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Comparative studies on the germination of Scots Pine and Norway Spruce seed under different temperatures and photoperiods

Vergleichende Studien über die Keimung von Kiefern- und Fichtensamen unter verschiedenen Temperaturen und Photoperioden

Jämförande studier över groning av tall- och granfrö under olika temperaturer och fotoperioder

by

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Introduction

For testing the germination percentage of Scots pine and Norway spruce seed, the International Rules for Seed Testing (1966) prescribe an alternating temperature of 20—30°C and 8 hours light daily for 21 days. At the Department of Forest Genetics, Royal College of Forestry, Stockholm, seed of Scots pine and Norway spruce is usually germinated at a constant temperature of about 20°C under continuous light for 30 days. MÜLLER-OLSEN, SIMAK and GUSTAFSSON (1956) and SIMAK (1957) used 23°C (constant) and 8 hours light daily for 30 days for testing the germination of Norway spruce and Scots pine seed. In order to be able to compare the results of the germination tests carried out under different sets of conditions, it is necessary to find out, how constant and alternating temperatures and different photoperiods affect the percentage and the rate of germination of Scots pine and Norway spruce seed. The present investigation was undertaken to study this problem.

However, it may be pointed out that this paper does not deal with the general effects of light and temperature on the germination of seeds. Extensive work has been done on this subject and several reviews of the literature are available (e.g. EDWARDS 1932, EVENARI 1956, JONES 1961, MAYER and POLJAKOFF-MAYBER 1963, TOOLE *et al* 1956, VILLIERS 1961, WAREING 1956 and others).

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Set I:

Temperature: Alternating: 20°C for 16 hours and 30°C for 8 hours.
Light: About 1000 Lux artificial light from day-light tubes for 8 hours daily at 30°C.
Duration of the germination test: 21 days. (After International Rules for Seed Testing, 1966).

Set II:

Temperature: Constant: 23°C.
Light: The same as in set I, but given at 23°C.
Duration of the germination test: 30 days. (After MÜLLER-OLSEN, SIMAK and GUSTAFSSON 1956, and SIMAK 1957).

Set III:

Temperature: Constant: 20°C.
Light: The same as in set I, but given for 24 hours daily at 20°C.
Duration of the germination test: 30 days.

Set IV:

Temperature: Constant: 20°C.
Light: The same as in set I, but given at 20°C.
Duration of the germination test: 30 days.

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 test. A seed was considered as germinated, when the length of the root was equal to that of the seed itself.

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 = 50 cm, time of exposure = 3 seconds. The X-Ray Industrial Film Type "L" 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 germination percentages of all the samples were calculated uniformly on the basis of the number of filled seeds only in each lot.

It may be pointed out that the present investigation was carried out under strictly controlled conditions. The material was made

Material

Ten samples each of Scots pine *(Pinus silvestris* L.) and Norway spruce *(Picea abies* (L.) Karst.) seed of different years of harvest and with high and relatively lower germination percentages were used for the experiments. The details of the samples are given in Tables 1 and 2.

Table 1: Details of the samples of Scots pine.

Sample No.	Locality in Sweden	Latitude	Altitude in metres	Year of collection
1	Kristianstads län	55° 59′	110	1966
2	Kronobergs län	57° 3′	210	1966
3	Kopparbergs län	60° 15′	120	1966
4	Kalmar län	56° 38′	142	1966
5	Kalmar län	57° 40′	100	1959
6	Kalmar län	57° 36′	120	1958
7	Gävleborgs län	60° 50′	0—100	1956
8	Norrbottens län	65° 5′	335	1945—46
9	Örebro län	59° 0′	50—240	1961
10	Not known	Not known	Not known	1960

Table 2: Details of the samples of Norway spruce.

Sample No.	Locality	Latitude	Altitude in metres	Year of collection
1	Litschau-Seilern (Austria)	48° 56′	About 600	1954
2	Södermanland (Sweden)	59° 19′	40	1954
3	Kalmar län »	57° 36′	115	1966
4	Östergötland »	58° 20′	122	1966
5	Kalmar län »	56° 0′	60	1964
6	Norrbottens län »	66° 30′	150	1955
7	Skaraborgs län »	58° 0′	130	1954
8	Södermanland »	59° 10′	65	1950
9	Kristianstads län »	56° 0′	150	1964
10	Not known »	Not known	Not known	1952

Methods

The germination tests were carried out on pure seed of each sample (4×100) under the following sets of conditions:

uniform, as stated above, by radiographing 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 Jacobsen apparatuses made of stainless steel, and the type and level of water were the same in all of them. The control of temperature was achieved by automatic devices fitted to the apparatuses and there was a motor in each of them to keep the water in constant circulation. In this way, the temperature could be maintained uniform throughout the apparatuses. The light was switched on and of automatically by an electrical watch at the fixed hours simultaneously for all the apparatuses.

