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A Method of Stimulating the Germination of Pine Seed (Pinus silvestris)

En metod att stimulera tallfröets groning

Av

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A Method of stimulating the Germination of Pine Seed (Pinus silvestris)

by

LENNART NORDSTRÖM

The severe shortage of pine seed, which has long prevailed in the northern parts of Sweden, provides the background to the experiments here briefly described. To some extent this shortage has been due to labour shortages, which in turn have made it more difficult to collect adequate quantities of pine cones. But the further north one goes, and the higher above sea-level one mounts, the more the seed shortage is due to biological factors, and the more the organisational and economic factors take second place. In the northern parts of the country, and particularly at high levels, the climate is hard and the vegetative period short. Pine seed from these regions is thus often immature. This state of affairs has been tharoughly dealt with by several Scandinavian research workers, for Sweden especially Professor WIBECK. WIBECK has studied the reasons for poor seed maturity, and the connection between it and the summer temperature. He has also demonstrated that the immature pine seed to a certain extent only germinates one year after it has been sown or sometimes even later. WIBECK has also found a close connection between the degree of ripeness of the seed and the length of the embryo (WIBECK 1927).

As a result of low germination percentage and low plant percentage, the immature seed has low practical value. The difference between the germination percentage and the plant percentage is often very great. This points towards a possibility of improving seed supplies by means of measures which tend to raise the plant percentage. A study of such a possibility of raising the plant percentage should first of all clarify the nature and frequency of the various factors which hinder germination in field sowing or cause the death of the seedlings.

An introductory sowing experiment in this matter was made in soil under laboratory conditions. Pine seed from the North, with a germination percentage of 86, was

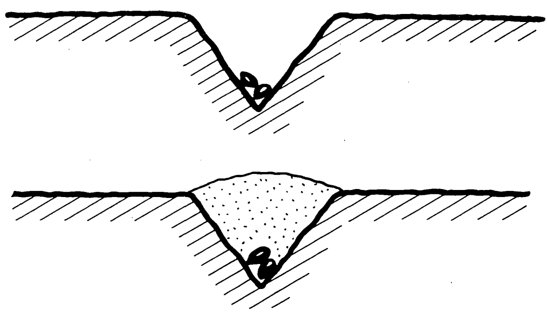

Fig. 1.

Fig. 1. At the top: Seeds have not been bedded down. The seeds have good acces to light, but there is risk of drying. Below: Seeds have been bedded down and therefore they have good humidity conditions, but are not being stimulated to germinate by the influence of light.

used for the experiment. The following results per 100 seeds sown were obtained when the experiment was interrupted 40 days after the sowing:

Plants	36
Germinated seed	9
Rotten seed	6
Healthy ungerminated seed	47
Seeds that could not be found	2
	Total 100 seeds

During the experiment the soil temperature varied between 14° and 18° C. Of *particular interest* is the large number of ungerminated, but fully healthy, seeds. Most of them would have germinated in the germination apparatus. There is no difficulty in attributing the probable reason why they did not germinate when sown in soil. The reason is probably lack of light. Seeds sown in the soil are hidden from the light, while those sown in the apparatus have full access to it. For more than a century it has been well-known that the seeds of quite a number of plants strongly depend upon light for their germination. (Baldwin, also Lehmann and Aichele). This is in the highest degree true of pine seed. In certain sowing methods the pine seeds' need of light for germination has ben met by placing the seeds in the bottom of a little open furrow in the ground, where they have lain with full access to light (see Fig. 1). These methods, however, have shown certain disadvantages; seed sown in this way suffer from poor humidity conditions for their germination, and also run the risk of drying up.

None of the sowing methods indicated in principle in Fig. 1 can be said to be good ones. Obviously it is a question of finding a method which allows the seeds to germinate under good humidity conditions while at the same time powerfully stimulating germination by means of light or in some other way.

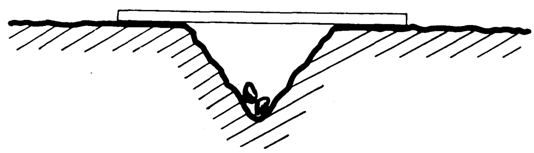

Fig. 2. The seeds have not been bedded down, but, despite this, they are protected against evaporation by the glass pane. The light has free access to the seeds.

Such a method, which however can only be used under laboratory conditions, is shown in principle in Figure 2. In this case, too, the seeds have been placed in a furrow, but they have been covered over with a pane of glass, which prevents evaporation but allows a full flow of light to reach the seeds. Figure 3. shows such a sowing, carried out under laboratory conditions. Figure 4. shows such a sowing after 45 days. The glass panes have been removed as soon as the plants needed it in order to grow upwards. As soon as the glass panes have been removed, sand has been poured into these parts of the sowing strips. The increase in the production of plants was 208 %, according to a check made 45 days after the sowing. This appears in Figure 5., which presents the same experiment as Figure 4 in the form of a graph.

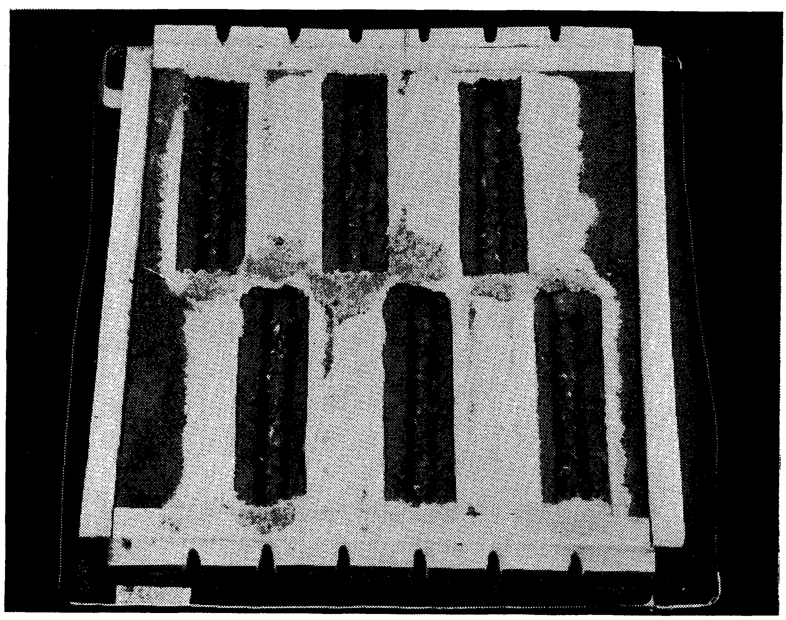

Fig. 3. The seeds have been sown in six sowing furrows. Half the length of each furrow, containing 50 seeds, has been covered with glass. In the other half of each furrow, the seeds have been bedded down with drift sand immediately after sowing.

