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Effect of X-rays on Seeds of Scots Pine from Different Provenances (Pinus silvestris L.)

By KIHACHIRO OHBA[1]) and MILAN SIMAK[2])

Forest Research Institute, Stockholm, Sweden

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Introduction

The experiment reported in this paper was undertaken to obtain information about the radiation sensitivity of pine seeds from different provenances.

Variation of radiation sensitivity among strains within particular species has already been studied in some agricultural plants. Thus, JOHNSSON (1933) found a greater sensitivity to radiation in the red and the white varieties of *Atriplex hortensis* than in the green ones. SMITH (1942) discovered a mendelian factor decisive for the sensitivity of *Triticum monococcum* to X-rays as expressed by seedling growth and survival. MÜNTZING (1941) concluded in his experiment with autotetraploid and diploid *Hordeum distichum* that "the autotetraploid line is more resistant to X-rays because it has four quite homologous genomes instead of only two as in the diploid". The genetic damages in a chromosome of the tetraploid barley can therefore be counterbalanced by a normal condition in the other homologous chromosomes. TEDIN and HAGBERG (1952) found that the X-ray sensitivity differed between the sweet and the bitter lupine, *Lupinus luteus*. GREGORY (1956a and b) observed a variation in sensitivity to X-rays in experiments with *Arachis hypogea*. SARIĆ (1957) reported the tetraploid form of *Petkus winter* rye to be less sensitive to X-rays than the diploid one, and LAMPRECHT (1956, 1957) described certain pea varieties which were more sensitive to X-rays than others. GELIN *et al.* (1958) published a report concerning genetically conditioned influences on the radiation sensitivity of peas. They found that the reaction to radiation is determined by the moisture content of the seeds, germination temperature, and other factors important for plant growth. Recently SMALIK *et al.* (1960) have found variation in the X-ray sensitivity of four potato varieties. The authors stated that long established varieties (date of origin) and varieties with high protein content are more sensitive to X-rays. LAFFERS (1960) stated that gerrninant seedlingc of *Picea abies* from high elevations were more resistant to gamma rays than seedlings of lowland origin, i. e. principally a result similar to that of this experiment.

Table 1. — Description of the material

No.	Provenance	Altitude (m)	Latitude	No. trees
1	Kojkul	175	66°20'	10
2	Bölensberget	398	63°55'	10
3	Hissjö	90	63°55'	8
4	Olingsjön	490	61°45'	10
5	Ovanåker	300	61°20'	4
6	Sunne	150	59°50'	9
7	Sanda	54	59°10'	8
8	Långenäs	75	57°40'	8
9	Byarum	295	57°30'	8
10	Bjärges	45	57°25'	8

Maferial and methods

Pine seed lots (*Pinus silvestris* L.) representing ten provenances in various parts of Sweden were used. *Table* 1 describes the origin of these seeds and presents the number of harvested trees in each provenance.

After collection in the autumn of 1959, the cones were sent to the Forest Research Institute where the seeds were extracted. Since the radiation sensitivity of pine seeds depends on the developmental stage of the embryo (GUSTAFSSON and SIMAK, 1958), only fully developed seeds were used (IV A). Seeds from each of the provenances were examined and divided into embryo classes by the X-ray photo method (SIMAK and GUSTAFSSON 1953).

Table 2 shows that embryo class IV predominates in all the seed lots. Thus, the selective use of these seeds provides samples that rather faithfully represent the population stuctures. The high percentage of well developed seeds in northern Sweden is unusual (cf. GUSTAFSSON and SIMAK 1956), and it was probaly caused by the exceptionally good conditions for seed ripening which prevailed in this part of the country in 1959 (cf. EHRENBERG *et al.* 1955).

Since the moisture content of seeds determines their radiation sensitivity (EHRENBERG 1955, GUSTAFSSON and SIMAK 1958), it was standardized by equilibrating the seeds for one week with an air current of 45 per cent relative humidity, obtained by passing the air through 9.8 molar KOH.

Table 2. — Analysis of the seed material

NO.	Weight of 1000 seeds in class IVA	Embryo and endosperm spectrum, per cent								
		Empty seeds	IA	IIA	IIIA	IVA	IIB	IIIB	IVB	Ab-norm. seeds
1	3.602	28	1	1	3	64	—	—	1	2
2	4.177	6	1	10	18	61	3	—	—	1
3	3.399	9	1	2	3	79	1	1	4	—
4	5.139	13	—	2	5	77	—	—	1	2
5	4.600	20	1	2	2	74	—	—	1	1
b	5.103	1	—	—	2	97	—	—	—	—
7	3.693	5	—	1	1	90	—	—	1	2
8	4.968	4	—	—	1	94	—	—	1	—
9	4.823	7	—	—	3	90	—	—	—	—
10	3.469	16	—	4	3	69	1	2	5	—

[1]) National Institute of Radiation Breeding, Ohmiya-machi, Naka-gun, Japan.