Besides the above arrangements, the Jacobsen apparatuses were placed in a climate chamber, the temperature and humidity of which (20°C and 60 % resp.) were controlled automatically by special devices. The chamber had double doors with space in between, so that one door could be closed before opening the other. In this way, the entry of light from outside was prevented.

Results

1. Germination Percentage:

The germination percentages of the samples of Scots pine and Norway spruce under the four sets of conditions described above (cf. Methods) are given in Tables 3 and 4.

Table 3: Germination percentages of Scots pine samples under the four sets of conditions.

Sample No.	Germination percentages under the four sets: I	II	III	IV
1	100	98	99	98
2	98	98	98	99
3	99	99	100	98
4	98	98	99	97
5	89	88	89	87
6	89	91	88	88
7	95	93	95	94
8	79	76	79	78
9	80	78	80	79
10	45	44	44	45

Table 4: Germination percentages of Norway spruce samples under the four sets of conditions.

Sample No.	Germination percentages under the four sets: I	II	III	IV
1	90	87	89	86
2	71	72	70	70
3	100	98	98	99
4	100	98	100	99
5	95	96	97	96
6	48	52	47	47
7	50	52	50	49
8	54	56	56	56
9	94	94	92	94
10	31	33	37	35

The results given in Tables 3 and 4 were analysed statistically by "t-test." There were no significant differences among the germination percentages of the samples under the four sets of conditions in both the species.

2. Rate of Germination

The rates of germination of each sample under the four sets of conditions are shown in Figures 1—10 for Scots pine and in Figures 11—20 for Norway spruce seed.

a) Scots pine:

When one compares the germination rates of Scots pine samples at 20—30°C and at 20°C under similar light conditions (sets I and IV), one finds that the samples seem to germinate faster in the first few days of the test at the alternating than at the constant temperature. However, from a certain point onward, which is different for the different samples (e.g. the seventh day in Figs. 1—3, the tenth day in Fig. 7, and the twelfth day in Figs. 5 and 6, etc.), the rates tend to slow down. Thereafter, there are only small differences in the germination rates of the samples in the two sets.

A comparison of the germination rates of Scots pine samples at 20—30°C and at 23°C under similar light conditions (sets I and II), shows slightly different tendencies than those described above for sets I and IV. In the first few days of the test, the rate appears to be faster in set I than in set II in some samples (cf. Figs. 1, 7, 8 and 10), whereas the reverse seems to be true in most of the others (cf. Figs. 2, 3, 5 and 6) or the rate appears to be varying between the

two sets (cf. Fig. 4). However, from a certain point onward, which is different in the different cases (e.g. the sixth day in samples 2 and 3, the seventh day in samples 1 and 4, the tenth day in sample 5, the twelfth day in samples 9 and 10, etc.) there seem to be only small differences in the rates of germination of the samples in the two sets.

When one compares the germination rates of the samples at 23°C and at 20°C under similar light conditions (sets II and IV), one finds that the rate appears to be slightly faster at the former than at the latter temperature during the first few days of the test. However, from a certain point onward (e.g. the eighth day in Figs. 1—3, the tenth day in Fig. 4, the twelfth day in Figs. 5 and 9, the sixteenth day in Figs. 7, 8 and 10, etc.), the germination rates are rather identical in the two sets.

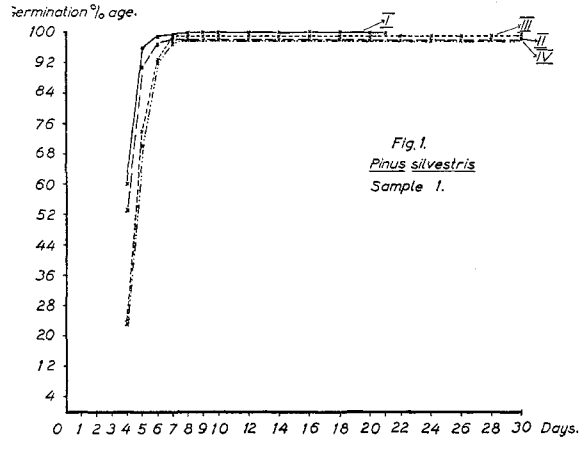


Fig. 1.
Pinus silvestris
Sample 1.

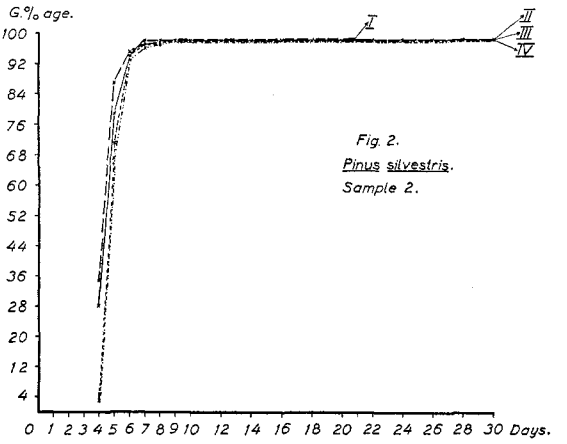


Fig. 2.
Pinus silvestris.
Sample 2.

