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Investigations on the suitable germination duration for *Pinus silvestris* and *Picea abies* seed

Untersuchungen über die geeignete Keimdauer für Föhren- und Fichtensamen

Undersökningar av den lämpliga groningstiden för tall- och granfrö

by

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ABSTRACT

In this investigation the effect of the germination periods of 14, 21 and 30 days was studied on the percentage and the rate of germination of *Pinus silvestris* and *Picea abies* seed. Samples from areas lying between 50°N and 68°N latitudes were used. Seed with well-developed embryo and endosperm and with high viability, as well as that with reduced viability due to age or due to poor embryo and/or endosperm development was tested. The results showed that in the former type of seed, a germination period of 14 days may be adequate. However, in the latter type of seed, a longer period (21 or 30 days) may be desirable, so that a sample can attain its maximum germination percentage. It is therefore suggested that in the International Rules for Seed Testing, a germination period of 14 days may not be fixed rigidly for these two species, but be flexible, so that it can be prolonged, if necessary, to suit the requirements of a given sample.

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Introduction

Various durations have been tried by different workers for testing the germination of Scots pine and Norway spruce seed on Jacobsen apparatus. Thus Huss (1951) allowed a 30 days germination period to seed of these species intended for purely scientific experiments and usually 10 days to that meant for practical purposes. Müller-Olsen and Simak (1954) used 30 days for Scots pine and Müller-Olsen *et al* (1956) 30 and 50 days for Norway spruce seed. In other studies (e.g. Gustafsson and Simak 1956, Simak 1957, etc.) seed of both *Pinus silvestris* and *Picea abies* has been germinated for 30 days. Also Simak and Kamra (1963), Kamra (1963), and Kamra and Simak (1965) used 30 days for testing the germination of the seed of these two species. However, Heit (1958 and 1961) considered a period of 14 days as adequate for determining the germination of Scots pine and 16 days for Norway spruce seed. The International Rules for Seed Testing (1966) prescribe a period of 21 days for testing the germination of the seed of these two species. Consequently, in later investigations Kamra and Simak (1968) and Simak and Kamra (1968) used a three weeks duration for studying the germination of Scots pine and Norway spruce seed.

It is of interest to mention that the AOSA Rules (1965) (Association of Official Seed Analysts of USA and Canada) prescribe a test duration of 16 days for *Picea abies* and 14 days for *Pinus silvestris* seed. Magini and Zanzi Sulli (1968) suggest a reduction of the test duration for both Scots pine and Norway spruce seed from 21 to 14 days in the International Rules for Seed Testing. Also Jensen (1968) is in favour of shortening the test period to 14 days for the seed of these two species.

A reduction of the germination period to 10 days for Scots pine and Norway spruce seed was proposed by Tirén (1948). He suggested certain correlative functions with the help of which the expected germination percentage at the end of 30 days could be calculated on the basis of the germination results after 10 days. However, he pointed out that some precautions were necessary in the use of these correlative functions. Huss (1951) mentioned that these correlative functions were not in general use then.

The present investigation was undertaken to study the germination of Scots pine and Norway spruce seed for 2, 3 and 4 weeks and on the basis of these results, to discuss the question of the suitable germination duration for these two species.

Material

Eighteen seed samples of Scots pine (*Pinus silvestris* L.) and nineteen of Norway spruce (*Picea abies* (L). Karst.) from areas lying between latitudes 49°—66°N and 49°—68°N respectively, and situated in different countries were used for the experiments. The material included fresh and old seed, and fresh seed with incompletely developed embryo and/or endosperm which is of common occurrence in northern latitudes (e.g. in Northern Sweden). The details of the samples are given in Tables 1 and 2.

Table 1: Details of the samples of Scots pine studied.

Sample No.	Locality and country of origin	Latitude	Altitude in metres	Year of collection
1	Örebro län, Sweden	59° 12′	85	1968
2	Kopparbergs län, Sweden	60° 0′	160	1968
3	Skaraborgs län, "	58° 52′	110	1968
4	Värmlands län, "	59° 55′	200	1968
5	Gävleborgs län, "	61° 20′	250	1968
6	Älvsborgs län, "	59° 0′	150	1968
7	Norrland, "	65°—65° 59′	0—199	1968
8	Norrland, "	64°—64° 59′	300	1968
9	Norrland, "	65°—65° 59′	305	1968
10	Hessisches Bergland, W. Germany	50° 40′	300—600	1967/68
11	Kronobergs län, Sweden	57° 03′	210	1966
12	Nordbayern, W. Germany	49° 45′	Not known	1965/66
13	Södermanland, Sweden	59° 03′	55	1964
14	Kalmar län, "	57° 45′	110	1963
15	Odenwald Spessart, W. Germany	50° 15′	300—600	1961/62
16	Kalmar län, Sweden	57° 36′	120	1958
17	Gotland, "	57° 27′	40	1952
18	Gotland, "	57° 55′	40	1951

Table 2: Details of the samples of Norway spruce studied.