[2]) Forest Research Institute, Stockholm 51, Sweden.

Table 3. — Some characteristics of the control seed

Provenance No.	Adjusted water content of seeds (per cent)	Germination (per cent)	Germination time	Length of hypocotyl (mm)	Length of root (mm)
1	8.6	95	9.2	23	27
2	8.8	100	8.8	23	30
3	8.9	99	9.0	23	25
4	8.3	98	7.7	28	34
5	8.3	99	8.4	26	30
6	8.6	97	7.8	29	35
7	9.0	99	8.8	26	30
8	9.3	98	9.7	26	31
9	8.3	98	8.7	27	34
10	9.1	100	9.2	22	25

The moisture content of the seeds after equilibration varied between 8.1 and 9.3 per cent of the weight of dry seeds *(Table 3)*.

The experiment comprised the following irradiation series 0 r - 600 r - 1200 r - 2400 r - 3600 r and 4800 r.

The X-ray unit was operated under the following conditions: 150 KV, 10 mA, focus 50 cm, filter 0.5 mm Cu + 1.0 mm Al, and dose rate 27 r/min. Doses were measured by a Duplex dosimeter. Each dose was administered simultaneously to samples from all the provenances, and during the irradiation the seeds were kept in small paper boxes.

The experiment was designed with three replications (blocks) totalling 102 (3 × 34) seeds per treatment. Immediately after irradiation every seed was individually sown at a depth of 5 mm in sand specially prepared in stainless steel boxes. The seeds were placed at regular intervals in randomly distributed rows, each of which represented one irradiation series. The germination beds were kept moist during the entire experiment by constant subirrigation (Gustafsson and Simak 1958). The intensity of the continuous artificial light was approximately 1000 Lux at the surface of the germination beds and temperature fluctuated between 22° C and 25° C. Emerging seedlings were recorded daily and marked with rings. The observations terminated 50 days after sowing.

After the termination of the experiment the seedlings were measured and the data were then processed to values expressed in per cent of corresponding measurements of the controls. These parameters are given in *table 3*.

Results

The following characteristics were studied:

1. Indicators of radiation sensitivity
   a) germinability,
   b) time of germination,
   c) seedling mortality,
   d) seedling development:
      i. hypocotyl length,
      ii. root length.
2. The radiation sensitivity of the seeds in relation to the ecological factors at the original habitats.

1. *Indicators of radiation sensitivity*

It should be emphasized that the germinability is calculated on the basis of *the number of seeds sown*. The other indicators of radio-sensitivity are based on *the number of seeds germinated* (time of germination and seedling mortality) and *the number of live seedlings* at the termination of the experiment (hypocotyl length and root length).

Since the germinability and the number of surviving seedlings were particularly low after the highest irradiation dosage, the values for germination time, seedling mortality, hypocotyl length and root length obtained after this exposure must be judged with some reservation.

a) Germinability (Table 4)

Doses lower than 2400 r did not affect germinability of seed samples from any of the ten provenances. Only provenance No. 8 showed reduced germination after irradiation with 2400 r. Nine of the ten seed lots responded to an irradiation of 3600 r with reduced germinability. Germinability of all seeds definitely decreased on exposure of 4800 r. Large differences in sensitivity to X-irradiation of 3600 r and 4800 r occur among the various seed lots, No. 4 showing high resistance and several of the others high sensitivity. For the 3600 r series the differences in X-ray sensitivity between seed lots from various provenances were tested in a variance analysis and they have been found significant *(Table 8)*.

Table 4. — Germinability after 50 days (per cent of control)

Provenance No.	r-dose 0	600	1200	2400	3600	4800
1	100	96	101	102	82	45
2	100	97	93	98	79	27
3	100	101	101	97	75	20
4	100	100	100	100	96	80
5	100	102	99	101	77	40
6	100	102	101	100	83	21
7	100	97	98	93	72	35
8	100	98	99	72	42	18
9	100	101	100	98	62	11
10	100	99	100	98	77	35

b) Germination time (Table 5)

The time of germination has been expressed as follows:

$$\text{Germination time} = \frac{\sum_1^{50}(d \times n)}{S},$$

where d = days from sowing and n = No. germinated seedlings on day d. S is No. germinated seedlings up to the 50th day.