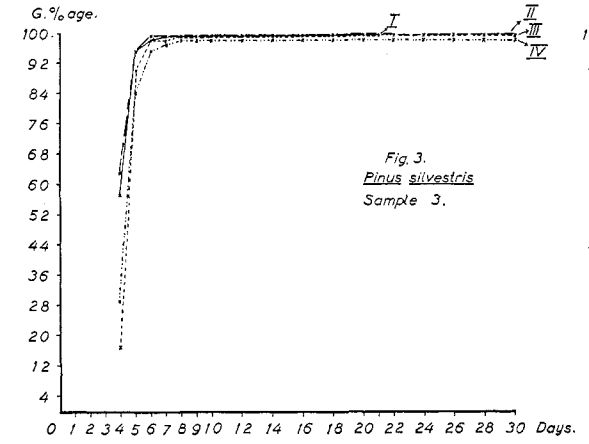


Fig. 3.
Pinus silvestris
Sample 3.

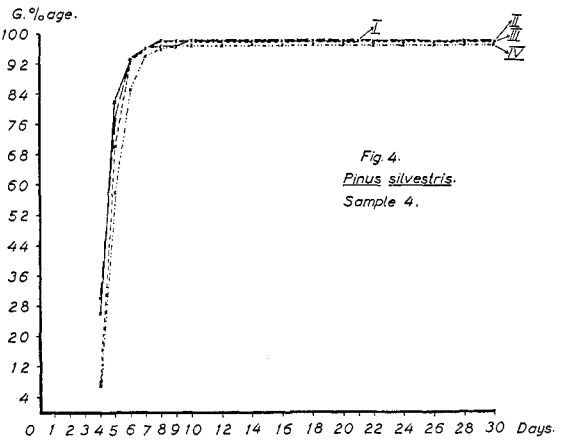
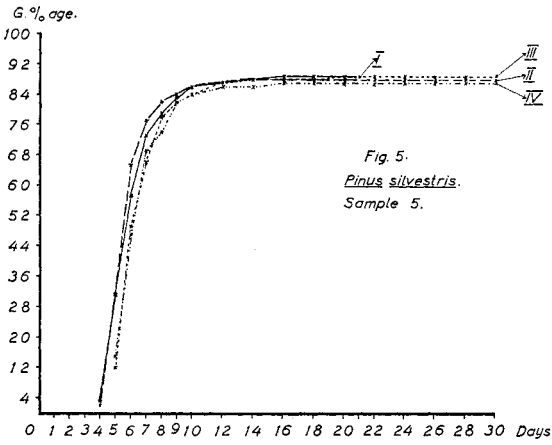
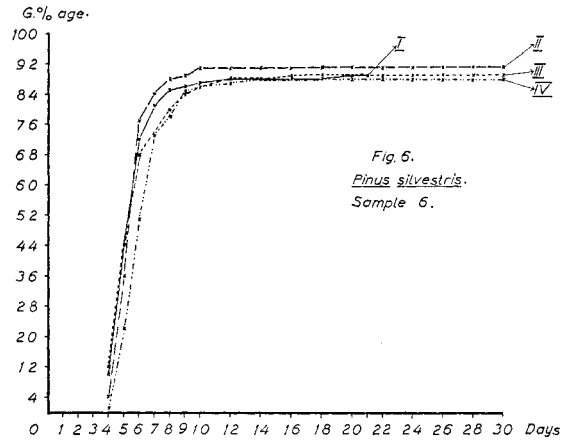
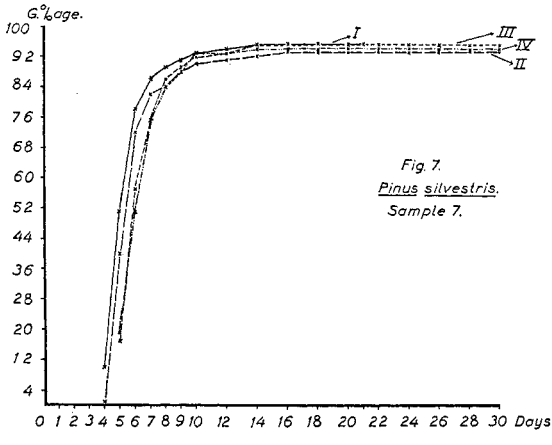
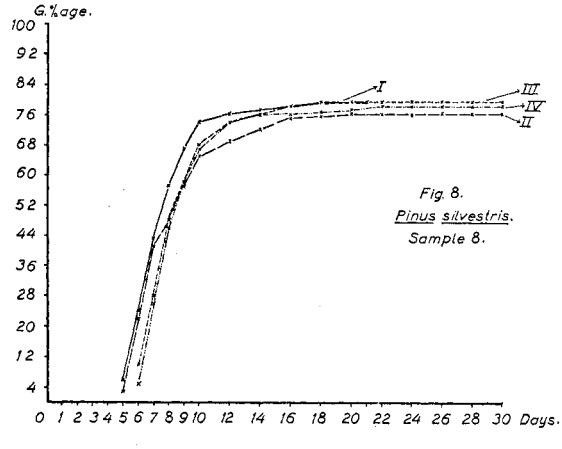


