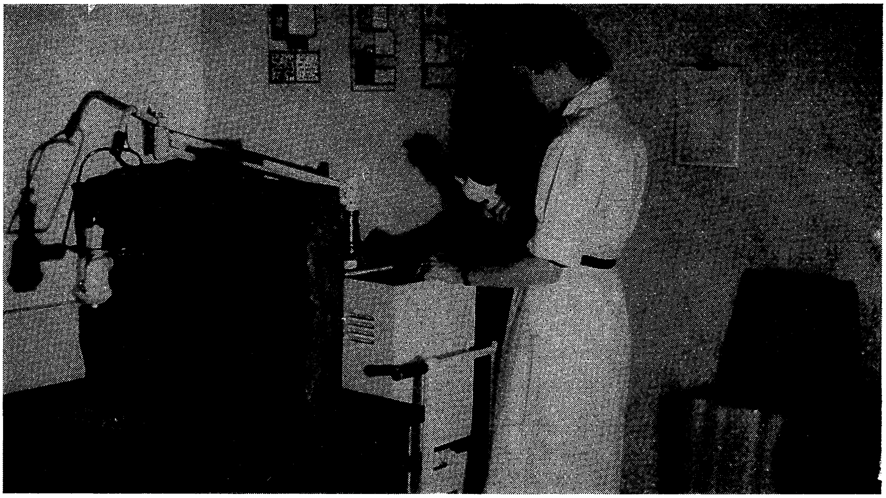
From each cone-lot a sample of 100 cones were taken at random. After extraction—for 16 hours at 49° C.—the seeds were de-winged by hand. By means of the seed-sampling board (HUSS 1951), adapted for the occasion, 6 working samples, each comprising 50 seeds, were taken out and weighed. In this way 300 good as well as empty seeds were available for the experiment. To ensure the individual examination we made use of special cardboard frames, provided with 2×50 oval perforations intended for the seeds. Each hole measured 6×3 mm thus giving ample space for one seed. Grease-proof paper was pasted on one side of the frame to prevent the seeds from falling through. The frames, filled with seeds, were fastened to the photographic plates with clips, exposed, processed and dried (Fig. 3). Following an introductory inspection of the plates, empty seeds from the four main frames were removed and replaced with good seeds from the two reserve frames, so as to give 4 frames, entirely filled with good seeds. Through entering the replacements in a journal, full control of the position and identity of each individual seed was preserved.

The seeds were now transferred to a circular piece of filter-paper in the same position as in the frames, and placed in the Jacobsen germinator. For the following 30 days, the germination was under daily control, and the sprouts were removed, when their roots reached a length of 4 mm, and the date thereof was entered in the journal.

In this way it has been possible to obtain information of the germinative capacity and the embryonic and endospermic characteristics of each individual seed.

Examination of the photographic plates

The characteristics of embryo and endosperm are described in fig. 5. To form an idea of the "individual factor" of the person who carries out the embryo-classification, 6 persons each classified 50 seeds from a sample containing all embryo-classes. Three out of the 6 persons had never previously been occupied with embryo-classification, and one was, in addition, quite unfamiliar with the internal morphology of the seed. After a short instruction, however, everybody was able to class the seeds without difficulty and quite satisfactorily (Fig. 4).



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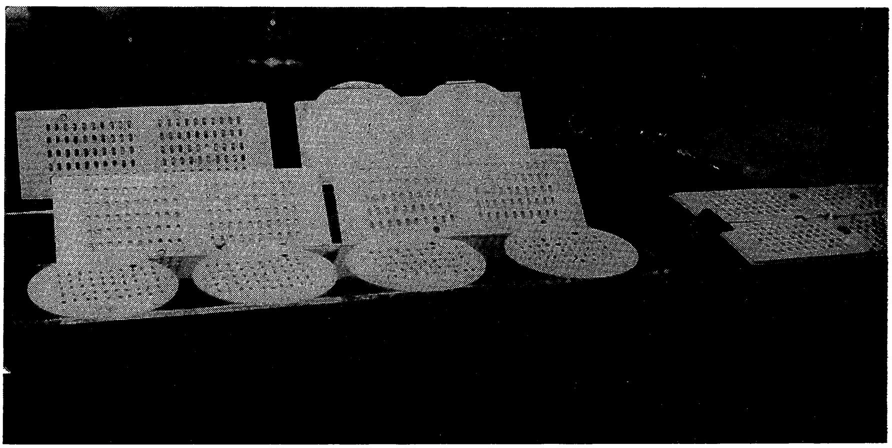


B

Fig. 3. A Operating the X-ray plant. The photographic plate with seed frames is seen beneath the X-ray tube. A lead-screen protects the operator from radiation.