Table 5. — Germination time (per cent of control)

Provenance No.	r-dose 0	600	1200	2400	3600	4800
1	100	99	101	116	143	175
2	100	100	109	122	152	184
3	100	95	104	121	147	208
4	100	103	104	120	139	193
5	100	99	103	120	151	216
6	100	100	104	123	159	209
7	100	110	109	139	173	197
8	100	111	117	133	147	153
9	100	99	110	127	176	209
10	100	106	105	123	150	244

No significant stimulative effect of X-rays on the germination time was observed. Clearly an increase in time is required for germination as dosage increases. Seeds exposed to 4800 r required about twice as long time for germination as did the control seeds. The differences between the seed lots with respect to germination time increased with rising dosage.

c) Seedling mortality (Table 6)

The seedling mortality has been expressed in per cent by:

$$\frac{\text{No. dead seedlings}}{\text{No. germinated seeds}} \times 100.$$

Mortality was 0 to 2 per cent in the controls. The mortality was intermediate for seeds exposed to 2400 and 3600 r. In the 3600 r-series the seedlings from the provenances 6, 8, 9 and 10 showed a mortality exceeding 55 per cent,

Table 6. — Seedling mortality (per cent)

Provenance No.	r-dose			
	0	2400	3600	4800
1	1	5	28	73
2	2	1	30	100
3	0	7	41	64
4	0	1	12	54
5	1	6	35	68
6	0	16	62	96
7	0	12	33	63
8	0	45	57	89
9	0	26	59	87
10	1	9	60	61

whereas Nos. 1, 2 and 4, displayed a mortality lower than 30 per cent.

Seedlings resulting from irradiated seeds appeared weak and were frequently attacked by fungi. Fungal attacks, however, have not been observed on the control seedlings in spite of the fact that they were growing close to irradiated and attacked seedlings.

d) Seedling development

Besides hypocotyl length and root length, seedling aspects and colour were also observed. Seedlings from heavily irradiated seeds often produced dark green, dwarfish, thickened cotyledons and hypocotyls, or exhibited pale green spots. When such abnormal hypocotyls were examined anatomically disturbances in the tissues were found *(Fig. 1)*.

i. Hypocotyl length (Table 7): — The length of the hypocotyl is measured from the seed bed surface to the point of cotyledon ermergence. — After a dosage of 600 r some of the seed lots showed a slight stimulation of the hypocotyl length, but the discrepancies lie within the limits of error. Generally, there was a clear decrease in hypocotyl length following the higher doses. Although the data representing each provenance are rather varying it may be seen that

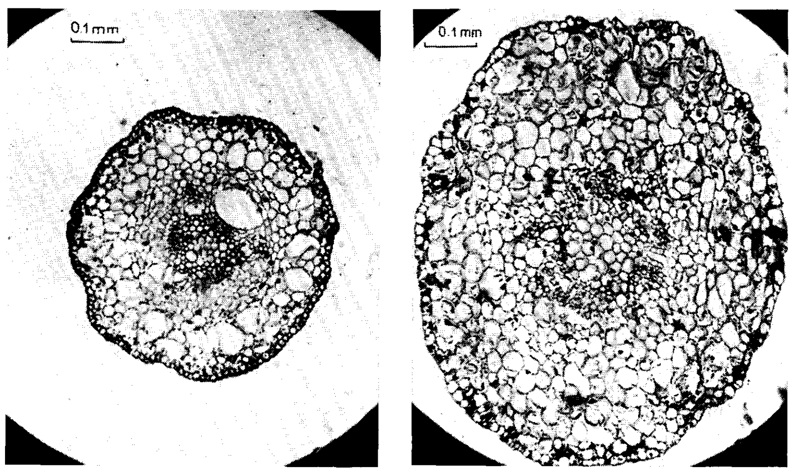

Fig. 1. — Cross-section through the hypocotyl of a Scots pine seedling from non-irradiated seeds *(a)* and from seeds irradiated with 3600 r *(b)*. The picture of the non-irradiated seedlings clearly shows tissue differentiation in epidermis, endodermis, xylem etc. In the irradiated seedling, however, a strong disturbance is noticeable in the formation of these tissues. – In the irradiated seedling the hypocotyl is usually thicker than that of the non-irradiated seedling.