Sample No.	Locality and country of origin	Latitude	Altitude in metres	Year of collection
1	Oberharz, W. Germany	51° 40′	300—600	1967/68
2	Harzvorland Westerhof, W. Germany	51° 45′	Under 300	1967/68
3	Westdeutsches Bergland, W. Germany	50° 50′	300—600	1967/68
4	Norrland, Sweden	64° 30′	400	1967
5	Norrland, "	64° 30′	40	1967
6	Norrland, "	65°—65° 59′	400—449	1967
7	Norrland, "	66°—66° 59′	0—199	1967
8	Norrland, "	67°—67° 59′	300—349	1967
9	Värmlands län, Sweden	59° 26′	55	1967
10	Norrland, "	66°—66° 59′	0—199	1967
11	Norrland, "	67°—67° 59′	200—299	1967
12	Norrland, "	67°—67° 59′	200—299	1967
13	Oberharz, W. Germany	51° 35′	300—600	1964/65
14	Bad Schandau, E. Germany	50° 56′	300—425	1964
15	Schwäbish-Frankischer Wald, W. Germany	49° 20′	Not known	1961/62
16	Sosa-Torfhaus Revier, E. Germany	50° 35′	800	1958/59
17	Kalmar län, Sweden	57° 30′	260	1958
18	Norrbottens län, Sweden	66° 30′	150	1955
19	Kristianstads län, Sweden	55° 0′	110	1954

Methods

For the germination tests, pure seed (4 × 100) of each sample was used. In order to determine the number of empty and insect-attacked seeds in the material to be put for germination, each lot was radiographed using soft x-rays. The conditions for radiography were: kV = 14, mA = 5, focus-film distance = 50 cm, and the time of exposure = 3 seconds. The X-Ray Industrial Film Type "L" ("Low speed"), manufactured by CEA Works, Strängnäs, Sweden, was used. It was developed in the X-Ray Rapid Developer and fixed in the X-Ray Express Fixative, manufactured by Tetenal Photo Works, Hamburg, West Germany.

The first count of the germinated seeds was taken on the fourth day, followed by a daily count up to the tenth day. Thereafter, the germinated seeds were counted every other day. At each occasion, the counted seeds were removed from the tests. A seed was considered as germinated, when the length of the root was at least equal to that of the seed itself. The germination percentages of all the samples were calculated uniformly on the basis of the number of filled seeds in each lot.

The following conditions were used for the germination tests:

Temperature: 20 °C (constant).

Light: About 1 000 lux for 8 hours daily from day-light tubes.

Distance between water level and seed bed on Jacobsen apparatus = 13 cm.

Total duration of the germination tests: 30 days.

The investigation was carried out under strictly controlled conditions. The material was made uniform by radiographying the lots before putting them for germination. In this way, the number of empty and insect-attacked seeds in each lot could be determined and the calculations of germination percentage and rate made on the basis of the filled seeds only. The germination tests were carried out on two Jacobsen apparatuses of stainless steel of exactly the same model, and the type and the level of water were the same in both of them. The light was switched on and off automatically by an electrical watch at the fixed hours simultaneously for both the apparatuses. The Jacobsen apparatuses were placed in a climate chamber, the temperature and the relative humidity of which (20 °C and 60%, respectively) were controlled automatically by special devices. The maximum variation of temperature was 1 °C.

Results

(a) Embryo and endosperm development:

The embryo and the endosperm development in the seed samples investigated was studied from the radiographs. It was observed that samples 7, 8 and 9 of Scots pine and 4, 6, 7 and 8 of Norway spruce had incompletely developed embryos (mostly belonging to classes II and III), usually with well-developed (class A) but sometimes with poorly developed (class B) endosperm (according to the classification of Müller-Olsen, Simak and Gustafsson 1956). Sample No. 5 of Norway spruce had better developed seed than that of the above-mentioned samples, with many seeds belonging to class IV A. However, several seeds of classes III A and II A were also present. In all the other samples of both the species, the seed was well-developed and belonged either exclusively to class IV A or only rarely contained a few seeds of classes III A or II A.

(b) Germination percentage

The germination percentages of the samples after 14, 21 and 30 days are given in Table 3 for Scots pine and in Table 4 for Norway spruce.

Table 3: Germination percentages of the samples of Scots pine.