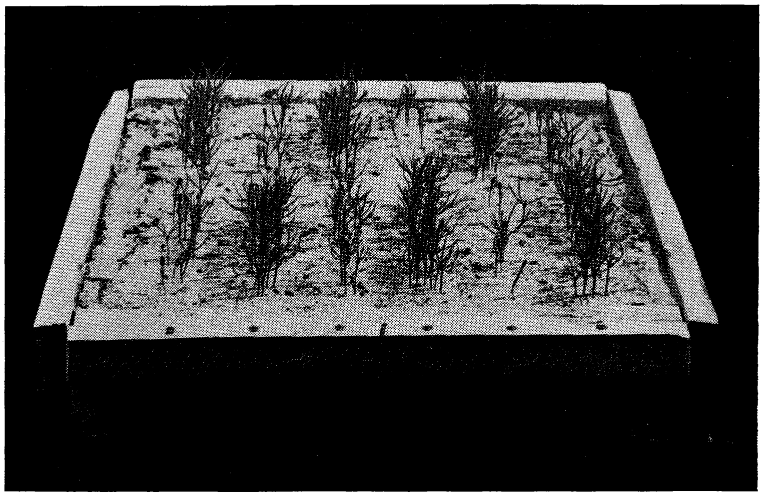

Fig. 4. The picture shows a 45-day old experiment carried out as in Fig. 3. Seed data: Age 0 years, height above sea-level 260—300 m., parallel of latitude 63° 00′, germination capacity 86 %, empty seed 0 %. During the experiment the soil temperature has varied between 11.5 and 18 degrees. Same experiment is shown in Fig. 5.

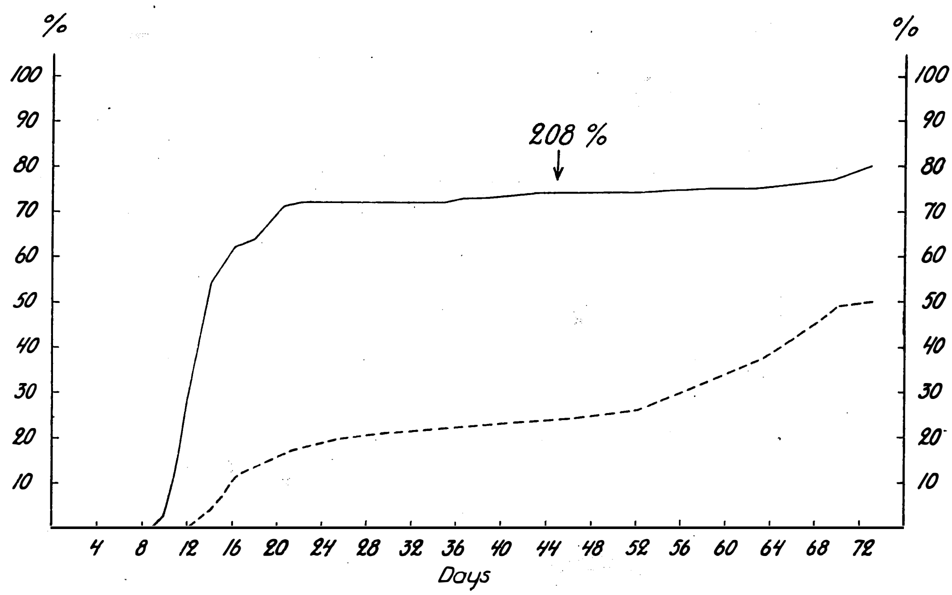

Fig. 5. Graphic presentation of the results of the experiment shown in Fig. 4. »%» refers to number of seedlings per 100 seeds sown. »Days» refers to time from sowing date. The upper curve shows the output of seedlings from the seed which has germinated in light beneath glass. The lower curve shows the same output for seed bedded down imedlately after sowing.

In practise it is impossible to use this method of sowing under glass, which has been tried out in the laboratory. It seems therefore that experiment must continue to aim at replacing the stimulation to germination which comes from light by some other factor. If a practical and applicable method of this sort could be found it would obviously greatly increase our chances of improving the seed supply.

Before these projected experiments could be made, however, another way of dealing with the problem presented itself. It was based on two well-known phenomena, namely:

1. In practise two ways of extracting seeds from pine cones have been used. In the one case it has been done by warming up the cones and drying them by means of direct sun heat. In the other case, the cones have been warmed in special containers, using an artificial source of heat. For a very long while now it has been maintained by many authors that seed which has been extracted by the former method shows the better germination capacity.

2. As stated above, WIBECK has shown that seed originating in the North will, to a large extent, germinate only one year after sowing. This is the more remarkable considering the structure of pine seed and its sensitivity to frost when damp. By way of hypothesis it has been suggested that the delayed germination must be regarded as a positive adjustment to severe climatic conditions, typical of this genus. Thanks to delayed germination, the provenance of seedlings from any one seed-year is spread out over several years, offering a good chance that at least one of these years will offer the seedlings favourable conditions to develop in. This explanation is regarded by the present author as improbable, for reasons given above.

The two circumstances mentioned before, i. e., partly the superiority of seeds extracted by sun heat, and partly the strangely delayed germination of North Swedish seed, has given rise to a method of stimulating germination. Both circumstances can be explained, if the light, in order to stimulate the germination process, does not need to be supplied during the actual germination time, but can be applied to the dry seed before it germinates. When extracting by sun heat, the seeds are exposed to sunshine as soon as the cones open, i. e., it is possible that the seeds receive the requisite stimulation to germinate at this time. If seed that has been extracted in an extraction plant, working with artificial heating, is bedded down in the soil when sown, then this seed receives very little light either when being extracted, or after it has been sown; and this may well be the reason why it germinates so long after being sown.