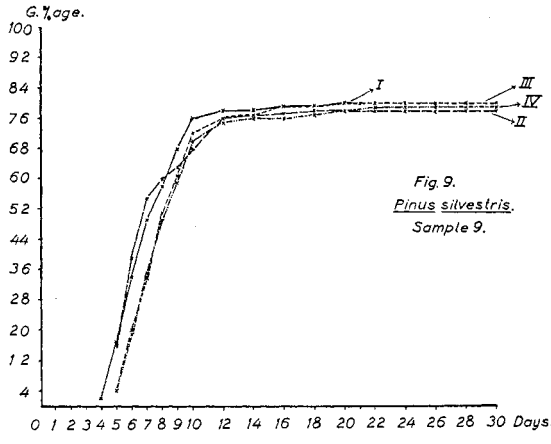
Fig. 4.
Pinus silvestris.
Sample 4.

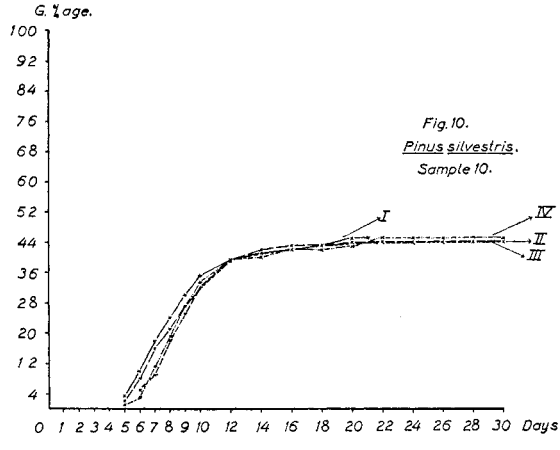












Figs. 1—10: Rate of germination of the samples of Scots pine.

The effect of photoperiod on the rate of germination of Scots pine seed can be studied from sets III and IV. Both these sets have a constant temperature of 20°C, but the duration of light is 24 hours daily in set III and 8 hours daily in set IV, the intensity and quality being the same in both the cases. A comparison shows that the rates are similar in the two sets. However, in samples 1, 2, 3, 4, 6 and 8, the rate appears to be slightly faster in set III than in set IV during the first few days of the test, while the differences in the rates are varying between the two sets in samples 5, 7, 9 and 10. It seems, therefore, that in the present investigation there are no consistent differences in the rates of germination of Scots pine samples under 8 and 24 hours light daily.

b) Norway spruce:

By comparing the rates of germination of the Norway spruce samples at 20—30°C and at 20°C under similar light conditions (sets I and IV), one finds that they show, in principle, the same general tendencies as those described above for the corresponding sets of Scots pine. Thus most of the samples of Norway spruce seem to germinate more rapidly in the first few days of the test under the alternating than under the constant temperature conditions. However, it is interesting to note that from the eighth day in sample 5, the twelfth day in sample 8, and the fourteenth day in sample 10 (cf. Figs. 15, 18 and 20), the rate of germination appears to be faster at the constant than at the alternating temperature.

A comparison of the germination rates of Norway spruce samples at 20—30°C and at 23°C under similar light conditions (sets I and II), shows that several of the samples seem to germinate faster at the alternating than at the constant temperature during the first few days of the test (e.g. Fig. 16: up to the seventh day; Fig. 18: up to the eighth day; Figs. 13 and 15: up to the tenth day; Fig. 12: up to the sixteenth day, etc.). However, from a certain point onward (cf. the eighth day in Fig. 20, the ninth day in Figs. 16 and 18, and the twelfth day in Figs. 15 and 17, etc.), the reverse seems to be true.

From the above observations it appears, therefore, that the rate of germination of Norway spruce seed is not *necessarily* more rapid at the alternating than at the constant temperature when judged by all the samples and by the whole period of the germination test.

