Flowering and pollination in Scots pine (*Pinus silvestris* L.)

Blomning och pollinering hos tall (Pinus silvestris L.*)*

by

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CONTENTS

Introduction

In connection with crossing experiments in Scots pine, *Pinus silvestris,* carried out at the Genetics Department on a large scale since 1949, some special investigations were made in 1953 with a more limited material as to the effect of inbreeding on cone and seed setting, the quality of the seeds and the occurrence of parthenocony. Parallel testings of the cross-breeding techniques were made, such as determining the most suitable time for the isolation of the female flowers.[1]

The importance of a satisfactory solution to these latter problems is stressed by the fact that the 27 pines, selected for annual crossing experiments are growing in widely different parts of the country, ranging from 58° N. in the South of Sweden to the Arctic Circle in the North. Consequently the flowering periods of these pines differ considerably, dependent on when the spring sets in at the different localities and on the weather during the flowering period itself. There is a variation of the onset of the flowering between the individual trees in the same stand, too. For practical reasons the female flowers of the trees at one locality all have to be bagged at about the same time and the pollination has to take place in the course of a few days. Thus the stage at which the female flower buds can be isolated without risks of contamination from foreign pollen and without risks of damaging the buds by an extended isolation period has to be known as exactly as possible, as well as the earliest and latest stages of the female flowers at which the pollination is effective.

In the present paper the first part deals with the experiments made with two trees in order to find out the latest stage of the female flowers at which isolation is still safe, or—from another point of view—how early a pollination can be performed with good results as regards seeding.

In the second part some other trees were tested as to their capacity of self-fertilization and their capability of developing cones without pollination, *i.e.* parthenocony (Söderberg 1953).

[1] The term »flower» here used in its broad sense as a reproductive organ (Cumming and Righter 1948).

Material and methods

In 1933 a progeny test with Scots pine from 39 different provenances was planted at Ramningshult about 100 kilometres north of Stockholm (Langlet 1936). Many of the now 27 year old trees have reached flowering age and are regularly used for crossing experiments. This material is convenient for provenance crosses in order to study the heterosis effect in hybrid plants, and for testing individual trees of different origin as to their capability of self-fertilization.

For the present experiment 28 pines from 6 different provenances were selected as mother trees (Table 1). Two of the trees, No. 3—103 and 49—502, were used for a detailed study of the stages at which the female flowers

Table 1. Provenances used in the experiments.

No.	Provenance	Latitude	Height above see-level
3	Gyltige, Halland, Sweden..............	56° 47′	100 m
20	Hällnäs, Västerbotten, Sweden.........	64° 20′	300—400 m
39	Frederiksværk, Denmark...............	56° 2′	20 m
42	Målselv, Norway......................	69° 10′	50 »
43	Tranöy, »	69° 10′	40 »
49	Svanöy, »	61° 30′	50 »

can be isolated without risks of undue pollination before the isolation. The other 26 pines were tested as to their capability of inbreeding as well as of developing cones without pollination. The stage of the flowers, when bagged, was recorded, too, with the same purpose as in part I, *i.e.* to find out the latest safe stage for isolation, thus completing the results previously attained from our ordinary work with pine crossings (Plym Forshell 1953, Ehrenberg et al. 1955). The different developmental stages of the ovulate strobili were roughly classified as follows (Fig. 1):

0. female flower buds hardly discernible,

1. female flower buds clearly discernible, but not reaching above the vegetative bud,

2 a. female flower buds emerging above the vegetative bud but still narrow and with a pointed tip,

2 b. female flower buds clearly visible above the vegetative bud, swollen, obtuse, the bud scales still closed,

3 a. the scales of the female flower buds just opened, the red or green conelet perceivable at the top,

3 b. the top of the conelet appearing above the bud scales,

4. the conelets fully developed with cone scales extending at right angles to the axis.