Table 7. — Hypocotyl length/Root length (per cent of control)

Provenance No.	r-dose					
	0	600	1200	2400	3600	4800
1	100	106	98	96	82	68
	100	93	87	88	73	56
2	100	98	99	90	78	0
	100	81	91	82	67	0
3	100	106	98	91	77	62
	100	98	98	87	68	48
4	100	92	94	82	83	72
	100	100	104	91	75	62
5	100	95	89	88	74	69
	100	98	100	90	74	75
6	100	94	94	81	69	0
	100	91	94	75	69	0
7	100	95	92	84	67	52
	100	99	96	72	43	28
8	100	103	96	84	69	72
	100	100	89	85	66	56
9	100	96	94	82	68	53
	100	96	95	77	60	56
10	100	105	107	96	71	63
	100	111	102	86	51	55

the values for the provenances No. 6, No. 7, No. 8, and No. 9 are comparatively low after high doses. The differences in the hypocotyl length between the provenances obtained after an exposure of 3600 r are significant *(Table 8)*.

ii. Root length (Table 7): — Roots, like hypocotyls, sometimes showed insignificant growth stimulation following irradiation of seeds with the two lowest doses. The average root length after a dosage of 3600 r amounts to 65 per cent of the control value and the variation extremes amount to 43 per cent and 75 per cent for the samples No. 7 and No. 4 respectively. The differences in root length between the provenances are significant for this dosage *(Table 8). Table* 7 further shows that generally root growth is inhibited more than hypocotyl extension for seeds irradiated with 3600 and 4800 r.

2. *The radiation sensitivity of the seed in relation to the ecological factors at the original habitats*

The results show great differences between the provenances with respect to the radiation sensitivity of the seeds. Since the provenances examined are situated in different regions (latitude, altitude, micro-climate, site conditions, etc.), the question arises whether there is any relationship

Table 8. — *Analysis of variance:* The radiation sensitivity of the seed (expressed by germinability, seedling mortality, hypocotyl length and root length) in relation to the growing season, — the 3600 r-series

	Source of variation	Degrees of freedom	Germinability Mean square	Seedling mortality Mean square	Hypocotyl length Mean square	Root length Mean square
1	within provenances	20	60.633	76.567	14.200	88 300
2	between provenances:					
3	regression on length of growing season	1	1979.603	4891.853	681.612	1399.254
4	deviations	8	452.837	382.535	24.282	198.943
5	total „between"	9	622.478	883.570	97.319	332.311
6	total	29				
	Ratios of variation:					
	For testing of regression $\frac{3}{4}$		4.37⁰	12.79**	28.07***	7.03*
	For comparison between provenances $\frac{5}{1}$		10.27***	11.54***	6.85***	3.76**
	Regression coefficient		−0.393±0.188	0.618±0.173	−0.231±0.0436	-0.331±0.125
	Regression equation y =		132.3 —0.393 x	—49.7 +0.618 x	108.0 —0.231 x	113.6—0.331x

between the radiation sensitivity of the seed lots and the ecological conditions prevailing at the original habitats. The ecological conditions can be partly expressed by the length of the growing season. We have adopted LANGLET's (1936) expression of the length of the growing season as the number of days per annum with a mean minimum temperature of + 6⁰ C. In this experiment the length of the growing season thus varies between 118 days (provenance No. 1) and 173 days (provenance No. 8). The formula used for calculation of the length of the growing season (514.18 - 5.85 L - 0. 0736 H + 0. 000365. L. H) includes the latitude (L) and the altitude (H) of each provenance, thus two climatical factors determine the morphological and physiological variability of Scots pine (LANGLET 1936 and 1959).

The radiation sensitivity of the seeds in relation to the length of the growing season of the various provenances was studied in the 3600 r series with respect to germinability, seedling mortality, the hypocotyl length and root length.

The analysis of variance in *table 8* shows that the differences in sensitivity to X-rays between the seed lots are very significant (P = 0 .001) regarding germinability, seedling mortality, and hypocotyl length and significant (P = 0 .01) for root length. The analysis of variance further shows that the X-ray sensitivity of the seed lots is related to the length of the growing season. Seeds from provenances with short growing season are less sensitive to X-rays than seeds from provenances with long growing season (cf. regressions in *Figs. 2—5*). This relationship is significant for seedling mortality, hypocotyl length and root length but insignificant for germinability *(Table 8)*.

Discussion

Pine seed from a population is a heterogenous material for irradiation experiments. Heterogeneity of origin, heterozygosity, seed size, seed maturity etc. are some of the factors that may affect the result.

The fact that the seeds used in this experiment originate from several trees in each provenance is perhaps most important in this respect. SIMAK *et al.* (unpubl.) found considerable differences in the radiation sensitivity between Scots pine seed lots due to variation between the individual trees of a population and between the small seeds and the large seeds of one tree. Simultaneously, it was found that seeds from a tree with spontaneous chromosome aberrations were more sensitive than seeds from trees with normal cell division.

Thus the original population structure of a sample of mixed seed is changed by irradiation; seeds from separate trees being influenced to a varying extent. Eo ipso, the seedlings in various radiation series genetically represent a population composition entirely different from the original one (control).