When one compares the germination rates at 23°C and at 20°C under similar light conditions (sets II and IV), one finds that the rate in several samples seems to be faster at the former than at

the latter temperature in the first few days of the test (e.g. Figs. 14 and 19: up to the eighth day, Figs, 20 and 12: up to the twelfth and the fourteenth day respectively, Fig. 18: up to the twentieth day, etc.). However, the germination rate appears to be faster at 20°C than at 23°C in the following cases: Figs. 11 and 15 (from the eighth to the tenth day), Figs. 13, 14 and 20 (from the seventh, the fourteenth and the twenty-second day onward, respectively). Thus, the examples given above seem to show that the rate of germination of Norway spruce seed is not *necessarily* faster at 23°C (set II) than at 20°C (set IV), when judged by all the samples and by the whole period of the test.

Regarding the question of the duration of light and the rate of germination, many samples seem to show a somewhat faster rate

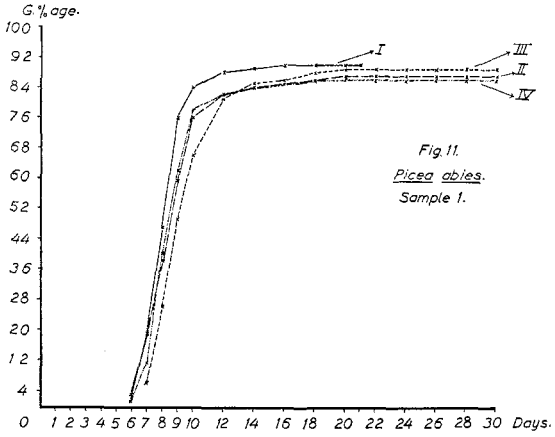


Fig. 11.
Picea abies.
Sample 1.

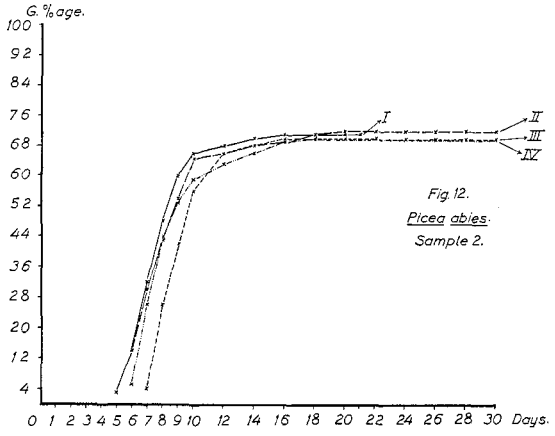


Fig. 12.
Picea abies.
Sample 2.

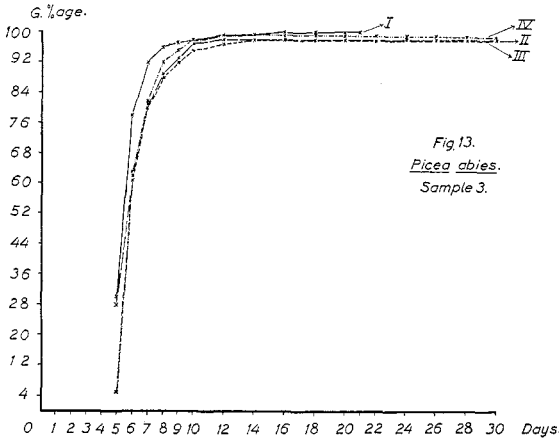


Fig. 13.
Picea abies.
Sample 3.