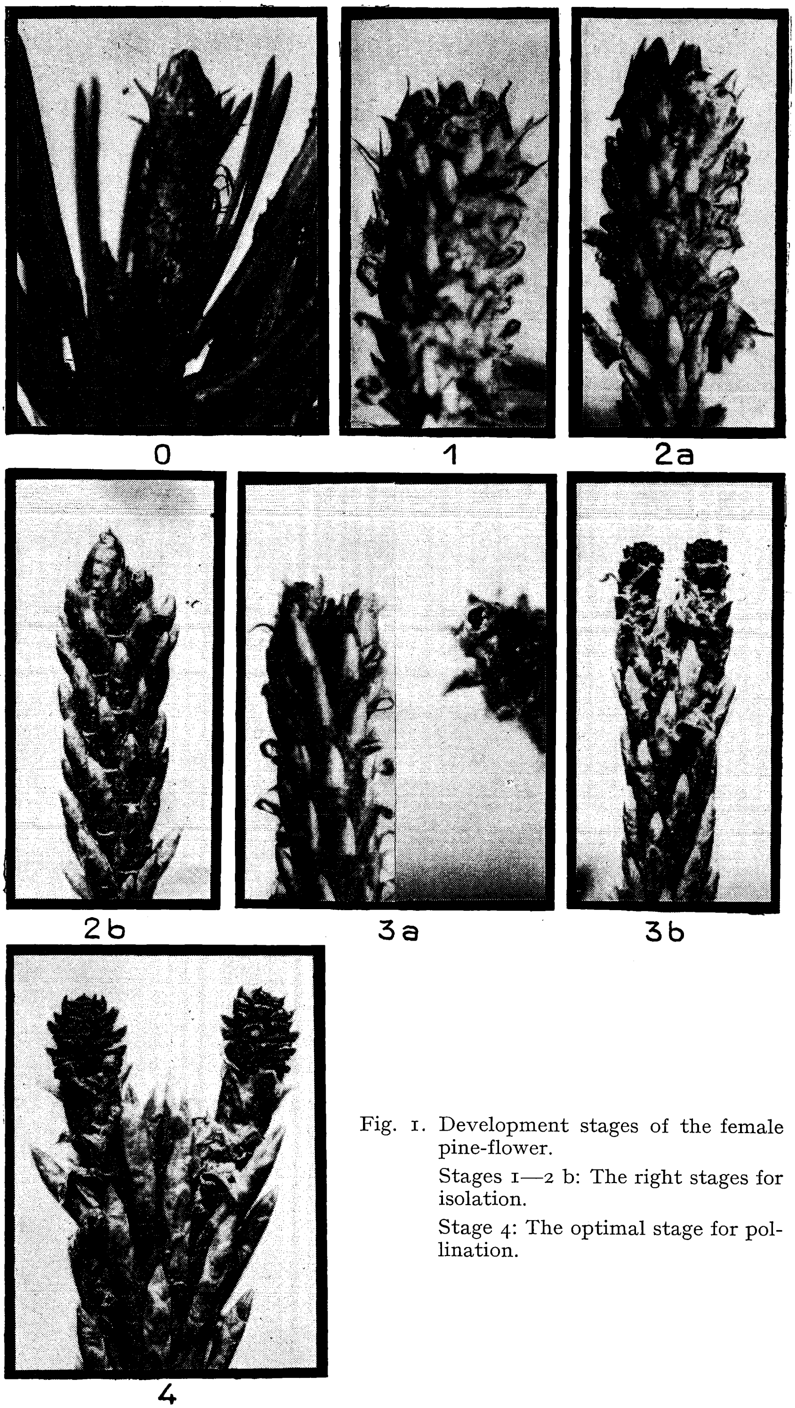

Fig. 1. Development stages of the female pine-flower.

Stages 1—2 b: The right stages for isolation.

Stage 4: The optimal stage for pollination.

The method used for the crossings, described by C. Syrach Larsen (1934) and Cumming and Righter (1948) and others is the one usually accepted in forest tree breeding work in Sweden, at present modified in certain details. The female flower buds are isolated with double parchment bags about a week before flowering time. Male flowers are collected from the trees selected as father trees, the pollen is extracted and stored in glass pipettes. When the female flowers are fully developed, the pollen is applied to them by inserting a pipette through a hole in the paper bag, and blown out on the flowers, the hole afterwards being closed with gummed paper and another parchment bag put outside the first one. A label with a number is fastened to the twig beneath each bag. About 10—14 days after the pollination the bags are removed. The following year the cones, each with its label, are collected. The bags do not seem to cause any damage to the buds or conelets, even if left on the twigs for three weeks or more (cf. Cumming and Righter 1948, Wright 1953).