Röntgenapparaten. Filmplåten med fröprov ligger under röntgenröret. Blyplåten på bordet skyddar arbetande personal mot röntgenstrålningen.

B Implements and materials. In the top right-hand corner is seen a suction-device for picking up single seeds. Under that, two photographic plates, without and with seed-frames.
The left-hand part of the photograph is occupied by seeds in various stages of treatment. Top: seed-frames, with and without filter-paper, placed between glass-plates for safe transport. Bottom: The frames have been removed and the seeds remain on the filter-papers, which are now ready for the germinator.

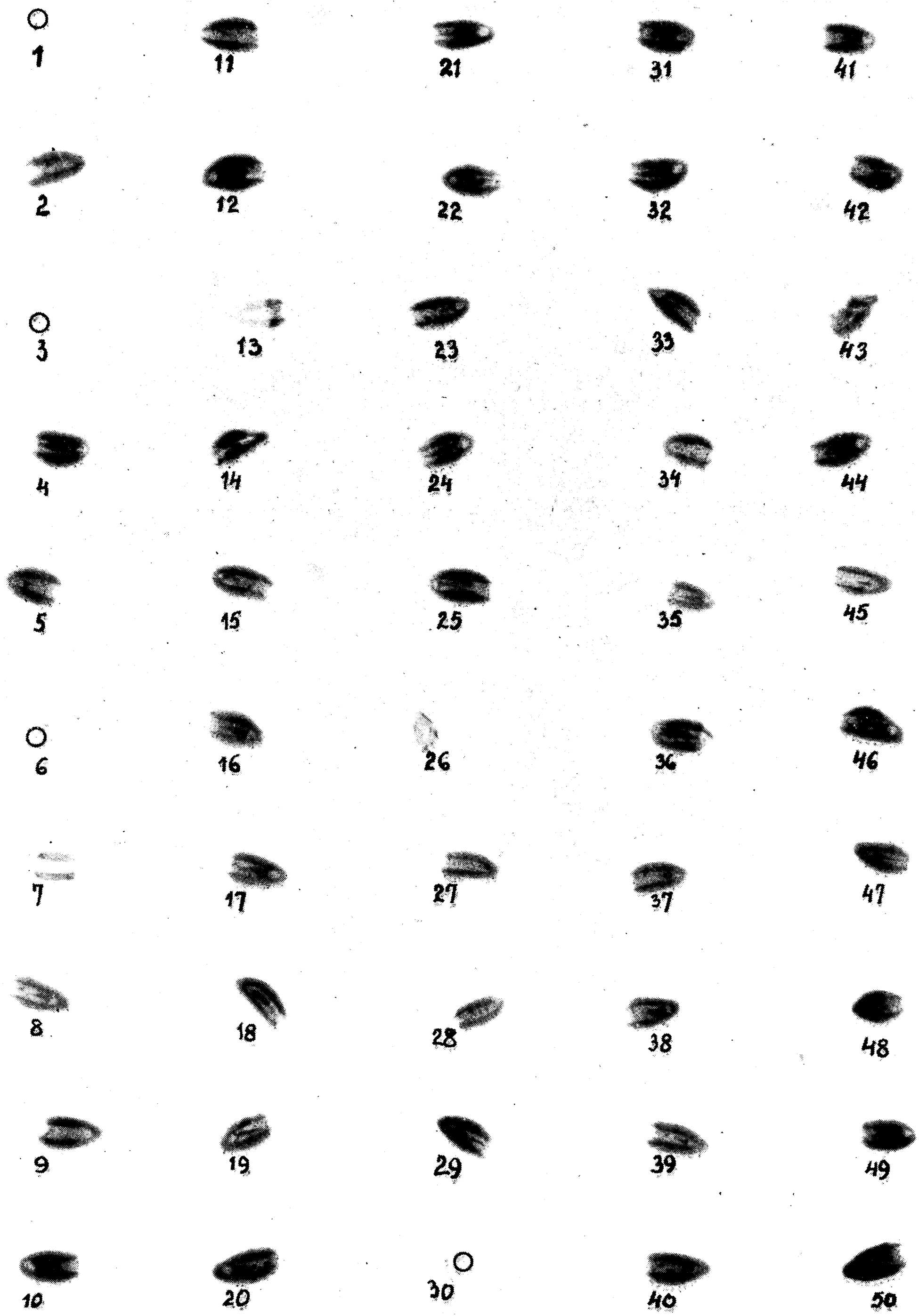
Tekniska hjälpmedel för försökets utförande.