Sample No.	Germination percent after 14 days	21 days	30 days
1	92	93	93
2	98	99	99
3	88	88	88
4	96	96	96
5	99	99	99
6	98	98	98
7	59	60	61
8	41	43	45
9	23	26	27
10	90	91	92
11	98	98	98
12	88	89	89
13	51	52	52
14	57	60	60
15	76	82	83
16	80	82	82
17	23	24	25
18	9	18	21

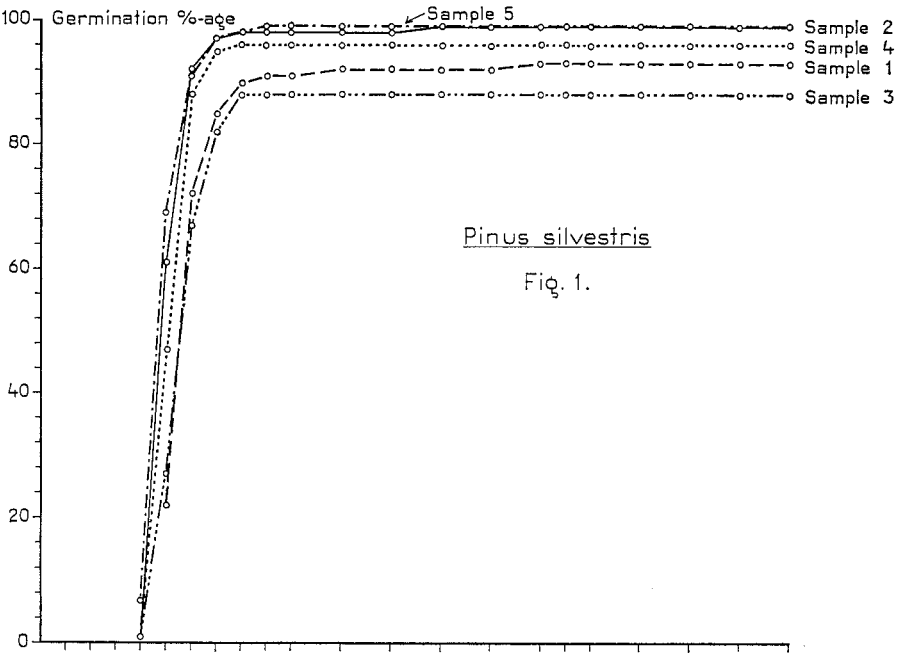
Table 4: Germination percentages of the samples of Norway spruce.

Sample No.	Germination percent after 14 days	21 days	30 days
1	93	94	94
2	97	98	98
3	96	96	96
4	30	36	39
5	79	81	82
6	29	34	40
7	13	20	22
8	23	27	33
9	99	99	99
10	30	42	44
11	58	63	64
12	59	74	75
13	97	99	99
14	96	97	97
15	46	57	58
16	18	24	26
17	95	97	98
18	22	26	26
19	72	76	77

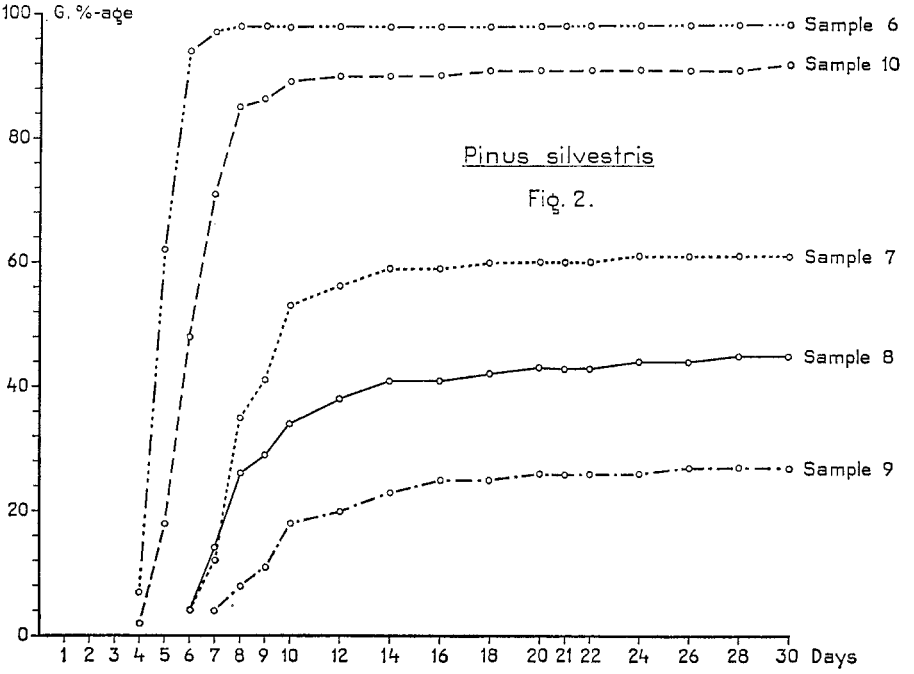
It may be observed from Tables 3 and 4 that in the samples with well-developed embryo and endosperm and with high viability (e.g. Nos. 1—6 and 10—12 of Scots pine, and 1, 2, 3, 9, 13 and 14 of Norway spruce), there is only slight or no increase in the germination percentage between the 14th and the 21st day and almost none between the 21st and the 30th day. However, in several of the samples with reduced viability due to poor embryo and/or endosperm development, or due to age, the germination percentage increases between the 14th and the 21st day and often also between the 21st and the 30th day. Examples are samples 4—8, 10—12, 15, 16, 18 and 19 in Norway spruce, and 8, 9, 14, 15 and 18 in Scots pine.