The working hypothesis used for our further experiments can briefly be stated as follows:

If pine seed is exposed to sunshine for long enough, then this light treatment may possibly act favourably on the subsequent germination, both as regards the number of germinated seeds and the germination rate. It may be that the light treatment will have this effect, even where the moisture content is as low as it usually is in newly extracted seed.

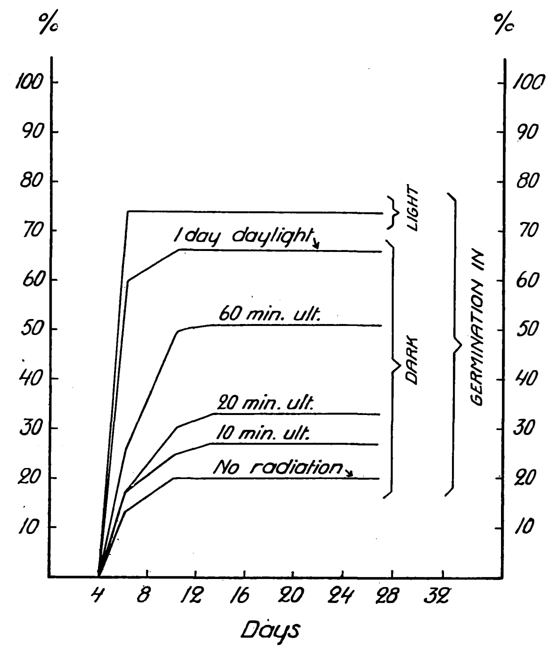

Fig. 6. The percents refer to number of germinated seeds per 100 seeds laid out for germination study. »Days» refers to the time which has passed since seed was laid out for germination study. Seed data: Age 0 years, height above sea-level 0—50 m., parallel of latitud 59° 30′, germination capacity 75 %, empty seed 0 %.

To test this hypothesis a small-scale germination experiment was made, both in the germination apparatus (JACOBSEN'S, experiment time 30 days), and in sowing experiments partly in sand and partly underground in laboratory conditions. A number of field experiments have also been made. It would be to go too far to give details of these experiments here. From now on we shall therefore restrict ourselves to giving an account only of some of them, by presenting them in the form of graphs. Further, certain interesting points are dealt with, relative to seeds damaged in the de-winging process. Finally, a brief summary is given of results so far attained.

Some experimental results in graph form

The first experiment was made in the dark part of the year, when it was hard to obtain intense sunlight, compelling us to use ultraviolet light for certain seed samples. As a light source a quartzlamp (Philips »Biosol»), intended for medical purposes, was used. The current used was 250 watts, lighting distance about 2 m., and the wavelength about 2.800 to 6.000 Ångström units. From a seed sample, 6 sub-samples were taken out, and of these three were treated for 10, 20 and 60 minuters respectively

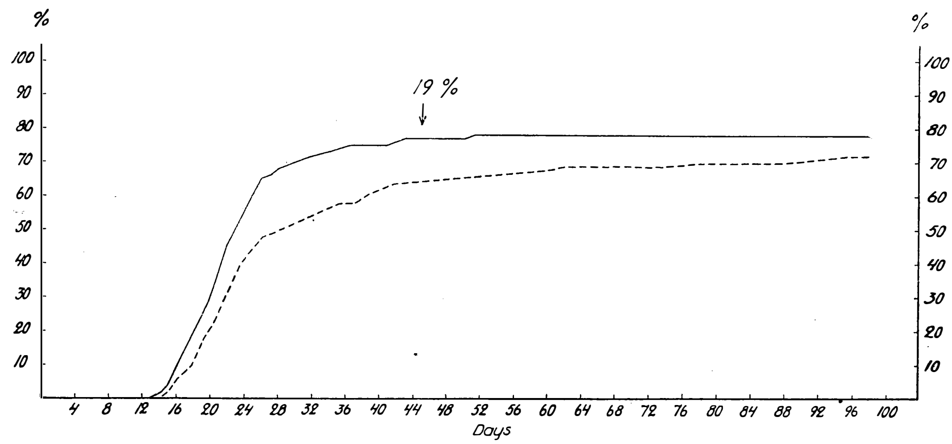

Fig. 7. Seed data: Age 6 years, height above sea-level 301—400 m., parallel of lat. 64° 20′, germination capacity 93 %, empty seeds 0 %.

with ultraviolet light. One sample was supplied with daylight for one day, during which direct sunlight reached the seeds for about 5 hours. Two samples were left entirely without light. One of these was laid out for germination under transparent domes, and all the others under domes of opaque glass. The domes stood on opaque bases so that no light could penetrate from beneath. The results appear in Figure 6. The light treatment has yielded a strong and unambiguous reply in harmony with the working hypothesis. By previously lighting the pine seed for one day with daylight, the germination attained in a germination experiment in darkness has been multiplied several times. This result was verified in several check experiments using different seed supplies. In these the sunligt treatment led to multiplication of the germination

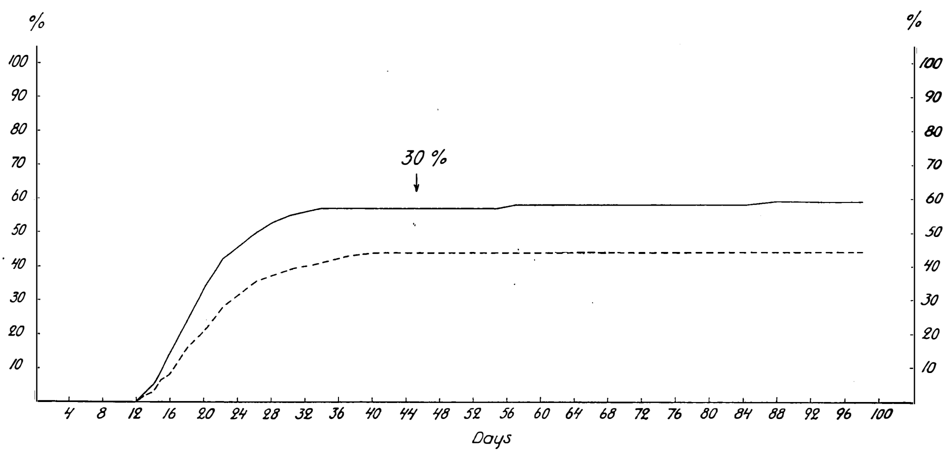

Fig. 8 Seed data: Age 4 years, height above sea-level 201—300 m., parallel of lat. 63° 00′, germination capacity 83 %, empty seeds 0 %.