The analysis of the seeds was made by the X-ray method, described by Simak and Gustafsson (1953 and 1954).

I. Isolation at different stages of the female flowers

On the two afore-mentioned Scots pines, No. 3—103 and 49—502, 115 and 122 buds were isolated, respectively. The isolations were done at different stages of the female flowers, beginning with stage 0 and continuing to stage 4 (Table 2).

At the same time as the isolation took place the flowers were pollinated. For the aim of the experiments it was of importance to secure that pollen reached the female flowers. To rely on wind pollination only was considered too unsafe in this case.

On each tree the isolated flowers were separated, according to pollination technique, in two groups, A and B. In group A the bud or conelet was pollinated, bagged, and afterwards left untouched in the bag. In the other group B the buds or flowers were pollinated and immediately after that and before the bagging the whole shoot with the female organs was dipped in water in order to wash off the pollen freshly applied and even the pollen, that might have reached the buds or flowers before the artificial pollination was performed.

A mixture of pollen from several pines growing nearby was used.

Tree No. 3—103 yielded no cones whatsoever in group A until stage 3 b, where one pollinated flower out of ten resulted in a cone with ten seeds, eight of which belonged to seed class IV, the other two being empty. The

Table 2. Pollination and isolation at different stages of the female flowers.

Tree No.	Stage	Number of		Mean cone		No. of seeds	Embryo types					Per cent full seeds	No. of seeds per cone	Per cent cones
		flowers	cones	length mm	weight g		0	I	II	III	IV			
	0	1	0	—	—	—	—	—	—	—	—	—	—	—
3—103	1	11	0	—	—	—	—	—	—	—	—	—	—	—
	2 a	10	0	—	—	—	—	—	—	—	—	—	—	—
Group	2 b	7	0	—	—	—	—	—	—	—	—	—	—	—
A	3 a	10	0	—	—	—	—	—	—	—	—	—	—	—
	3 b	10	1	36.0	4.6	10	2	—	—	—	8	80.0	10.0	10.0
	4	10	4	46.3	5.8	73	7	—	—	3	63	90.4	18.3	40.0
3—103	0	1	0	—	—	—	—	—	—	—	—	—	—	—
	1	9	0	—	—	—	—	—	—	—	—	—	—	—
Group	2 a	9	0	—	—	—	—	—	—	—	—	—	—	—
	2 b	6	0	—	—	—	—	—	—	—	—	—	—	—
B	3 a	9	0	—	—	—	—	—	—	—	—	—	—	—
	3 b	11	0	—	—	—	—	—	—	—	—	—	—	—
	4	11	3	43.0	4.7	41	6	—	—	—	35	85.4	13.7	27.3
49—502	1	9	0	—	—	—	—	—	—	—	—	—	—	—
	2 a	13	0	—	—	—	—	—	—	—	—	—	—	—
	2 b	13	2	29.0	1.6	2	—	—	—	—	2	100,0	1.0	15.4
Group	3 a	10	4	35.3	2.5	12	1	—	—	2	9	91.7	3.0	40.0
	3 b	14	9	39.0	3.6	70	7	—	—	1	62	90.0	7.8	64.3
A	4	6	6	40.0	4.1	111	11	—	—	4	96	90.1	18.5	100.0
	o.p.		9	35.1	3.4	156	17	—	—	4	135	89.1	17.3	—
49—502	0	1	0	—	—	—	—	—	—	—	—	—	—	—
	1	8	0	—	—	—	—	—	—	—	—	—	—	—
	2 a	9	0	—	—	—	—	—	—	—	—	—	—	—
Group	2 b	10	0	—	—	—	—	—	—	—	—	—	—	—
	3 a	10	2	36.5	2.5	8					8	100.0	4.0	20.0
B	3 b	12	9	39.7	3.5	109	19		10	6	74	82.6	12.1	75.0
	4	7	3	45.7	5.2	47	8		2	1	36	83.0	15.7	42.9