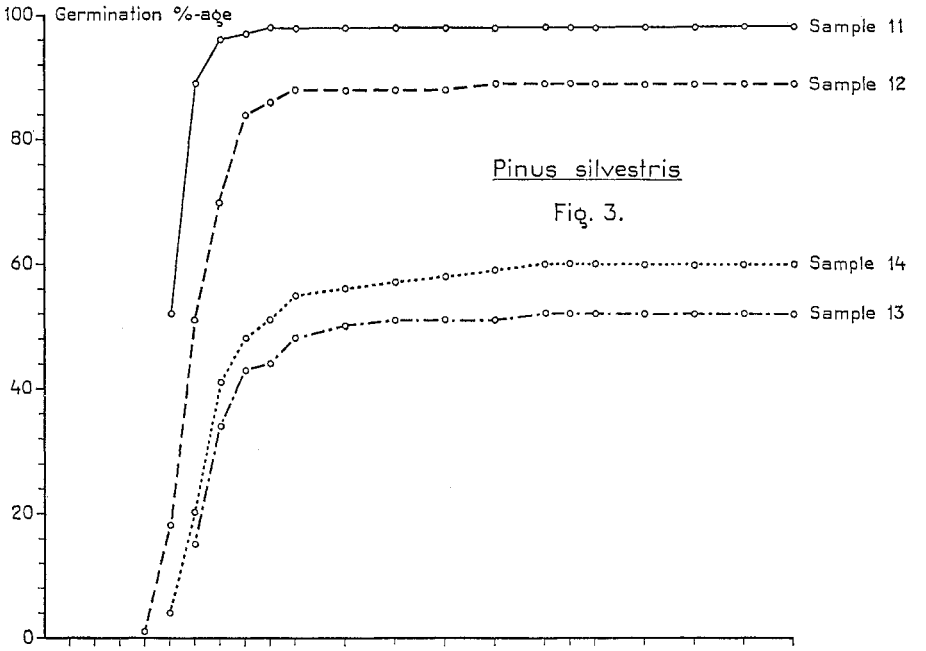
(c) Germination rate:

The germination rates of the samples of Scots pine are shown in Figures 1—4 and those of Norway spruce in Figures 5—8. It may be observed that samples with well-developed embryo and endosperm and high viability (Nos. 1—6 and 10—12 of Scots pine, and 1, 2, 3, 9, 13 and 14 of Norway spruce) germinate rapidly and practically complete their germination within the first eight to twelve days. As against this, the samples with reduced viability germinate slowly and their germination percentage increases progressively up to three or four weeks. Examples are samples 14, 15 and 18 of Scots pine and 15, 16, 18 and 19 of Norway spruce (cf. Figs. 1—8). Also fresh seed with incompletely developed embryo and/or endosperm germinates slowly and usually attains its full germination percentage after a period longer than two weeks (cf. samples 7—9 of Scots pine and 4—8 of Norway spruce).