EMBRYO-CLASS

Seed No.	0	I	II	III	IV	Seed No.	0	I	II	III	IV
1	■					26	BCDE	AF			
2			■			27			■		
3	■					28			■		
4					■	29			BCDF	AE	
5			■			30	■				
6	■					31				■	
7		■				32				A	BCDEF
8			■			33			AF	BCDE	
9			■			34			■		
10				■		35				■	
11			■			36					■
12				■		37			■		
13		■				38			D	ABCEF	
14			■			39			■		
15			■			40			■		
16				■		41				■	
17				■		42			■		
18				■		43					
19				■		44				■	
20			ABD	CEF		45			■		
21				E	ABCDF	46				ABCF	DE
22				■		47				■	
23			■			48			■		
24				ABCDF	E	49				ACDEF	B
25			■			50				■	

Fig. 4. The result of 6 persons' examination of a seed photograph. Where the opinions differ, the person's initial is printed in the square in question. Unanimity is marked by a black square.

Till höger: Röntgenfotografier av 50 frön, vilka klassificerats oavhängigt av sex personer (A—F). Personernas bedömning är angiven med resp. bokstav i fig. till vänster. Vid enig bedömning hos alla sex personerna äro embryoklasserna markerade i svart.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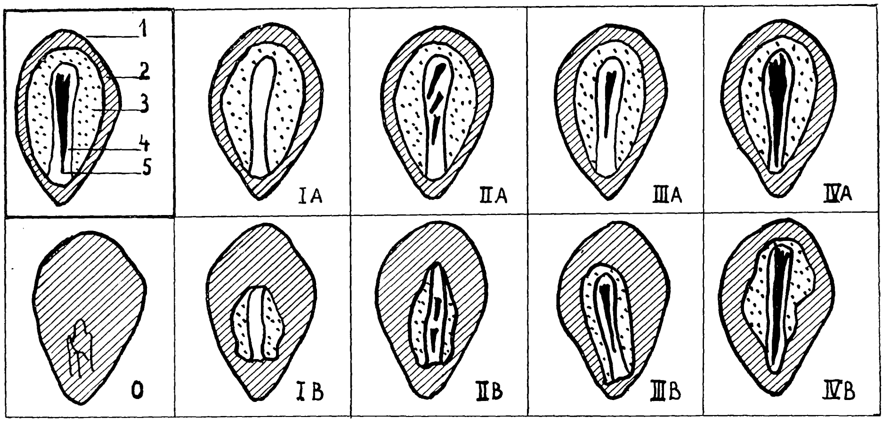
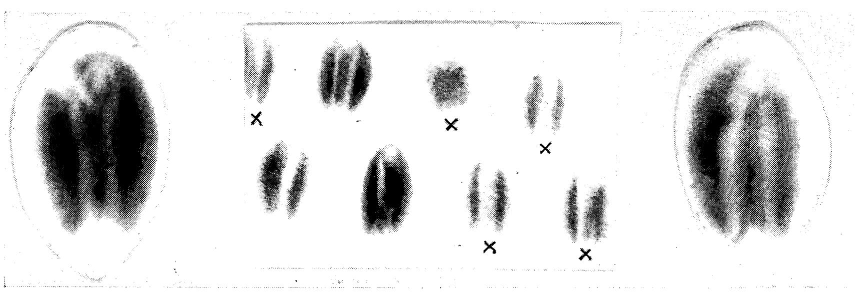
Embryo- and endosperm classes.



1. Seed-coat, 2. Cavity between seed-coat and endosperm, 3. Endosperm, 4. Embryonic cavity, 5. Embryo.

1. Fröskal, 2. Tomrum mellan fröskal och endosperm, 3. Endosperm, 4. Embryohåla, 5. Embryo.

O IB IIB IVA



A B C

Fig. 5. A. Seed, injured by rough extraction. B. Various degrees of X-ray absorption. The seeds marked with x did not germinate or germinated poorly. C. Seed with reversed (upside-down) embryo.