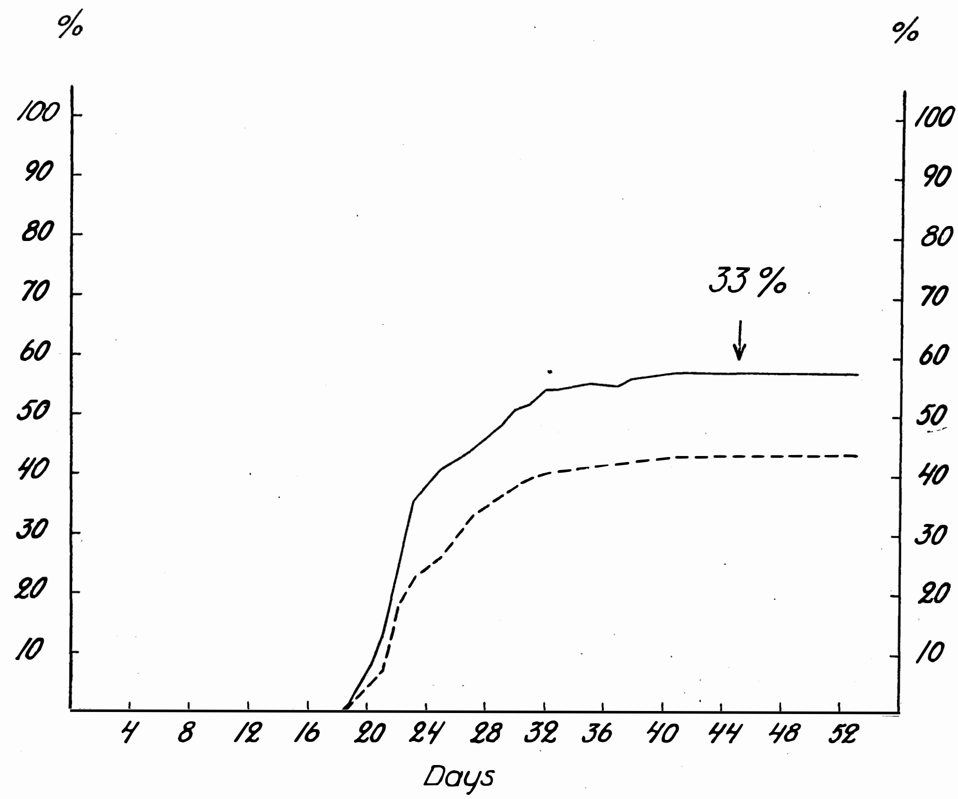

Fig. 9. Seed data: Age 2 years, height above sea-level 50 m., parallel of lat. 66° 20′, germination capacity 80 %, empty seeds 0 %.

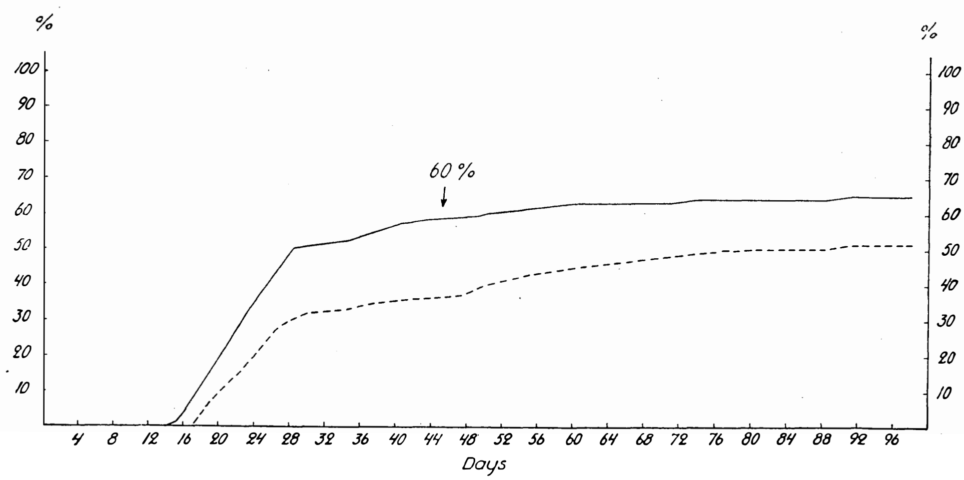

Fig. 10. Seed data: Age 0 years, heigt above sea-level 330—360 m., parallel of lat. 63° 00′, germination capacity 75 %, empty seeds 0 %.

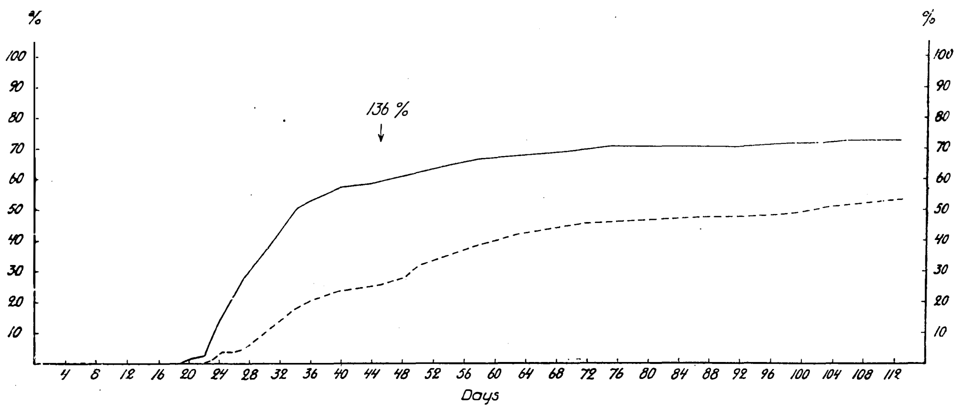

Fig. 11. Seed data: Age 0 years, height above sea-level 350—390 m., parallel of lat. 63° 00′, germination capacity 84 %, empty seeds 0 %.

results obtained in experiments made in darkness. For very vital and mature seeds from the Southern parts of the country the effects of light treatment proved to be weaker, or even non-existent. The results obtained suggest that, as the age of the seed rises, the less it is dependant on light for its germination.