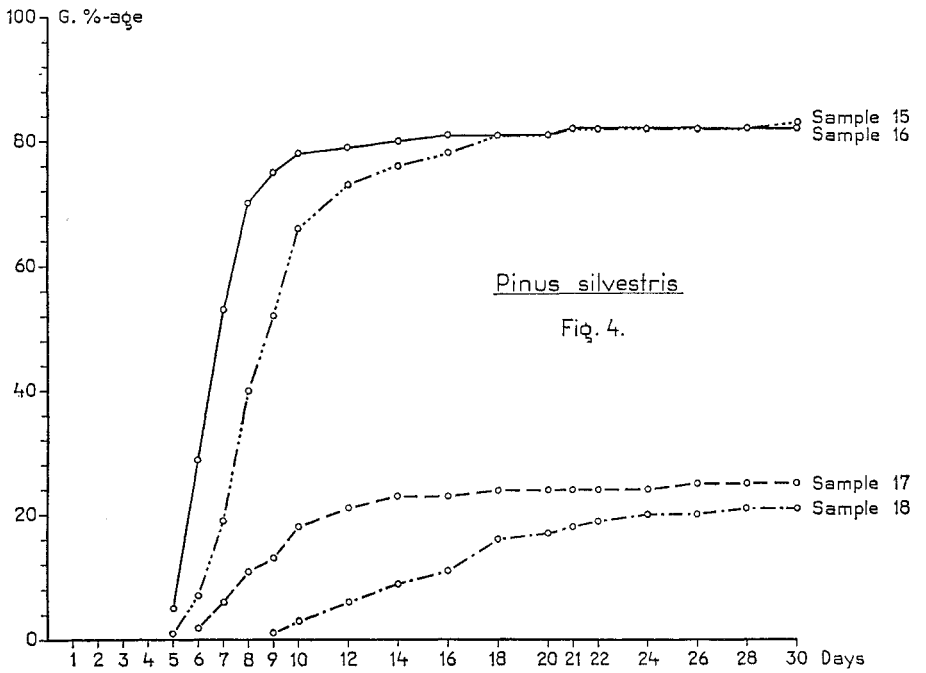


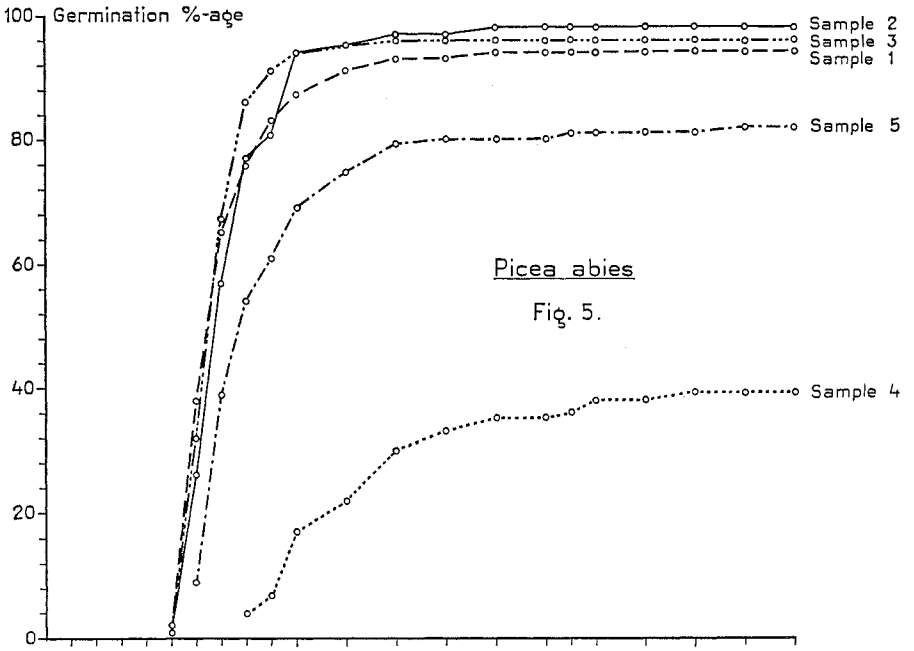
Figures 1—2: Rate of germination of Scots pine samples.