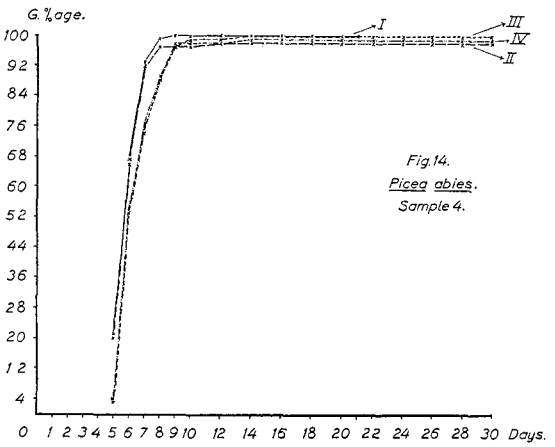
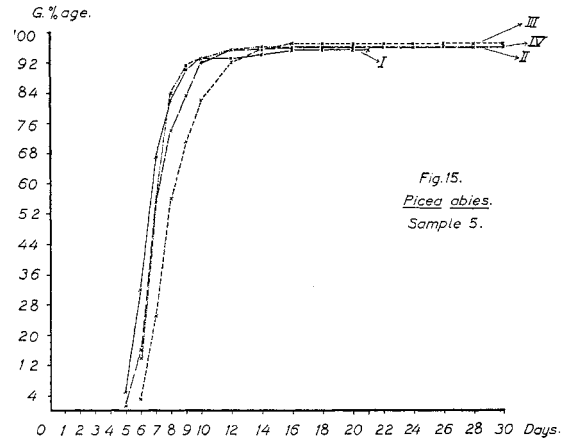
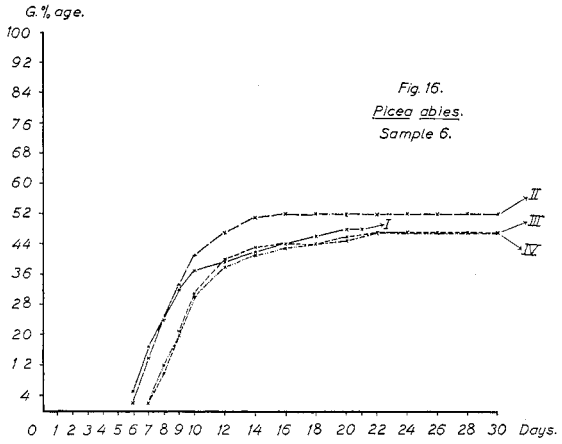
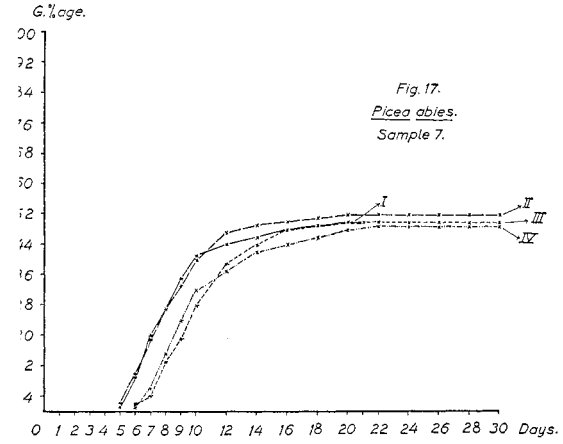
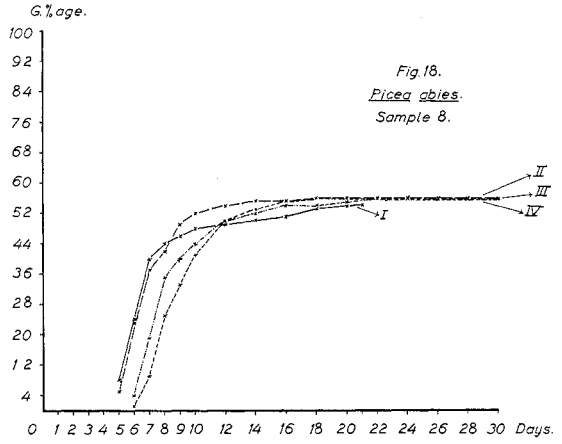


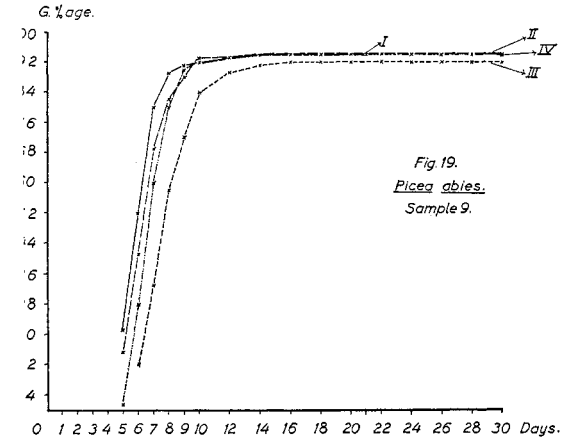
Fig. 14.
Picea abies.
Sample 4.

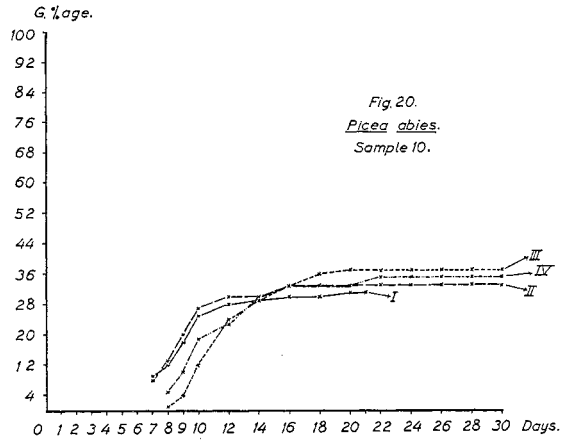












Figs. 11—20: Rate of germination of the samples of Norway spruce.

in the first few days of the test under 8 than under 24 hours light daily (sets IV and III, respectively). For example: Figs. 12, 11 and 15 (up to the tenth, the twelfth and the fourteenth day, respectively), Figs. 17, 18 and 20 (from the seventh to the tenth day, from the sixth to the tenth day, and from the eighth to the tenth day, respectively, etc.).