Another relevant influence of importance for this experiment was the great variation in the number of seedlings for the various provenances and irradiation series. Consequently, the mean values of hypocotyl length and root length calculated on the basis of these numbers of seedlings will have different weights. Thus, of 102 seeds sown, 85 seedlings from provenance No. 4 but only 18 seedlings from provenance No. 8 were available for measurements of seedling properties in the 3600 r series.

The variation in the number of seedlings developing from the irradiated seed lots is an unavoidable result of the experiment. Certainly, investigation of the effects of irradiation on the properties of seedlings can be omitted, but the consideration of these seedling properties may here be of great value for further studies of this problem.

The results must therefore be regarded against this background.

The low radiation doses 600 r — 1200 r cause an increase in germinability, rate of germination, hypocotyl length and root length for seed and seedlings from certain provenances. The effect, however, is very slight and it would require a special investigation with lower radiation exposures and a larger material to decide whether this stimulation is significant. Although a similar stimulation occurs in most radio-biological experiments, it seems to be of minor value for practice (SIMAK and GUSTAFSSON 1953, SAX 1955, GUSTAFSSON and SIMAK 1959).

A radiation exposure of 1200 r — 4800 r reduced the germinability, the rate of germination, and the seedling development for all the seed lots, and seedling mortality was raised. These effects of radiation increased with rising dosage. Coinciding with these damages, disturbances in cell division also increased with a disorganization of the seedling anatomy *(Fig. 1)* and mortality as ultimate results (SUSZKA *et al.* 1960).

To enable a close study of the relationship between the radiation sensitivity of seeds and the source of origin, the