ten flowers, pollinated and isolated at stage 4 resulted in four cones with 18.3 seeds per cone or 73 seeds altogether. About 90 per cent of the seeds contained embryos mainly belonging to seed class IV, the rest or seven seeds were empty. The washed buds and conelets in group B, stages 0—3 b, did not develop into mature cones, but stage 4 in this group gave similar results as stage 4 of group A: eleven flowers were pollinated and 3 cones harvested, containing 41 seeds. 85.4 per cent of the seeds belonged to seed class IV, the remaining ones to seed class 0. There is a small difference, though, between the results obtained at stage 4 of the two groups. In B, the percentage of cones harvested was lower, the cones were smaller and lighter, the number of seeds per cone and the percentage of full seeds were lower, too, than in group A.

The material studied is too small to allow of any general conclusions but there seems to be a tendency to a lower cone and seed setting in group B in general, where the conelets were washed before the bagging. The same tendency is noticeable in the other tree, used in this experiment. This pine, No. 49—502, reacted in a somewhat different way to the different times of isolation. In the two groups no cones developed from the buds pollinated and isolated at stages 0—2 a, but already at stage 2 b, group A, pollen applied to the female buds must have been able to reach the pollen chambers.

From stage 3 a and onwards, 40 to 100 per cent of the pollinated flowers in this group yielded cones containing seeds of generally very good quality. In group B, on the other hand, cones resulting from flowers pollinated, washed, and bagged at stage 3 a, 3 b, and 4 were harvested, but the percentage of well developed cones was less than in group A. The seed setting was poorer and the seed quality markedly inferior, seed class II for the first time being represented among seeds from stages 3 and 4 (Table 2).

Nine open-pollinated cones collected from tree No. 49—502 contained 17.3 seeds per cone and a high percentage (89.1) of full seeds of good quality, thus resembling the cones of stage 4 from the same tree.

Conclusions

Judging from the results, isolation of female flowers for artificial crossing purposes ought to take place as early as in stage 1—2 a to be absolutely safe. As soon as the cone scales have opened and the conelets are visible at the top, pollination of the female flowers is possible (cf. Dengler 1940), and even earlier there is some risk of contamination. The two trees used here were different as regards the earliest stage that yielded cones and seeds after pollination, and probably there is a general variation in this respect in pines, mostly depending on accidental factors, but isolation is recommended latest at stage 2 b, *i.e.* when the female buds are clearly visible but the cone scales still closed (cf. Dengler 1932, 1940, Cumming and Righter 1948, Nienstadt and Kriebel 1955 as regards hemlock). Snow, Dorman and Schopmayer (1943) report bagging *P. caribæa* up to stage 3 a and consider it safe.

As mentioned above (p. 6) the artificial pollination was made to ensure pollen supply to the female organs, the essential aim of the experiment being to determine the latest safe stage for isolation. Through the washing off of the flower bearing shoots in group B we added a factor that one often has to reckon with in the practical breeding work, namely rainy weather. If the results obtained in group A and group B are compared, there seems to be a clear inferiority as regards cone and seed setting at *all* stages in group B. Naturally the freshly applied pollen is to a great extent washed away by the treatment, and, apparently, the possibilities for such vital pollen that already exists on the buds or conelets before the bagging stage to reach the pollen chambers are further diminished by the moisture. Moreover, pollen very rapidly loses its vitality when moist, or it germinates in the water outside the pollen chambers and is destroyed later on. Thus when moist and rainy weather is prevalent during the flowering period, seed setting in pine is lowered not only by the well-known fact that pollen distribution in nature is highly impeded under such circumstances (Andersson 1955) but also by the difficulties for the pollen to remain on the buds and to reach the pollen chambers. Consequently isolation of female flowers can be performed as late as at stages 2 b and 3 a in moist weather without any great risks of foreign pollination.

Well developed cones as regards cone length and cone weight were obtained only from flowers isolated at stage 4. The percentage of mature cones and the number of seeds per cone increased the more the development of the conelets reached the optimum stage 4 at the time of pollination and isolation. This is clearly demonstrated in tree No. 49—502, group A where for example the number of seeds per cone rises from 1 at stage 2 b to 18.5 at stage 4, the corresponding figure after open pollination being 17.3. The earlier the pollination and isolation of the female flowers are done, the smaller the cones and the inferior the cone and seed setting.