However, after some days of germination, the rate appears to be faster under 24 than under 8 hours photoperiod in several samples (e.g. Fig. 14: from the tenth day onward, Fig. 17: from the twelfth day onward, Fig. 11: from the fourteenth day onward, Figs. 15 and 20: from the sixteenth day onward, etc.). From the examples given above, it appears that in the present investigation, there are no consistent differences in the rates of germination of Norway spruce samples under 8 and 24 hours photoperiods.

Discussion

The germination percentages of Scots pine and Norway spruce seed (cf. Tables 3 and 4) show that there are no statistically significant differences among the values of a given sample under the four sets of conditions. It seems, therefore, that the seed of both these species is capable of germinating under the different temperature and light conditions used here and of giving comparable results. This observation supports, in principle, the experience of HEIT (1958 and 1961), who reports the germination of Scots pine and Norway spruce seed at different temperatures both with and without light.

For the rate of germination several interesting comparisons among the different sets of conditions have been made under the Results. From these it appears that the rate of germination of Scots pine and Norway spruce seed is not *necessarily* faster at the alternating than at the constant temperatures when judged by all the samples and by the whole periods of the germination tests.

The above observations about the effect of temperature on the percentage and the rate of germination agree with the view of MAYER and POLJAKOFF-MAYBER (1963) who state (page 45): "A rise in temperature does not necessarily cause an increase in either the rate of germination or in its percentage. Germination as a whole is therefore not characterized by a simple temperature coefficient. This can be understood if it is appreciated that germination is a complex process and a change in temperature will affect each constituent step individually, so that the effect of temperature which is observed will merely reflect the overall resultant effect."

Although the alternating temperature of 20—30°C does not seem to be better than the constant temperatures of 23°C and 20°C for the germination of Scots pine and Norway spruce seed, it may be mentioned that the alternating temperatures are not only favourable but even required for the germination of some other species of seed, e.g. *Agrostis alba, Cynodon dactylon, Nicotiana tabacum, Oenothera biennis, Rumex crispus,* etc. (cf. MAYER and POLJAKOFF-MAYBER, 1963). The mechanism of action of the alternating temperatures on the germination of seeds has been discussed by several authors (e.g. NIETHAMMER and TIETZ, 1961; MAYER and POLJAKOFF-MAYBER, 1963, etc.).

Regarding the question of the duration of light and the germination of Scots pine and Norway spruce seed, the results of the tests at 20°C under 8 and 24 hours light daily (sets III and IV) did not show any consistent difference between the effects of the two photoperiods on the rate and practically no difference in their effects on the percentage of germination. It seems, therefore, that any of these two photoperiods could be used for testing the germination percentage of these two species. The problem of the effect of light on the germination of conifer seed has been discussed by several workers, e.g. JONES 1961, NYMAN 1963, KANTOR and SIMANCIK 1966, etc.

One might say that the duration of the germination test was 21 days in set I and 30 days in sets II, III and IV, and this could influence the germination percentage of a sample. In this connection, it may be pointed out that 21 days are prescribed in the International Rules for Seed Testing (1966) for testing the germination percentage of Scots pine and Norway spruce seed. Since set I was according to the above rules, the period of 21 days had to be followed. However, in order to make the duration of the germination tests the same in the four sets, the samples in set I were allowed to germinate up to 30 days. No further germination was observed from the 21st to the 30th day in any of the samples in this set. It may be mentioned here that HEIT (1958 and 1961) considers the period of 14 and 16 days as adequate for the germination of Scots pine and Norway spruce seed respectively under the same conditions as those of set I. Thus, in the present investigation the results of the germination tests in set I for 21 days may be considered comparable with those of sets II, III and IV for 30 days.

Summary

1. The present paper deals with a comparison of the percentages and the rates of germination of samples of Scots pine and Norway spruce seed under different sets of temperatures and photoperiods. Ten samples each of *Pinus silvestris* L. and *Picea abies* (L.) Karst., some with high, others with lower germination percentages were taken for the experiments. The details of the material are given in Tables 1 and 2.

2. Four sets of germination conditions: three with 8 hours light daily and alternating temperature of 20—30°C and constant temperatures of 23°C and 20°C, and one with 24 hours light daily and 20°C were used. For further details of the sets, see the Methods.

3. There were no statistically significant differences among the germination percentages of the samples of Scots pine and Norway spruce seed under the four sets of conditions (cf. Tables 3 and 4).