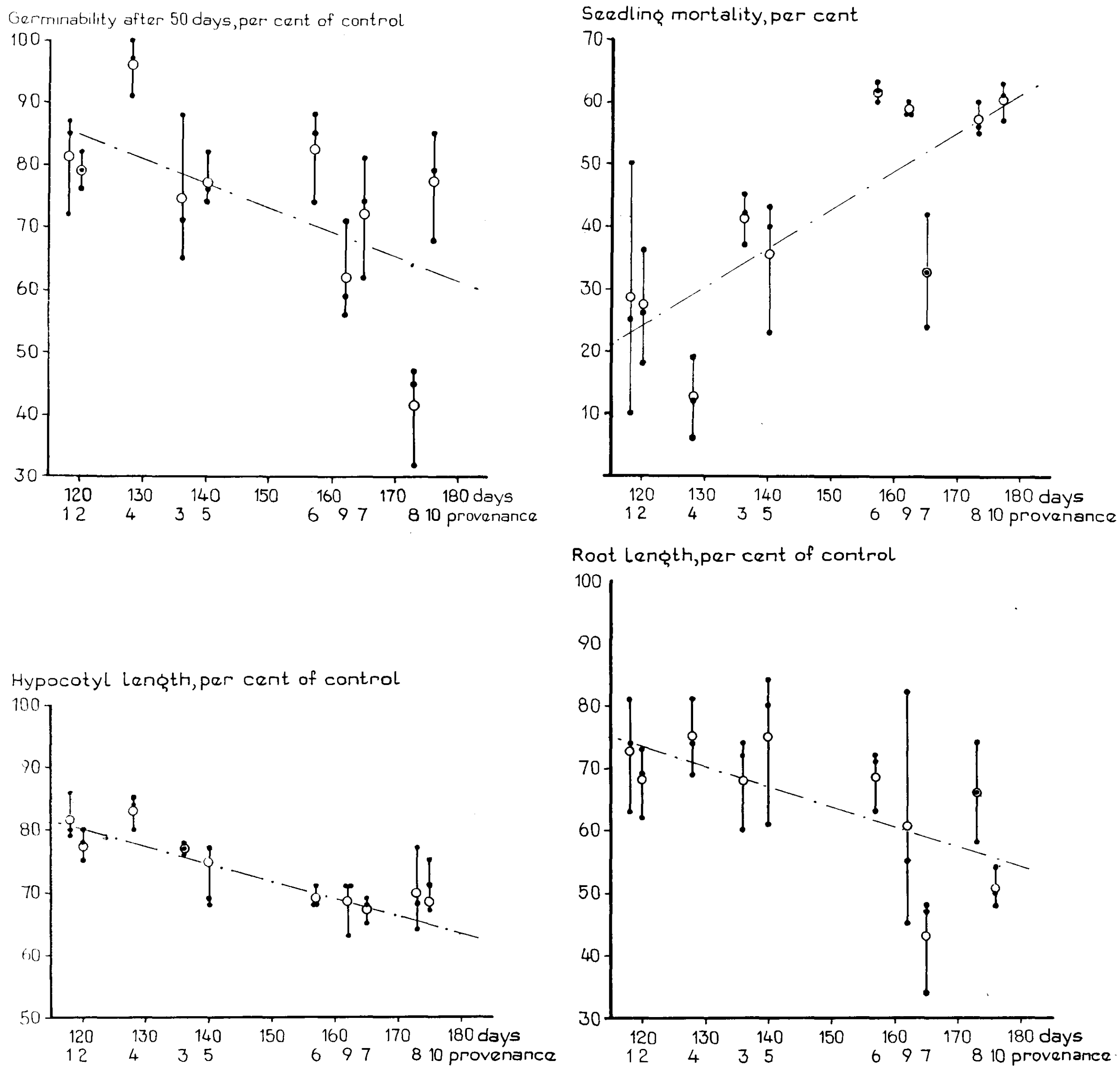

Fig. 2, 3, 4 and 5. — Dose of application: 3600 r. — The length of growing season is expressed in days on the X-axis. — The provenances are placed according to their computed length of growing season (cf. text).
• indicate values of replicates.
o indicate mean values of the replicates.

length of the growing season has been calculated by means of the latitude and altitude for each provenance (LANGLET 1936). Owing to the great variation in latitude (57^0 N — 66^0 N) and altitude (45 m — 490 m) between the provenances investigated, the length of the growing season appeared to be a criterion very suitable for a study of the radiation sensitivity of seeds from ecologically different areas. It is realized, however, that this ecological definition of each provenance is incomplete since other factors, too, should be considered. Nevertheless, the investigation has shown that a relationship exists between the length of the growing season and the radiation sensitivity of the seeds. The relationship was most feasibly studied in the 3600 r series. The reason for studying the material in this series was that the X-rays had no differentiating effect with respect to the provenances in the low irradiation series (600 r — 1200 r) cf. *tables 4, 6 and 7.* In the highest series, however, the material was insufficient for such an investigation.

The relationship between the length of the growing season and the radiation sensitivity of the seed is most clear with respect to the length of the seedlings (hypocotyl and root). After radiation exposure seedlings representing provenances with short growing season are relatively longer than seedlings representing provenances with long growing season. Similar relationships are valid for the germinability. Seedling mortality is higher for material from provenances with long growing season. The regression deviations from zero are significant in all cases except for germinability. It may be emphasized, however, that germinability is the factor which has been most subject to great variation during the course of the experiment on account of minor changes in the experimental set-up (variation in sand moisture, depth of sowing etc.). Root length, too, is rather strongly influenced by variations in the moisture and structure of the seed bed. Hypocotyl length is the characteristic least influenced by these factors (except depth of sowing). It may be concluded from above that seeds from provenances with a long growing season are more sensitive to X-rays than seeds from places with short growing seasons.

The source of variation in X-ray sensitivity could possibly be found in the specific physiological and biochemical features of seeds from places with different length of growing season; i. e. in the variation in the content of water, proteins, fats and ferments. These features may be genetically conditioned in certain cases (SCHMIDT 1930).

The water content of the seed lots investigated and equilibrated ranged from 8.1 per cent to 9.3 per cent (provenance Nos. 4 and 8, respectively), an apparently slight difference. However, according to investigation carried out by OHBA (1961) variations in the water content of this magnitude may be of great importance for the irradiation results. OHBA showed for Japanese red pine *(Pinus densiflora)* that the sensitivity to gamma rays increased sharply especially for a water content of the magnitude of 6—9 per cent.

In this experiment, however, no trends were noticeable in an analysis of the relationship between the length of the growing season and the water content of the seed. Seed moisture can consequently be discounted as a possible source of variation.

According to SCHMIDT's investigations (1930) seed from North Sweden with short growing season has a high content of catalase. Certain investigations seem to indicate that a high content of catalase in seed is a protection against X-ray exposure. An experiment with catalase apositive and catalase anegative species of bacteria (MITTLER and LAVERTY 1953) proved the catalase apositive species to be more resistant to ultra-violet radiation than the others. This was ascribed to the decomposing effect of the catalase on the damaging peroxide produced by irradiation. BARRON (1948), too, mentioned that catalases counteract radiation damages. SINGH (1941) proved that the content of catalase in seeds from *Zea mays, Triticum vulgare, Cicer arietinum* and *Carthamus tinctorius* is changed by X-ray exposure; — at low doses of X-rays the content of catalase is higher (stimulation), at higher doses it is decreasing. Parallel to changes in the content of catalase, the germinability also increases or decreases. EHRENBERG and NYBOM (1954) were unable in their experiments with barley to show a protective effect of the catalase, however.