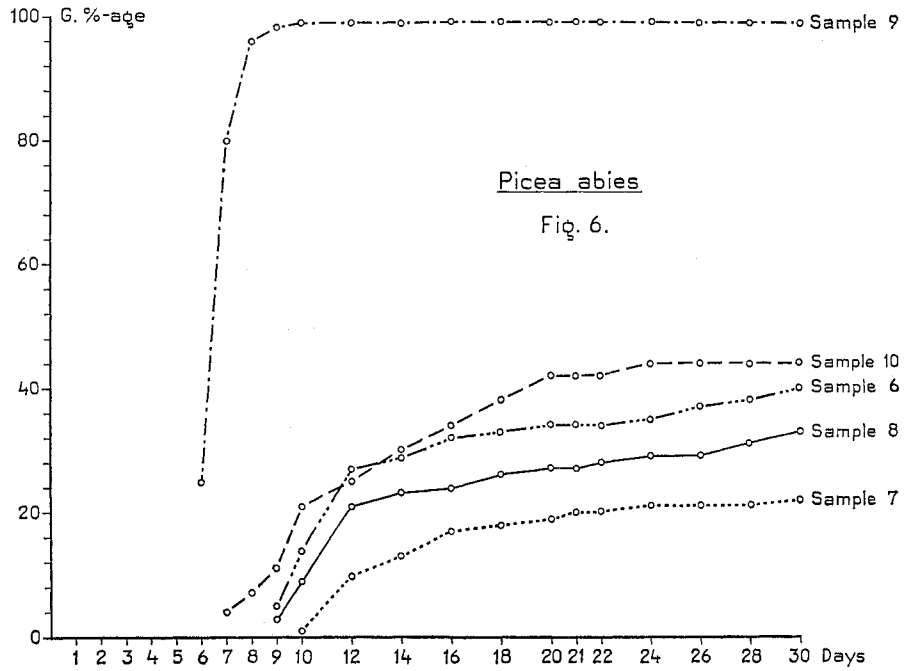


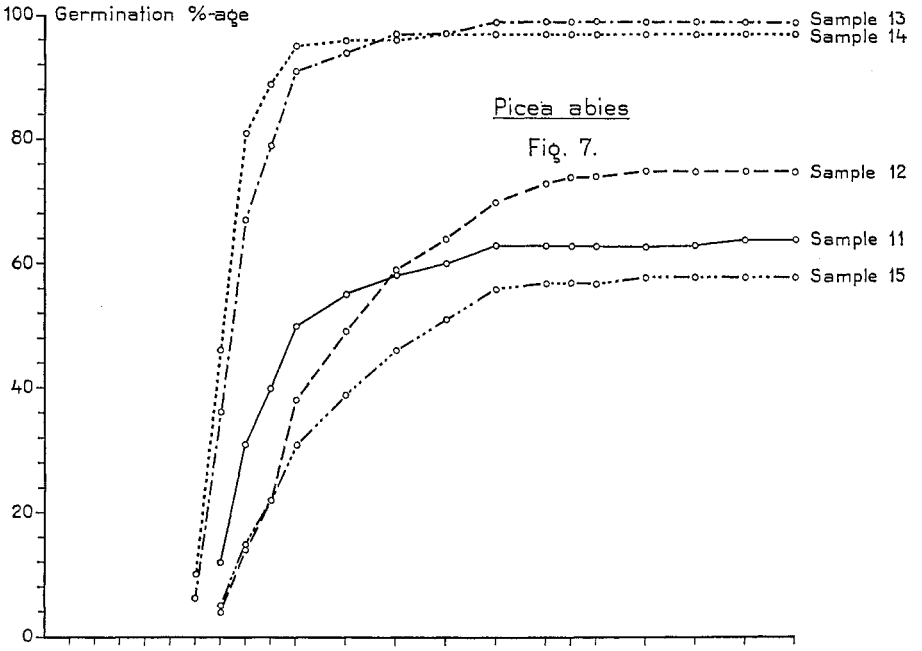
Figures 3—4: Rate of germination of Scots pine samples.



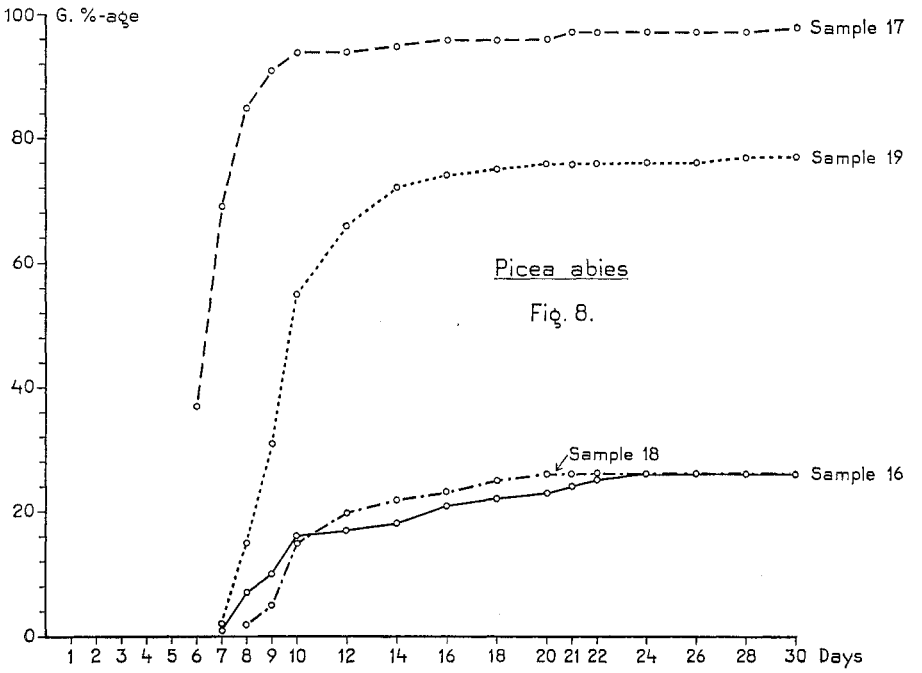


Figures 5—6: Rate of germination of Norway spruce samples.





Figures 7—8: Rate of germination of Norway spruce samples.