While waiting for a time of year when field experiments could be made, a number of sowing experiments were made under laboratory conditions, partly in sand and partly in soil. Some of the results from the sowing experiment in soil appear in Figs. 7—14. The number of plants per 100 light-treated seeds sown has been marked by a continuous line. The light treatment consisted of three day's radiation with sunlight. Along the horizontal axis are marked the number of days which elapsed after sowing. The dotted line shows the number of plants which came up from seeds that were n o t treated with light. Earth temperature during the experiment varied mostly between 12° and 18° C. In each diagram a percent value has been given 45 days after

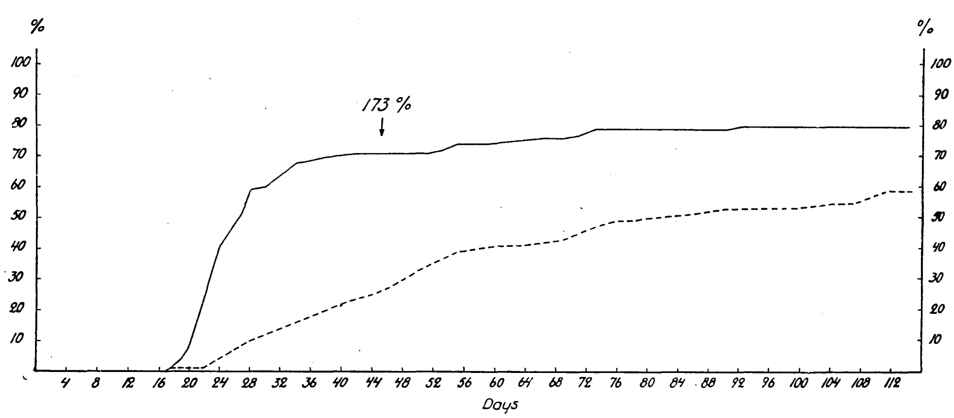

Fig. 12. Seed data: Age 0 years, height above sea-level 260—300 m., parallel of lat. 63° 00′, germination capacity 86 %, empty seeds 0 %.

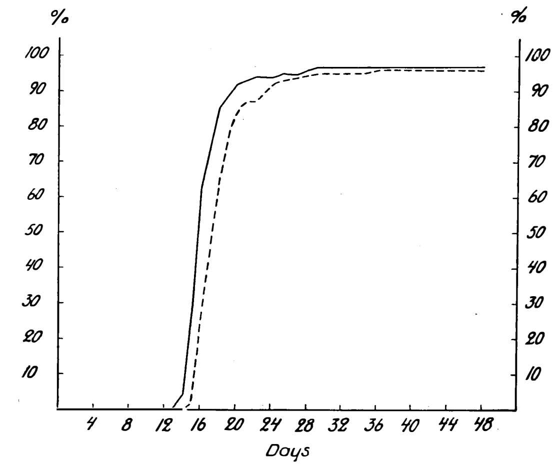

Fig. 13. Seed data: Age 0 years, height above sea-level 0—50 m., parallel of lat. 59° 40′, germination capacity 98 %, empty seeds 0 %.

the sowing. This value gives the percentual increase in the number of plants attained 45 days after the sowing as a result of the seed's light treatment prior to sowing.

Figures 7—12 show the results of sowing experiments made with seed from the north of Sweden. It is interesting to note, partly the sharp increase in plant production resulting from the preceding light treatment; and partly that this increase is least for seed from Northern Sweden, according to Figures 7, 8 and 9, which relate to old seed. Figure 13 shows an experiment made with noticeably vital seed from the Stockholm district. Finally, Figure 14 shows that even seed coming from the south, in this case from Central Germany, can also react to previous sunlight treatment by an increase in seedling yield.

These laboratory experiments with soil-sowing were arranged in such a way that the germination factors as far as possible were identical with conditions in the field.

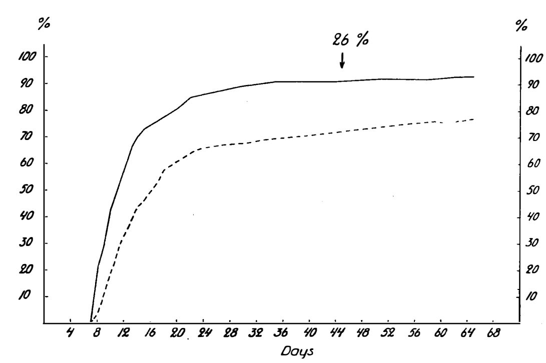

Fig. 14. Seed data: Age 0 years, height above sea-level 500—600 m., parallel of lat. 50° 20′, germination capacity 93 %, empty seeds 0 %.

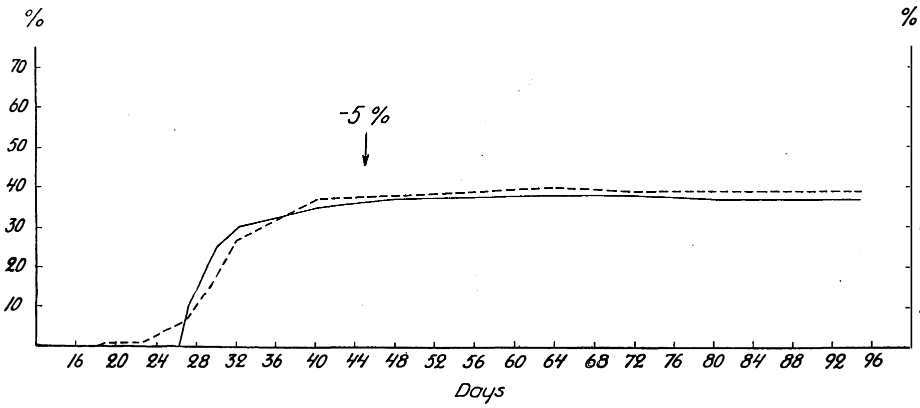

Fig. 15. Seed data: Age 2 years, height above sea-level 250 m., parallel of lat. 62° 50′, germination capacity 66 %, empty seeds 9 %.