Summary

The object of the present investigation was to study the radiation sensitivity of Scots pine seeds *(Pinus silvestris* L.) collected from ten different provenances in Sweden. To avoid undesirable effects caused by varying seed quality, only fully developed seeds were used. The water content of the sample seeds was standardized between 8.1 per cent and 9.3 per cent by equilibration.

The experiment comprised the following dosages of radiation: 0 r, 600 r, 1200 r, 2400 r, 3600 r, and 4800 r. 50 days after sowing, seeds and seedlings were observed with respect to the following characteristics:

1. Indicators of radiation sensitivity:
   a) germinability,
   b) time of germination,
   c) seedling mortality,
   d) seedling development:
      i. hypocotyl length,
      ii. root length.
2. The radiation sensitivity of the seeds in relation to the ecological factors at the original habitats.

The radiation sensitivity of seeds from different provenances varied widely. The ecological conditions of the provenances expressed by the length of the growing season according to LANGLET (1930) was studied with respect to their importance for the radiation sensitivity. It was found that Scots pine seeds from provenances with short growing season, northerly latitude and high altitude, were more resistant to X-rays than seeds of southerly latitude and low altitude.

Zusammenfassung

Titel der Arbeit: *Die Wirkung von Röntgenstrahlen auf Samen verschiedener Provenienz von Pinus silvestris.*

Die Aufgabe der vorliegenden Arbeit war es, die Strahlenempfindlichkeit der Samen von 10 verschiedenen schwedischen Kiefernherkünften zu untersuchen. Um unerwünschte Wirkungen durch verschiedene Samenqualität zu vermeiden, wurden nur voll entwickelte Samen untersucht. Der Wassergehalt der Samenproben wurde dabei auf 8,1—9,3% im Gleichgewicht gehalten.

Das Experiment umfaßte die folgenden Strahlendosen: 0 r, 600 r, 1200 r, 2400 r, 3600 r und 4800 r. 50 Tage nach der Aussaat wurden die Samen und Sämlinge nach den folgenden Eigenschaften bonitiert:

1. Anzeiger für die Empfindlichkeit:
   a) Keimfähigkeit,
   b) Zeit der Keimung,
   c) Sterblichkeit der Sämlinge,
   d) Sämlingsentwicklung:
      i. Länge des Hypokotyls,
      ii. Wurzellänge.
2. Die Strahlenempfindlichkeit der Samen in Beziehung zu den ökologischen Faktoren an den natürlichen Standorten.

Die Strahlenempfindlichkeit der Samen verschiedener Provenienzen variierte in weitem Rahmen. Die ökologischen Bedingungen der Provenienzen nach LANGLET (1930), ausgedrückt in der Länge der Vegetationsperiode, wurde im Hinblick auf ihren Einfluß auf die Strahlenempfindlichkeit untersucht. Es wurde festgestellt, daß Samen von *Pinus silvestris*-Herkünften aus Gebieten mit kurzer Vegetationsperiode, hohen nördlichen Breitengraden und aus großer Meereshöhe gegen Röntgenstrahlen resistenter waren als solche aus südlichen Breiten und geringer Meereshöhe.

Résumé

Titre de l'article: *Action des rayons X sur des graines de pin sylvestre (Pinus sylvestris L.) de différentes provenances.*

L'objet de ce travail est l'étude de la sensibilité aux rayons X de graines de pin sylvestre de 10 provenances suédoises différentes. Pour éliminer l'influence de la variation de la qualité des graines on a employé seulement des graines bien développées. La teneur en eau des échantillons a été ramenée à un taux variant de 8,1% à 9,3%.

L'expérience comprend les doses de radiations suivantes: 0 r, 600 r, 1.200 r, 2.400 r, 3.600 r, 4.800 r.

50 jours après le semis les graines et les semis ont été examinés d'après les caractères suivants:

1. Indicateurs de la sensibilité aux rayons:
   a) Faculté germinative,

b) Durée de germination,
c) Mortalité des semis,
d) Développement des semis:
i. Longueur de l'hypocotyle,
ii. Longueur des racines.

2. Sensibilité des graines aux rayons, en relation avec les facteurs écologiques du lieu d'origine.

La sensibilité aux rayons des graines de diverses provenances varie largement. Les conditions écologiques des provenances furent exprimées par la longueur de la saison de végétation d'après LANGLET (1930). Les graines de pin sylvestre venant des stations à courte saison de végétation, septentrionales ou en haute altitude, résistent mieux aux rayons X que les graines de provenances méridionales ou de basse altitude.

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Referate

JOACHIM, H. FR.: **Über unterschiedliches Anwachsen von Pappelstecklingen in Pflanzenzuchtgärten.** Forst u. Jagd **10**, 57—61 (1960).