4. The germination rates of several samples appeared to be faster during the first few days of the tests at the alternating than at the constant temperatures under similar light conditions. However, from a certain point onward, which was different in the different cases, there were only small differences in the germination rates of the samples (cf. Figs. 1—20). Judging by all the samples and by the whole periods of the tests, the germination rate was not necessarily faster at the alternating than at the constant temperatures.

5. The germination tests under 8 and 24 hours light daily at 20°C did not show any consistent difference in both the species in the rate of germination, and practically no difference in the percentage of germination, under the two photoperiods.

6. The investigation has thus shown, that any of the four sets of conditions (I—IV) can be used for testing the germination percentage of Scots pine and Norway spruce seed.

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Zusammenfassung

Vergleichende Studien über die Keimung von Kiefern- und Fichtensamen unter verschiedenen Temperaturen und Photoperioden

1. Die vorliegende Arbeit beschäftigt sich mit einem Vergleich der Keimprozenten und der Keimungsgeschwindigkeit von Kiefern- und Fichtensamen unter verschiedenen Temperaturen und Photoperioden. Zehn Proben von je *Pinus silvestris* L. und *Picea abies* (L.) Karst. einige mit hoher andere mit niedriger Keimfähigkeit wurden für die Versuche verwendet. Die Einzelheiten des Materials sind in Tabellen 1 und 2 angegeben.

2. Vier verschiedene Kombinationen von Keimungsbedingungen: drei mit 8 Stunden Licht täglich und Temperaturen von 20—30°C, 23°C und 20°C, und eine mit 24 Stunden Licht täglich und 20°C wurden angewandt. Für weitere Information, siehe Methodik.

3. Es wurden keine statistisch signifikanten Unterschiede in den Keimprozenten der Kiefern- und Fichtenproben unter den vier Bedingungen festgestellt (vergl. Tabellen 3 und 4).

4. In den ersten Tagen erschien die Keimungsgeschwindigkeit von manchen Proben schneller bei Wechsel- als bei Konstanttemperatur unter gleichen Lichtbedingungen. Doch von einem bestimmten Zeitpunkt an, der für die verschiedene Proben verschieden war, waren es nur geringe Unterschiede in der Keimungsgeschwindigkeit (vergl. Figuren 1—20). Die Beurteilung auf Grund aller Proben und der ganzen Keimungsdauer zeigte, dass die Keimungsgeschwindigkeit bei Wechseltemperatur nicht unbedingt schneller war als bei Konstanttemperatur.

5. Die Keimungsversuche bei 20°C unter 8 und 24 Stunden Licht täglich zeigten keinen konsequenten Unterschied in der Keimungsgeschwindigkeit und fast keinen Unterschied in den Keimprozenten bei beiden Samenarten unter diesen zwei Photoperioden.

6. Die Untersuchung hat damit gezeigt, dass alle vier Kombinationen von Keimungsbedingungen (I—IV) gleichwertig für die Bestimmung der Keimfähigkeit von Kiefern- und Fichtensamen verwendet werden können.

Sammanfattning

Jämförande studier över groning av tall- och granfrö under olika temperaturer och fotoperioder

1. Föreliggande uppsats behandlar jämförelsen mellan groningsprocenten och groningshastigheten hos tall- och granfrö under olika temperaturer och fotoperioder. Tio prov av vardera tall- och granfrö, varav några med hög, andra med sämre grobarhet, användes till försöken. Detaljer om materialet återfinnes i tabellerna 1—2.

2. Fyra kombinationer (I—IV) av groningsbetingelser användes: tre med 8 timmar ljus per dygn och växeltemperatur 20—30°C, resp. konstanttemperatur 23°C eller 20°C samt en med 24 timmar ljus och 20°C. För ytterligare detaljer, se metodiken.

3. Inga statistiskt signifikanta skillnader i groningsprocenterna av tall- och granprov kunde fastställas mellan de fyra olika kombinationerna.

4. Groningshastigheten hos flera prov visade sig under de första dagarna vara högre i växeltemperatur än i konstanttemperatur under lika ljusförhållanden. Från en viss tidpunkt, som var olika i olika prov, kunde emellertid endast små skillnader i groningshastigheten observeras mellan de olika proven vid ovannämnda temperaturer (se figurerna 1—20). Bedömningen av resultaten, grundad på alla prov under hela groningsperioden, visar, att groningshastigheten inte nödvändigtvis är snabbare i växeltemperatur än i konstant temperatur.

5. Groningsförsök under 8 och 24 timmar ljus per dygn vid 20°C visade, att dessa två fotoperioder icke gav några konsekventa skillnader i groningshastighet och nästan ingen skillnad i groningsprocenterna hos tall- och granprov.

6. Undersökningen har således visat, att vilken som helst av de fyra testade temperatur- och ljuskombinationerna (I—IV) kan användas för bestämning av grobarhetsprocenten hos tall- och granfrö.