But naturally it was necessary to verify the results by field experiments. This has been done, though on a smaller scale. Sowing experiments in the field have been made in Central Norrland, at a height of 500 m. above sealevel, with seed from 6 different sources.

The results appear in Figs. 15—20. In Figs. 15—19 the experiments have been made with seeds from a large extraction plant. For the experiment shown in Fig. 20 seed which had been de-winged in the Forestry College by hand was used. In most of the experiments light treatment led to a significant increase in seeding yield. However, the increase was not so great as it seemed we had a right to expect on the basis of laboratory experiments. An exception to this was provided by the experiment described in Fig. 20, i. e., the one in which hand-dewinged seed was used. This led us to try and find out whether the seed delivered from the extraction centre had been damaged during de-winging in such a way that its germination had been somewhat stimulated.

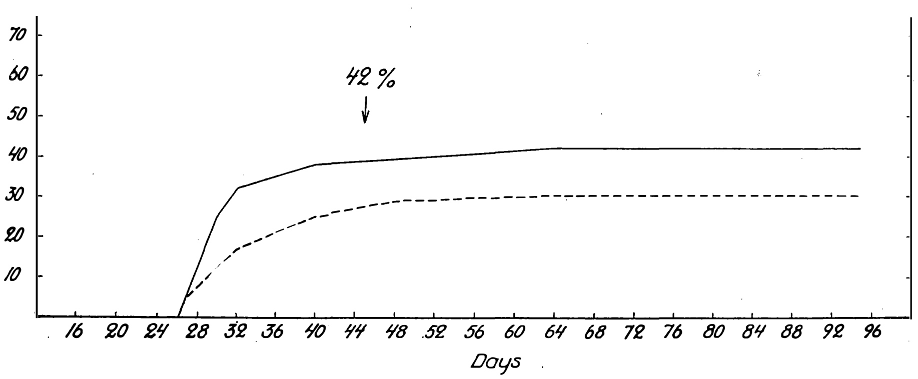

Fig. 16. Seed data: Age 1 year, height above sea-level 301—400 m., parallel of lat. 62° 20′, germination capacity 71 %, empty seeds 0 %.

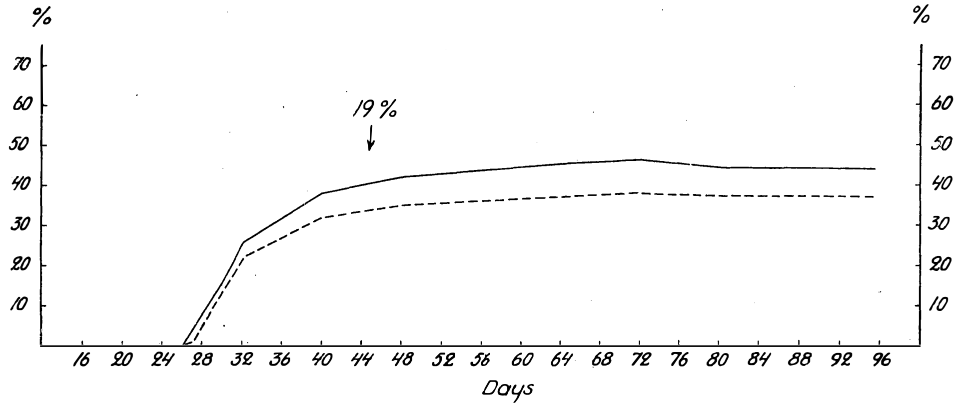

Fig. 17. Seed data: Age O years, height above sea-level 360 m., parallel of lat. 63° 10′, germination capacity 57 %, empty seeds 1 %.

Seeds Damaged during De-Winging

It is well-known that certain seeds which are reluctant to germinate can be freed from this reluctance by being bruised. According to LEHMANN and AICHELE (1931 p. 478) it is conceivable that there are three different explanations of this state of affairs; namely, irritation of the wound, facilitated absorbance of water, and facilitated air supply. HUSS (1950) has shown that a great many de-winging apparatus hitherto used in Sweden cause very serious damage to the seeds, — damage which cannot always be revealed by the microscope, but which does appear in germination studies. Similar strange damage to seeds has also been mentioned by ELIASSON and HEIT (1940), and also briefly by ROHMEDER (1942). It was conceivable that similar seed damage had affected the results of the field experiments in Figs. 15—19. To discover whether this was so or not, 9 subsamples were taken from a seed sample which had been carefully de-winged. Sample No. 1 was left entirely untreated, while the others were subjected to shocks by shaking within a tin can, whose interior was

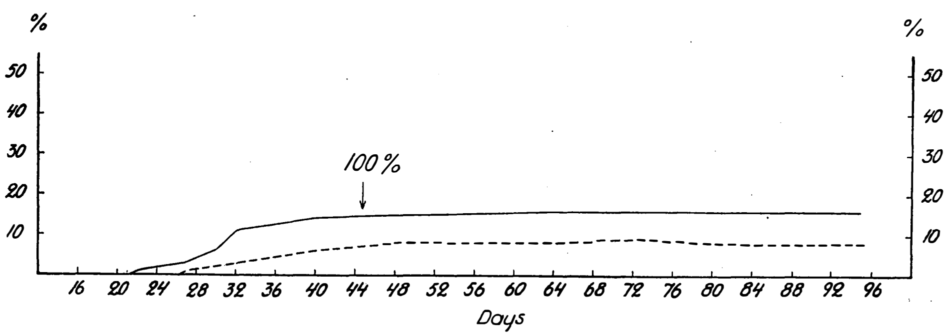

Fig. 18. Seed data: Age 0 years, height above sea-level 335 m., parallel of lat. 64° 25′, germination capacity 23 %, empty seeds 0 %.