Discussion

In the present investigation the constant temperature of 20 °C was used instead of the alternating temperature of 20—30 °C, as prescribed in the International Rules for Seed Testing (1966). This was done because of the fact that some earlier investigations showed that for the germination of Scots pine and Norway spruce seed the constant temperature of 20 °C was as good as and in some southern provenances of Scots pine even better than the alternating temperature of 20—30 °C (cf. Kamra 1967, Kamra and Simak 1968, Simak and Kamra 1968).

In this as well as in some other germination studies on *Pinus silvestris* and *Picea abies* carried out by the author and by Simak (e.g. those cited above), seeds with root-length at least equal to the seed-length, were considered as germinated. Also Huss (1951) regarded seeds with a root-length of at least 5 mm as germinated, which is practically the same criterion as the one mentioned above. The criterion of root-length at least equal to seed-length has proved to be both convenient and reliable. The advantage lies in the fact that an analyst finds it easier to decide quickly whether a seed should be considered as germinated or not, if he has only to compare the length of the root with that of the seed itself. If, however, he has to estimate, whether or not the length of the root is four times that of the seed, which is the criterion prescribed by the International Rules for Seed Testing (1966), it is not only more difficult for him to decide without the help of a measuring stick, but also needs a longer time. In addition, there is the difficulty that when the roots become long, they get entangled with each other and it is a time-consuming operation to separate the seedlings from each other without injuring them. Moreover, when the germination rate is studied by daily observations beginning with the fourth day, as has been done in the present as well as in the investigations cited above, the counting of the germinated seeds cannot be started on the fourth day, because then the roots have not yet attained four times the length of the seed. If one has to wait until the roots have grown to four times the length of the seed, one cannot fully observe and appreciate the differences in the germination rates of the different samples, which are usually clear in the first few days of the germination test and tend to become less distinct later on. These reasons explain why in the present as well as in the other investigations referred to above, the criterion of root-length at least equal to seed-length was used.

Coming now to the results of this investigation, it may be observed from Figures 1—8 that the samples have shown two types of germination courses. The first type is that in which the sample germinates rapidly and practically completes its germination within 8—9 days in the case of Scots pine and within 10—12 days in Norway spruce. This is the case with seed having well-developed embryo and endosperm and high viability. Here a 14 days germination period may be adequate. The second type of germination is that in which the sample germinates slowly, usually beginning between the sixth and the eighth day and continuing gradually for about three weeks or longer. This is true of seed with reduced viability or of fresh seed with incompletely developed embryo or endosperm or both. Müller-Olsen *et al* (1956) studied the germination of fresh Norway spruce seed with different degrees of embryo and endosperm development (embryo classes II—IV, and endosperm classes A and B) up to 50 days. Their results also showed that the lesser developed the embryo and the endosperm of the seed are, the longer it takes for the sample to attain its maximum germination value. Also for Scots pine, Simak and Gustafsson (1954) state: "Delayed germination, i.e. the germination after 30 days, is conspicuous in natural seed of northern provenances and correlated to the occurrence of embryo type II and III, but is less pronounced in southern provenances with a predominance of embryo type IV." Thus for fresh seed with incompletely developed embryo and endosperm (e.g. seed from high latitudes, like in Northern Sweden), and for seed with reduced viability, a fourteen days germination duration is not sufficient for determining the maximum germination percentage of a sample (cf. also Kamra 1967). If a fourteen days germination period is fixed for Scots pine and Norway spruce seed in the International Rules for Seed Testing, as has been suggested by Magini and Zanzi Sulli (1968), the analyst should be given the possibility to prolong this period for a week or more for those samples where he considers it necessary (e.g. in the case of reduced viability seed, incompletely developed seed, etc.). The prolonged germination period can then indicate the maximum germination value of a sample. Moreover, in a test shortened to 14 days or less, it is very necessary that the germination conditions are strictly uniform. As has been shown by Simak (1967), variations in the germination conditions can often distinctly influence the germination rate during the first few days of the test, which in its turn in a shortened test can give rise to differences in the germination percentages.

Conclusions

1. For *Pinus silvestris* and *Picea abies* a germination period of fourteen days seems to be acceptable in the case of seed with well-developed embryo and endosperm and with high viability.

2. In the case of seed with reduced viability due to age or due to incompletely developed embryo or endosperm or both, a longer test period (21 or even 30 days) may be desirable, so that the sample can attain its maximum germination percentage.

3. It is therefore suggested that the germination period of fourteen days for Scots pine and Norway spruce seed may not be fixed rigidly in the International Rules for Seed Testing, but be flexible, so that the analyst can prolong it, if necessary, to suit the requirements of a given sample.