Die Untersuchung diente im wesentlichen zwei vergleichenden Beobachtungen: (a) Feststellung des Austreibens von Pappelstecklingen mit und ohne Knospen und (b) Feststellung von Wurzelbildungsunterschieden bei beiden Stecklingsarten. — Zu (a) werden die beobachteten Verzögerungserscheinungen bei den Stecklingen ohne Knospen beschrieben, z. B. hatten 3 Wochen nach dem Stecken in einem Fall 80% der Stecklinge mit Knospen getrieben und nur 20% der Stecklinge ohne Knospen. Es wurden auch bei letzteren vielfach deformierte Blätter gefunden. — Zu (b) zeigten auch die Stecklinge mit Knospen die bessere Bewurzelung, wobei die Wundwurzeln vorherrschten. Stecklinge ohne Knospen, besonders die, die mehrere Triebe gemacht hatten, hatten dagegen auch mehr Rindenwurzeln entwickelt. — Schließlich wird festgestellt, daß das Anwachsen von Pappelstecklingen wesentlich von der Frühjahrswitterung beeinflußt werden kann, wobei Wechselwirkungen zwischen Feuchtigkeit und Wärme bestehen. — Sorteneigene Unterschiede zeigten sich ferner auf einer Anzucht-Versuchsfläche bei Eberswalde, wo in den Blocks I—III bei der Berolinensis keine Ausfälle zu finden waren, während die Rochester-Pappel in Block I = 6, Block II = 5, Block III = 6, zusammen 17 Fehlstellen aufwies. Interessant sind dort auch die Sorten Oxford mit nur 1 Ausfall, Regenerata mit 2 Ausfällen und Neupotz mit 3 Ausfällen. Bei der Marilandica wurden dort 14 Ausfälle verzeichnet. — Aus der Untersuchung von JOACHIM geht hervor, daß bei dem Anwuchserfolg in Pappel-Anzuchtgärten Witterung, Boden, Sorteneigentümlichkeiten und Stecklingsqualität als modifizierende Faktoren beteiligt sind. SEITZ

JOHANSEN, R. W., and KRAUS, J. F.: **Fertilizing cleft and bottle graft scions in an attempt to increase graft unions.** J. Forestry **57**, 511 und 514 (1959).

Versuche, die Anwuchsprozente bei Spalt- und Flaschenpfropfungen mit *Pinus elliottii* durch verschiedenartige Applikation von Düngelösungen zu erhöhen, blieben ohne Erfolg. Nährlösungen anstelle von Wasser führten bei Flaschenpfropfungen zu einem deutlichen Absinken der Pfropferfolge. Ebenso erwies sich das Spritzen der Pfropflinge mit 2,5%iger Phosphorsäure sowie die wöchentliche Behandlung mit 1,2%igem Ammoniumnitrat, 1,0%igem Kalium- und 1,5%igem Magnesium-Sulfat als schädlich. SCHÜTT

JOHNSSON, H.: **Föreningen Skogsträdförädling.** Aktuellt från sydöstra distriktet. (Verein für Forstpflanzenzüchtung. Aktuelles aus dem südöstlichen Distrikt.) Skogen 1960, H. 4.

Der Verfasser gibt eine gedrängte Übersicht über den derzeitigen Stand des Samenplantagenprogramms für den südöstlichen Teil Schwedens, das insgesamt 180 ha Plantagen vorsieht. Davon wurden bisher nur etwa 25 ha angelegt, in den kommenden Jahren dürften jedoch jährlich weitere 40 ha hinzukommen.

Die bisherigen Untersuchungen zur Technik der Plantage haben gezeigt, daß die gestellten Erwartungen im großen und ganzen zutreffen dürften, soweit es die Samenproduktion betrifft. Aber es sind noch weitere Fragen zu klären wie die Sicherung regelmäßiger Samenproduktion, Frostschutz, Schutz gegen Insekten, Baumschnitt u. a., die an den vorhandenen und bereits älteren Versuchsplantagen geklärt werden sollen.

Auch mit der Vorbereitung der Nachkommenschaftsprüfungen ist inzwischen begonnen worden.

Als Hauptfragen der künftigen Arbeit im südöstlichen Distrikt nennt der Verfasser:

Erkundung der Verhältnisse, unter denen geeignete Herkünfte vom Kontinent denen der heimischen Fichte vorzuziehen sind. Erkundung der am meisten geeigneten Herkünfte der ersteren. Versuche mit Hybriden zwischen heimischen und Kontinent-Herkünften der Fichte.

Prüfung der phänotypisch überlegenen Kiefernherkunft des Gebiets um Vimmerby (Småland) in Feldversuchen.

Versuche mit Herkunftshybriden der Kiefer.