A. Klängningsskadat frö. B. Olika absorption av röntgenstrålar hos friskt och hos dött eller nästan dött frö. Endast frö utan kryss gro tillfredsställande. C. Abnormt frö (embryots läge omvänt).

Results

Empty seeds

The determination of the percentage of empty seeds is of great practical value. The majority of the methods of sorting out the empty seeds from the good ones, which are also the more easily applied, are based upon removing the empty and lighter seeds with a vertical air-stream (VINCENT 1930, ROHMEDER 1938, HUSS 1951). The procedure may meet with difficulties when endosperm and embryo are poorly developed, so that good and empty seeds differ only slightly in weight, or, in the case of mixed seed-samples that possess a great variety of seed-weights. In practice, however, these methods prove satisfactory (TIRÉN 1948).

The X-ray method gives exact information about the quantity of empty seeds, as will be seen from fig. 5. Table 1 gives the percentage of empty seeds for the examined 89 samples. The determination is based on 200 seeds from each sample.

Embryo-qualities and germinative capacity

In the present paper the same definitions of embryo-classes are used as in SIMAK and GUSTAFSSON 1954:

Class O: No endosperm and no embryo (empty seed).
I: Endosperm but no embryo.
II: Endosperm and one or several embryos, none of which larger than the embryonic cavity.
III: Endosperm and one not wholly developed embryo which fills between half and 3/4 of the embryonic cavity.
IV: Endosperm and one fully developed embryo, which completely occupies the embryonic cavity.

The distribution, in per cent, of good seeds to embryo-classes will appear from the following table, where all material studied has been gathered.

Embryo-class	I	0.77 %
	II	2.12 %
	III	7.45 %
	IV	89.66 %
		100.00 %

The predominance of embryo-class IV is undoubtedly due to the favourable climatic conditions prevalent during the years 1952—53 (HUSS 1954). Even the northernmost and the highest localities have yielded seeds of excellent maturity. A greater representation of the other classes would naturally have resulted in a better all-round determination of the germinative capacity, and especially so for class II. For class I the low number of seeds is not so fatal as might seem. According to the definition of this class, the seeds do not possess any embryo at all and so no germination can be expected. The actual germination of 2 sprouts is due to an erroneous classification, as very small embryos are not easily discernible on the plates.

Table 2 communicates the germination results for the 4 embryo-classes after 30 days in the germinator. The latter value will subsequently be named the reduction-factor. The application of this aims at an easy and reliable way of determining the germinative properties of any given seed-sample.

A condition is, of course, that a strong correlation exists between embryonic quality and germinative capacity. How a working hypothesis, with this assumption, fits with the facts, will appear from table 1. The sum of divergencies between actual and calculated germination is obviously nil; it is the magnitude of the separate deviations which is of importance. The majority of the deviations lie in the interval $\pm$ 5 %, which for practical purposes is sufficiently small. In four instances only, the calculated germination is numerically more than 5 % above the actual value (sample No. 3 — 10.5 %; No. 10 — 5.5 %; No. 11 — 9.5 % and No. 18 — 9.5 %). In one case (sample No. 51) the deviation is + 7 %.

On the strength of this, an adequately strong correlation between the embryo-classes and the germinative properties ascertained in the Jacobsen germinator, may be claimed.

Endosperm-qualities and germinative capacity

The present work aimed from the outset at including the properties of the endosperm in the investigation. As the photographic plates, however, showed a preponderance of well-developed endosperms in the seeds, an extensive distinction between endosperm-classes was abandoned. Reduction-factors in table 2, therefore, only refer to endosperm-class A. The good endosperm quality may, by analogy with the embryos, be owing to the fine weather conditions during 1952 and 1953.

Few samples possessed any greater quantity of seeds with inferior endosperm. The most outstanding ones in this respect were the strongly diverging samples from table 2, viz. No. 3, 10, 11 and 18. It is questionable if these samples should be excluded from the general investigation of the embryonic conditions, but if they were, it would mean a reduction of the already small quantity of class II-seeds by about 20 %, as a close connexion between embryonic and endospermic properties is not infrequent. After all, the inclusion of the 4 samples

Tab. 2.

	Embryo-class		I	II	III	IV	Total
a	Number of seeds		137	377	1,327	15,959	17,800
b	germinated seeds	absolute	2	188	1,169	15,808	17,167
c		per cent = reduction-factor	1.46	49.87	88.09	99.05	

Calculation of the reduction-factors of embryo-classes I—IV for seeds of endosperm-class A.