The percentages of *full* seeds, on the contrary, were rather constant within the different groups, ranging between 80 and 100. As regards group B of both trees there is a tendency to a lower yield of full seeds when corresponding stages are compared, than in group A, a fact which again indicates the effect of bad environmetal conditions at the time of pollination, in this case the high moisture. With very few exceptions all the seeds obtained belonged to seed class IV. Seed class II is represented in group B, tree No. 49—502, only, by 10 seeds from 2 cones at stage 3 b, and 2 seeds from 2 cones at stage 4.

Naturally pollination at stage 4 gives the best results as regards cone and seed setting, the female flower then being at its optimum receptive stage (cf. Dengler 1932, 1940, v. Wettstein 1940, Cumming and Righter 1948, a. o.). However, seeds of good quality can be obtained after pollination at earlier stages, too, but the seed yield will be smaller and a certain percentage of seeds with lower vitality will be found even in trees with otherwise fully satisfactory seed setting.

To sum up: The earlier the bagging of the female flowers is done after they are clearly visible (stage 1.), the less the risk of contamination by foreign pollen. Pollination at earlier stages than stage 4 will give seeds of good quality, but the cone and seed setting will be lowered. Washing the buds or conelets at the time of isolation seems to diminish the risk of late bagging.

II. Isolation at different stages, controls, self-fertilization and open pollination

For this part of the experiment the female flowers of 26 trees were isolated at stages 1—3 a (Table 3), male catkins were collected from 11 of the trees, the other 15 ones having only one or two catkins, which gave too small an amount of pollen for the inbreeding test. On 23 of the trees some female flowers were left without bags in order to get cones after open pollination.

Table 3. Controls. Tree numbers, number of isolated flowers and number of cones obtained.

Tree No.	No. of isolated ♀ flowers at stages 1—2b	No. of cones	No. of isolated ♀ flowers at stages 3a	No. of cones	Total no. of isolated flowers	Total no. of cones
20—814	25	—	25	—	50	—
39—601	19	—	12	—	31	—
39—604	11	—	8	—	19	—
42—808	117	—	—	—	117	—
43—221	30	—	14	—	44	—
43—401	10	—	9	—	19	—
43—403	7	—	5	—	12	—
43—502	39	3	—	—	39	3
43—504	10	—	38	—	48	—
43—508	16	2	—	—	16	2
43—509	113	—	30	—	143	—
43—518	28	1	12	—	40	1
43—615	46	—	—	—	46	—
43—621	46	—	20	—	66	—
43—804	13	—	—	—	13	—
43—806	41	1	—	—	41	1
43—810	26	—	—	—	26	—
43—813	26	—	—	—	26	—
43—819	16	—	—	—	16	—
43—861	157	—	—	—	157	—
43—862	23	—	—	—	23	—
43—864	11	—	—	—	11	—
43—866	94	—	—	—	94	—
43—870	19	—	—	—	19	—
49—507	46	—	62	3	108	3
49—515	44	—	40	2	84	2
26 trees	1 033	7	275	5	1 308	12
%		0.7		1.8		0.9

Controls

The number of controls, *i.e.* isolated but unpollinated flowers, on each tree varied, depending on the number of flowers on the different trees (Table 3). Altogether there were 1 033 controls isolated at stages 1—2 b and 275 at stages 3 a, distributed among the 26 trees. In all, twelve cones were obtained

Table 4. Controls. Cone and seed setting after bagging at different stages.