Summary

1. The present paper deals with the question of the suitable duration for testing the germination of Scots pine (*Pinus silvestris* L.) and Norway spruce (*Picea abies* L. Karst.) seed. Germination periods of two, three and four weeks were tested.

2. Eighteen samples of Scots pine and nineteen of Norway spruce from areas lying between 49°N—66°N and 49°N—68°N latitudes respectively, and situated in different countries were used for the investigation (Tables 1 and 2). Seed with well-developed embryo and endosperm and with high viability, as well as that with reduced viability due to age or due to poor embryo and/or endosperm development was studied.

3. The results (Tables 3 and 4 and Figures 1—8) show that a germination period of 14 days may be adequate for seed with well-developed embryo and endosperm and with high viability. In the case of seed with reduced viability due to age or due to poorly developed embryo and/or endosperm (e.g. seed from high latitudes, like from Northern Sweden), a longer germination period (21 or even 30 days) may be desirable, so that the sample can attain its maximum germination percentage.

4. It is, therefore, suggested that the germination period of 14 days for *Pinus silvestris* and *Picea abies* seed may not be fixed rigidly in the International Rules for Seed Testing, but be flexible, so that it can be prolonged, if necessary, to suit the requirements of a given sample.

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Zusammenfassung

Untersuchungen über die geeignete Keimdauer für Föhren- und Fichtensamen

1. Die vorliegende Arbeit beschäftigt sich mit der Frage der geeigneten Keimdauer für die Bestimmung der Keimfähigkeit von Föhren- und Fichtensamen. Die Keimperioden von 2, 3 und 4 Wochen wurden geprüft.

2. Achtzehn Proben von Föhrensamen (*Pinus silvestris* L.) und neunzehn von Fichtensamen (*Picea abies* L. Karst.) aus Gebieten zwischen den Breitengraden 49—66°N bezw. 49—68°N und aus verschiedenen Ländern wurden für die Versuche verwendet (s. Tabellen 1 und 2). Sowohl Saatgut mit gut entwickeltem Embryo und Endosperm und hoher Keimfähigkeit, wie auch solches mit niedriger Keimfähigkeit infolge von Alter oder infolge unvollständiger Entwicklung des Embryos und/oder des Endosperms wurde geprüft.

3. Die Ergebnisse (s. Tabellen 3—4 und Abb. 1—8) zeigen, dass eine Keimdauer von 14 Tagen für das Saatgut mit gut entwickeltem Embryo und Endosperm und hoher Keimfähigkeit ausreichend ist. Dagegen ist für das Saatgut mit niedriger Keimfähigkeit infolge von Alter oder infolge unvollständiger Entwicklung des Embryos und/oder des Endosperms (z.B. das Saatgut aus hohen Breitengraden, wie aus Nordschweden), eine längere Keimdauer (21 oder 30 Tage) angebracht, damit die Probe ihren höchsten Keimprozent erreichen kann.

4. Es wird daher vorgeschlagen, dass in den Internationalen Vorschriften für die Prüfung von Saatgut die Keimdauer von 14 Tagen für Föhren- und Fichtensamen nicht streng festgelegt wird. Es soll möglich sein, diese Keimdauer zu verlängern, wenn es notwendig ist, entsprechend den Erfordernissen der jeweiligen Probe.

Sammanfattning

Undersökningar av den lämpliga groningstiden för tall- och granfrö

1. Detta arbete behandlar frågan om den lämpliga längden på groningsperioden vid bestämning av grobarheten hos tall och granfrö. Två, tre och fyra veckors groningstider testades.

2. Aderton prov av tall (*Pinus silvestris* L.) och nitton prov av gran (*Picea abies* L. Karst.) från områden mellan 49°N—66°N respektive 49°N—68°N latituder och från olika länder användes för undersökningen (se Tabellerna 1 och 2). Såväl frö med välutvecklat embryo och endosperm och med hög grobarhet som frö med lägre grobarhet på grund av ålder eller på grund av ofullständigt utvecklat embryo och/eller endosperm studerades.

3. Resultaten (se Tabellerna 3—4, och Figurerna 1—8) visar, att en två veckors groningsperiod kan anses som tillräcklig för frö med välutvecklat embryo och endosperm och med hög grobarhet. För frö med lägre grobarhet på grund av ålder eller på grund av ofullständigt utvecklat embryo och/eller endosperm (t. ex. frö från Norra Sverige) är en längre groningsperiod (21 eller 30 dygn) lämplig, för att fröet skall kunna uppnå sin maximala groningsprocent.

4. Det föreslås därför att det i de internationella reglerna för frökontrollen icke strikt skall fastläggas en 14 dygns groningsperiod. Denna bör vara flexibel så att den, om nödvändigt, kan förlängas, för att kunna anpassas efter fröets behov.