Beräkning av reduktionsfaktorerna i embryoklasserna I—IV för frö av endospermklass A.

in question does not seriously influence the reduction-factors of the other embryo-classes.

According to experiences from similar experiments, the endosperm may be classed as follows:

A: The endosperm almost fills up the seed-coat, and its absorbing ability to X-rays is normal.

B: The endosperm fills the seed-coat very incompletely. The absorption of X-rays is deficient (Fig. 5).

About 14 % of the seeds in the 4 above mentioned samples belong to endosperm-class B (Table 3).

This table, comprising figures from sample No. 3, 10, 11, and 18, illustrates to which extent the germinative capacity may be influenced by variations in endosperm qualities. Were these not taken into account, the actual germination of these samples would be considerably below the calculated reduction-factors given in table 3 (cp. d and e).

Table 3 also shows:

1) Considering the small quantity of seeds in the material, good accordance is found between the germination percentages for A-seeds and the reduction-factors; see e and d.

2) For all embryo-classes, seeds of endosperm-class B display a lower germination percentage than those of class A (c). The difference has its highest value for embryo-class II, and its lowest for class IV. Generally speaking, a given embryo-class with B-endosperm has approximately the same reduction-factor as the next lower embryo-class with A-endosperm.

It has already been suggested that the conclusions which may be drawn from this scanty material, are but of small consequence compared with the

Tab. 3.

			II		III		IV	
Embryo-class			II		III		IV	
Endosperm-class			A	B	A	B	A	B
a	Number of seeds		39	42	189	30	459	25
b	Seeds germinated after 30 days	absolute	18	2	156	13	440	17
c		per cent	46.15	4.76	82.54	43.33	95.86	68.00
d		per cent A+B	24.69		77.17		94.42	
e	Reduction-factor according to tab. 2		49.87		88.09		99.05	

The germinative capacity of Scots pine seeds of embryo-classes II to IV and endosperm-classes A and B. The seeds—from trees No. 3, 10, 11, and 18—were grown in Jacobsen's germinator.

Grobarheten (i Jacobsens apparat) hos tallfrö av embryoklasserna II—IV och endospermklasserna A och B.

much more dependable reduction-factors for class A-seeds. The material, however small, shows with sufficient clearness, concerning the determination of the endosperm qualities of the three higher embryo-classes, that safer results can be achieved by an improved technique in the X-ray method.

It has to be pointed out, that these endosperm-classes cannot so far be applied to seeds, injured by defective storing, premature harvesting of the cones a. s. o.

An example of this is given by SIMAK and GUSTAFSSON (1954). A 6-year-old graft of Scots pine with almost fully matured cones, was transplanted in late summer. Its seeds were photographed, and the plates showed good embryos, as well as endosperms that completely filled the seed-coats, but in spite of their high 1,000-seed weight and apparently good quality, the seeds germinated very poorly. The plates also showed that seeds, which did not germinate, possessed endosperms with alterations in X-ray absorption (Fig. 5).

A method to distinguish between the more or less pronounced qualitative differences in the properties of the seeds, as they appear on the X-ray plates, awaits further development.

Vigour of growth

The Jacobsen germinator usually presents a too optimistic picture of the seed-properties (ROHMEDER 1949, NORDSTRÖM 1953), as the growing conditions beneath the glass-cubes are considerably more favourable than those in the soil of a nursery. Practice, therefore, always has to calculate with a somewhat lower germinative power of the seeds, which depends on 1) the growth vigour of the seeds, and 2) the environments.

To estimate the growth vigour it is usual in connexion with the germination percentages to give the speed of growth, i. e. for Scots pine, the percentage of seeds that germinate during the first 10 days. As shown in fig. 6, both speed and vigour of growth are correlated to the embryonic and endospermic properties of the seeds.