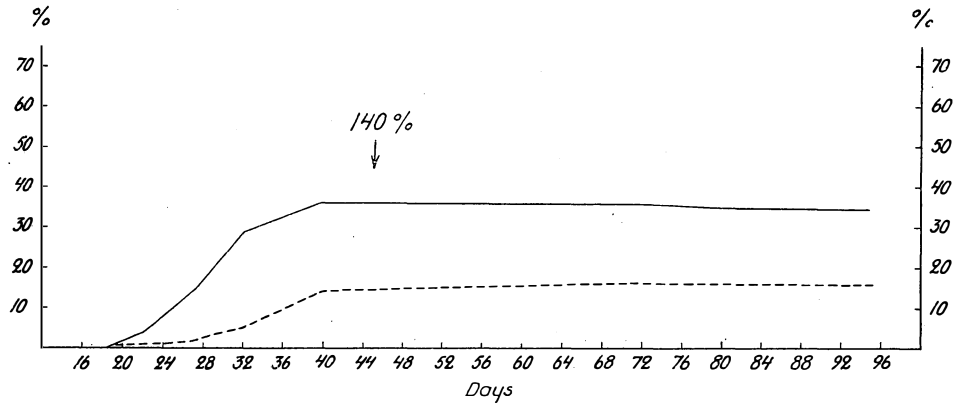

Fig. 19. Seed data: Age 0 years, height above sea-level 420 m., parallel of lat. 62° 50′, germination capacity 63 %, empty seeds 0 %.

smooth. For samples nr. 2—9 respectively the shaking period was 5, 10 and 30 seconds, and 1, 2, 3, 5 and 9 minutes. Thereafter each sample which had been treated in this way was divided up into yet smaller sub-samples, and the same thing was done to sub-sample nr 1. These smaller sub-samples were laid out for germination study in Jacobsen's apparatus, some in darkness, some in the light. The results appear in Fig. 21, and they agree well the original hypothesis. The results imply that, where the germination study is made in darkness, germination is stimulated, first rapidly, as the shaking period increases, then slowly sinks again. The undamaged seed samples show a very large difference as between germination studies carried out in the dark and in light. As the shaking period increases, this difference decreases, and, over a certain shaking period, disappears altogether. This means that the light treatment method presented in this essay has no effect when applied to a seed sample that has been bad-

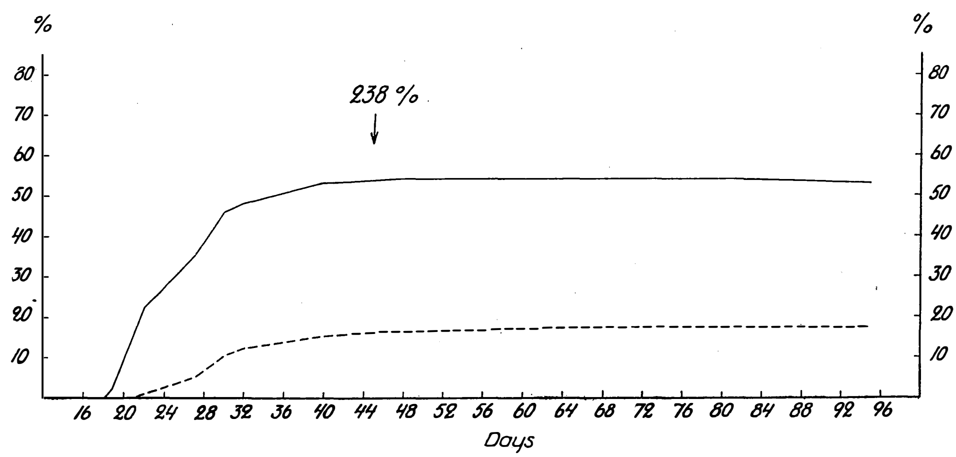

Fig. 20. Seed data : Age O years, heigt above sea-level 360—380 m., parallel of lat. 62° 50′, germination capacity 91 %, empty seeds 0 %.

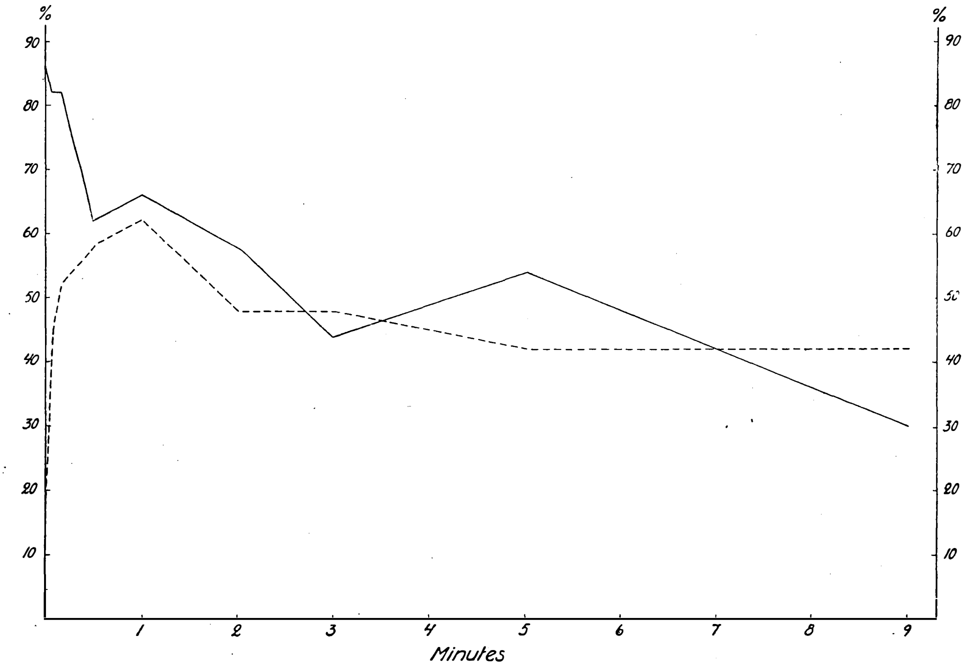

Fig. 21. »%» refers to the number of germinated seed per 100 seeds laid out for germination. On the vertical axis is noted shaking-time in minutes. The continuous line shows the results for germination in light, and the dotted line the results for germination in darkness. Seed data: Age 1 years, heigt above sea-level 300 m., parallel of lat. 63° 00′, germination capacity 86 %, empty seeds 0 %.

ly damaged during de-winging. The results of Fig. 21 have been verified under laboratory conditions by sowing in soil. The results presented here exemplify the fact, already known, that one factor which stimulates germination can often replace another. A seed sample which has been effectively stimulated to germinate by being shaken will thus not afterwards react to light treatment. In this context it must remembered that shock treatment, as well as stimulating germination, always seems to imply a certain amount of damage, as Huss has shown. This appears to some extent in Fig. 21 (the continuous line). See further Nordström 1953.