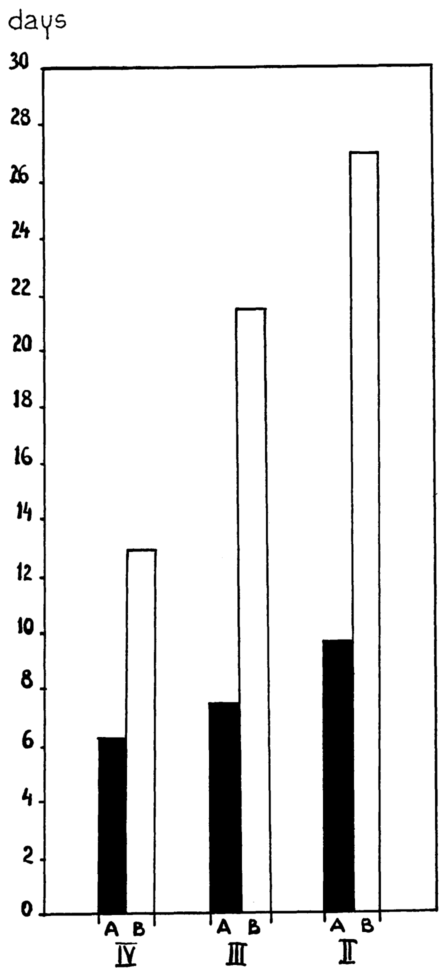


Fig. 6. The dependence of speed of germination for Scots pine-seeds (in Jacobsen's germinator) to embryo- and endosperm-classes.

Sambandet mellan frökvaliteten (embryo- och endospermklass) och groningshastigheten hos tallfrö i Jacobsens apparat.

This attempt at determining the vigour was based upon 9 samples, chiefly consisting of class A-seeds (No. 2, 5, 14, 49, 50, 51, 90[1], and 91[1]), and 4 samples with a comparatively strong representation of class B-seeds (No. 3, 10, 11, and 18). For each embryo-class the average speed of growth was calculated for the seeds which had germinated during 30 days; very few from the latter group. From this it appears, that the speed of growth increases with higher embryo- and endosperm-classes. It is obvious, too, that an improvement of embryo-class makes the seed less sensitive to variations of the endosperm. An estimation of the vigour is consequently possible from the reading of the X-ray plates.

The second factor, which affects the germinative capacity in nature, is the ecological conditions for germination as such. These conditions are practically beyond our absolute control, and it is therefore impossible to give an exact prognosis as to the germination in nature. The seed-control institutions usually apply standardized methods for approaching the value of "natural" germination; these methods include more demanding, yet normalized, conditions, resulting in a definite germination prognosis (ROHMEDER 1951). In order to supplement the present investigation in this respect, the following experiment was made.

About 1,700 seeds from the trees No. 2, 39, 48, and 90, divided to the 4 embryo-classes (endosperm A), were sown in sand at various depths, viz. 0.5, 1.0, 1.5, 2.0 and 3.0 cm. Simultaneously, an analysis was made in the Jacobsen germinator. The object was to ascertain to what degree the external conditions influence the germination of the different embryo-classes. The experiment was laid out in a green-house at a temperature of about 18° C. After 6 weeks the seedlings were counted (cf. fig. 7).

1) The highest germination percentages are found in the Jacobsen germinator.

2) For all depths of sowing, the germination is in direct ratio to the embryonic qualities (decreasing from IV to II).

3) The greater the depth, the less germination for all embryo-classes.

4) For an increase of depth, a reduction of embryo-quality involves a progressive decrease of germination.

So for embryo-class II: at 1.0 cm a very poor, and at 2.0 cm no germination at all. For class IV, germination was observed even in the 2.0 cm-group.

Seeds sown at 3.0 cm depth did not penetrate the surface of the bed after 6 weeks.

No. 90: Lat. 65° 0′, Long.: 18° 30′, Altitude: 410 m
No. 91: Lat. 67° 45, Long.: 23° 10′, Altitude: 300 m

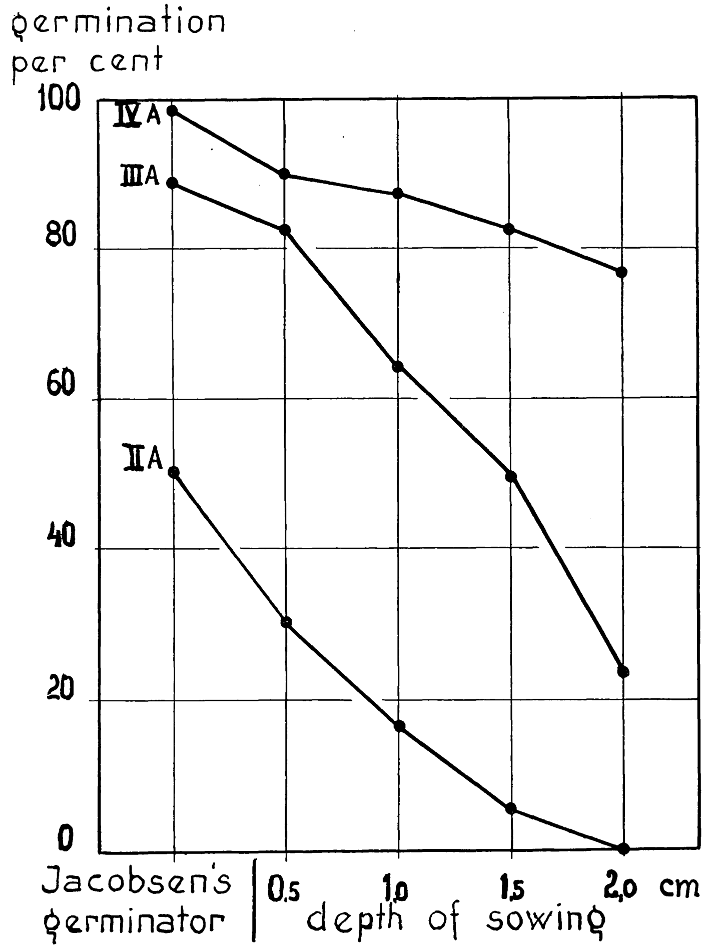


Fig. 7. The germination capacity of Scots pine-seeds as found in Jacobsen's germinator and of seeds, sown in sand at various depths.

Jämförelse mellan grobarheten i Jacobsens apparat och grobarheten vid olika såddjup i sand.

Summing up this experiment it becomes obvious, that the determination of embryo- and endosperm-classes also helps to ascertain the germinative vigour and so to establish the most favourable conditions of germination.

We want to point out, that similar and even more pronounced conditions may be found for seeds with B-endosperm. Different seed-bed media will naturally give different values of germination vigour.

Summary

The experiments were carried out with freshly collected seed-material of Scots pine.

For a working hypothesis of the investigation, a correlation between seed-qualities, i. e. embryo and endosperm properties, and germinative capacity together with germinative vigour was assumed. The aim was to adapt this supposed correlation to practical purposes.

The properties of the seed are easily and quickly determined by means of X-ray photography. The employment of soft rays in low dosages excludes the risk of injuring the seed.

The different stages of embryo and endosperm development can be observed on the photographic plates and classed in

a) 5 embryo-classes page 11
b) 2 endosperm-classes » 13

In the Jacobsen germinator the course of germination was followed for seeds that previously had been photographed, so as to obtain facts of the internal qualities of the seeds and of the speed of growth. The connexion between these facts could be examined for each seed separately.

Results: 1) A relatively strong correlation exists between embryo qualities and the germination in the Jacobsen germinator.

2) The connexion between germination results and readings of the photographic plates, with respect to embryo-classification, can be made closer and, in addition, endosperm qualities can be taken into account.

3) By means of X-ray photography, it is possible to estimate the germinative vigour in relation to the speed of growth in the Jacobsen germinator, and conclusions may be drawn as to the germination in nature.

For practical purposes the germinative capacity of freshly collected seed of Scots pine may be satisfactorily determined by means of X-ray photography.

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Sammanfattning

Röntgenfotografering vid grobarhetsanalyser av tall *(Pinus silvestris L.)*

Med hjälp av den röntgenfotografiska metod, som nyligen utarbetats vid genetiska avdelningen (Simak och Gustafsson 1953 a, b, 1954), kan frökvaliteten hos tall bestämmas med stor noggrannhet och snabbhet.

Med frökvalitet betecknas i denna uppsats embryots och endospermets utvecklingsgrad i ett fröprov.

Den på röntgenfotografisk väg fastställda frökvaliteten har jämförts med grobarheten i Jacobsen-apparaten och i sådder.

Analysen gav följande resultat:

1. Mellan frökvalitet och groningsprocent i Jacobsen-apparaten råder ett starkt samband.
2. Röntgenfotografier medge bestämda slutsatser rörande frönas vitalitet och därmed deras groningsbeteende under naturliga betingelser.

En röntgenanalys har betydande fördelar jämfört med en groningsanalys enligt traditionella linjer, den är snabbare, enklare, billigare och ger mera detaljerade upplysningar av omedelbart praktiskt värde.

Undersökningen har utförts med bistånd av Domänverkets personal.

Kottmaterialet insamlades under tiden 1—15 november 1953 och är representativt för hela landet.