The lighting effects obtained with machine de-winged seed in the field experiments (Figs. 15—19) are thus in all probability too low; i. e., they are not representative of the effects of light treatment in stimulating the germination of seed that has not been damaged in de-winging.

Summary of Results hitherto obtained. Conclusions

1. By treating dry pine seed with sunshine or ultraviolet light its germination is strongly aided, where this occurs in darkness, as is normal when sowing in plant nurseries or forest land.

2. As yet it is impossible to give the optimum treatment period, but the methods hitherto applied, involving three day's radiation with sunshine, have produced a powerful effect. Radiation has usually been carried out in such a way that the sunshine, before meeting the seeds, has had to pass through two panes of window-glass.

3. The effects of radiation remain for a long time. In one case it has been found that they lasted as long as 5 months from the time when radiation was carried out. As yet it is not known whether the effects of radiation diminish gradually in the event of seed being stored for several years after radiation.

4. The older or more vital the seed, the weaker the effects of radiation seem to be.

5. Seeds that have not been too severely damaged by shock can, despite such damage, still show a considerable germination percentage. As a result of such shock damage, such seed can remain entirely indifferent to radiation, as regards the latter's effect on later germination in darkness.

6. For genetic reasons a condition has been made that seed should be sorted according to its size-class before sowing in nurseries. If such sorting has been made, there is a better chance of selecting genetically fine specimens when sorting the seedlings. To this condition may now be added another: pine seed must be radiated before sowing. Otherwise it may happen that, when sorting, a selection is made of seedlings which have come from seeds requiring little light, i. e., seeds which have germinated early for this reason.

7. The method presented above can, of course, also conceivably be of use with other sorts of seed that are dependant on light for their germination. No such experiments have yet been made, however.

CONCLUSIONS

The question of whether radiation of dry seeds influences their later germination in darkness has been dealt with earlier by TAMMES, in 1900. He found that, for the sort of seed studied by him, light treatment had n o effect. It is not possible to state with certainty what the reasons were for this result. It may well be that the seeds studied by him are not influenced by light in their dry condition. Or it may be that his controlmaterial, i. e. non-radiated seeds. (according to his account), were, even so, subjected to quite a lot of light.

Tammes did, however, present the problem clearly, and, with this single exception, seems to have carried out his experiment logically. The negative results obtained by him seem thereafter to have held back research on the influence of sunshine on dry seed. However, several research workers have touched on closely contingent problems. Thus, for example, Gassner (1915) made the following experiment with the seeds of Ranunculus sceleratus. The seed was radiated in damp condition, and under such temperatures that germination could not occur. Radiation was then broken off, and the seeds were laid out for germination in darkness, in order to germinate under suitable temperature conditions. It appeared that the previous radiation had a favourable effect on the germination process. Even where the seeds, having been radiated in damp condition, were dried before being laid out for germination, the favourable effects of light still remained.

The radiation method is easy to apply in practise. The seed lying in a single layer, is subjected to direct sunlight for three days on end. The treatment need not be made directly before sowing, but can occur at any time during the spring when there is favourable weather. The same effects are obtained even if the light has passed through glass. Should the seed have been seriously damaged in de-winging, then light treatment will produce little or no effect.

Obviously certain questions remain, both of theoretical and practical interest. E. g.; Is there any advantage to be obtained by not allowing the light to reach the seed through glass? Does radiation have the same effect when it occurs at considerably lower than room temperature? What practical value does the method offer in the Southern parts of Sweden? To what extent will delayed germination affect the experimental results? What happens inside the seed during radiation?

Despite these remaining questions, it has been felt that the method should already be presented now, as it should be of considerable practical value and is also easy to apply.

Sammanfattning

EN METOD ATT STIMULERA TALLFRÖETS GRONING

Det är sedan mer än ett sekel känt att vissa frön för sin groning äro beroende av ljus. Detta gäller i rätt hög grad även för tallfröet. I undersökningen påvisas att tallfröna kunna förmås att gro villigt även i mörker *genom föregående ljusbehandling*. Ljusbehandlingen har nämnda effekt även om fröna vid belysningen hålla så låg fuktighetshalt, som vanligen är fallet under förvaring.

Det sålunda påvisade förhållandet kan praktiskt utnyttjas för att vid fältsådd av tallfrö erhålla högre plantprocent genom att fröna före sådden belysas med solljus under loppet av några dagar.

I undersökningen redovisas resultat av såväl laboratorieförsök som fältsådder. Resultaten av fältsådderna framgå av figurerna 7—12. I dessa figurer avser heldragen linje plantresultatet efter visst antal dygn (vågräta axeln) för ljusbehandlat frö. Den streckade linjen anger samma sak för icke ljusbehandlat frö. De för varje figur utsatta procentvärdena ange den av ljusbehandlingen förorsakade ökningen av plantutbytet enligt revision utförd 45 dygn efter sådden.

De erhållna resultaten innebära att ljusbehandlingens effekt avtager ju äldre fröna bli. Beträffande särskilt vitalt frö är effekten liten eller ingen. Avvingningsskadat frö visar liten eller ingen reaktion för ljusbehandlingen. Ovarsam avvingning synes härvid verka så att samtidigt som fröna erhålla vissa skador så bryts den groningshämning varmed de förut varit behäftade. Den enligt vissa av figurerna redovisade mycket kraftiga ökningen av plantutbytet hänför sig till norrländskt tallfrö.

I övrigt hänvisas till den mer ingående redogörelse som lämnats i Norrlands Skogsvårdsförbunds Tidskrift nr. 1 år 1953.

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