Tree No.	Isol. stages	No. of ♀ flowers	No. of cones			Per cent of deve-loped cones	Total No. of seeds	Embryo types					Per cent full seeds
			with seeds	without seeds	total			0	I	II	III	IV	
43—502	2b	39	—	3	3	7.7	—	—	—	—	—	—	—
43—508	2a	16	2	—	2	12.5	61	12	—	—	1	48	80.3
43—518	2a	28	—	1	1	3.6	—	—	—	—	—	—	—
	3a	12	—	—	—	—	—	—	—	—	—	—	—
43—806	2b	41	1	—	1	2.4	43	1	—	—	—	42	97.7
49—507	2a	46	—	—	—	—	—	—	—	—	—	—	—
	3a	62	3	—	3	4.8	26	3	—	1	—	22	88.5
49—515	2a	44	—	—	—	—	—	—	—	—	—	—	—
	3a	40	1	1	2	5.0	21	20	—	1	—	—	4.8

from six of the trees, *i.e.* 0.9 per cent of the flowers developed into cones, all the other ones having fallen off at different stages of development. Seven of the cones originated from flowers, isolated at stages 2 a—2 b (4 mother trees), the other five from flowers bagged at stage 3 a (2 mother trees). Of the former ones three cones from stage 2 b and one from stage 2 a contained no seeds at all (trees No. 43—502 and 43—518). On two other trees (No. 43—508 and 43—806) cones from the same two stages were harvested, containing both full and empty seeds. The full seeds, amounting to 87.5 per cent, were of excellent quality, 98.9 per cent of them belonging to seed class IV (Table 4).

From two trees only (No. 49—507 and 49—515) cones from flowers, isolated at stage 3 a, were collected. Of the two cones from tree No. 49—515, one contained no seeds at all. From the other one 21 seeds were extracted, 20 of which were empty and one of seed class II. The three cones from tree No. 49—507 rendered 2, 9 and 12 full seeds respectively and 3 empty ones. 95.7 per cent of the *full* seeds contained embryo and endosperm of good quality. In all, 90 flower buds were isolated at stage 2 a and 102 at stage 3 a on the two trees, but cones were only obtained from the latter stage.

Thus 0.7 per cent of the control flowers, isolated at stages 1—2 b developed into cones and still fewer or 0.3 per cent yielded some full seeds. The corresponding figures for flowers isolated at stage 3 a were 1.8 and 1.5 per cent. The agreement between these results and the ones reported in part I of this paper as regards the latest stage at which isolation is safe, is rather good. The mean percentage of cones and seeds obtained after isolation at stages 2 a—3 a was higher in the first experiment, where the pollination was secured by artificial means before the isolation, but the cone and seed yield was poor in both cases. Furthermore only 6 of the 26 pines tested in part II yielded any cones at all and only 4 of those developed cones with full seeds.

It is clear, that isolation of the female flowers of Scots pine at stages 2 a—3 a is not absolutely safe considering the risk of contamination by pollen floating in the air at that moment. The risk, however, seems to be rather a small one. Judging from this experiment it amounts to about 1 per cent, when all the trees are considered.

Self-fertilization

Eleven pines were selected as parent trees for the inbreeding test. Cones after open pollination were also collected from these trees (Table 5).

The flowers used in this experiment were all isolated at stages 1—2 b. In all, 214 flowers were bagged and later on selfed. The number of cones collected was 121, *i.e.* about 57 per cent of the flower buds developed into cones.

Regarding the cone setting there was a great variation from tree to tree, ranging from 26.7 to 100 per cent. Compared with the results after open pollination on the same trees the selfed flowers gave better or equal results on seven of the trees. In three cases the open pollination rendered a higher percentage of cones and for one tree the number of unbagged flowers was not reported. There seems to be a tendency to better cone setting after artificial pollination of bagged flowers even if the pollen applied originates from the same mother tree. However, the superiority of the bagged flowers might only be apparent in this respect, the percentage of cones developed being a rather doubtful value impaired by many errors.

With a few exceptions all the cones were well developed, the mean *cone length* from each mother tree varying between 30.8 and 42.9 mm. The variation of the cone length within a tree was less than the same variation between different trees as seen below:

Comparison between the mean cone lengths from different trees after selfing.

	Degrees of freedom	Sums of squares	Mean squares
Between trees	10	2442.93	244.293
Within trees	110	2409.43	21.9039
	120	4852.36	40.4363

$$\frac{244.293}{21.9039} = 11.1529^{***}$$

This is in accordance with the results previously attained in other experiments (cf. Plym Forshell 1953), where the cone length was found to be characteristic of the mother tree and not dependent of, for example, the

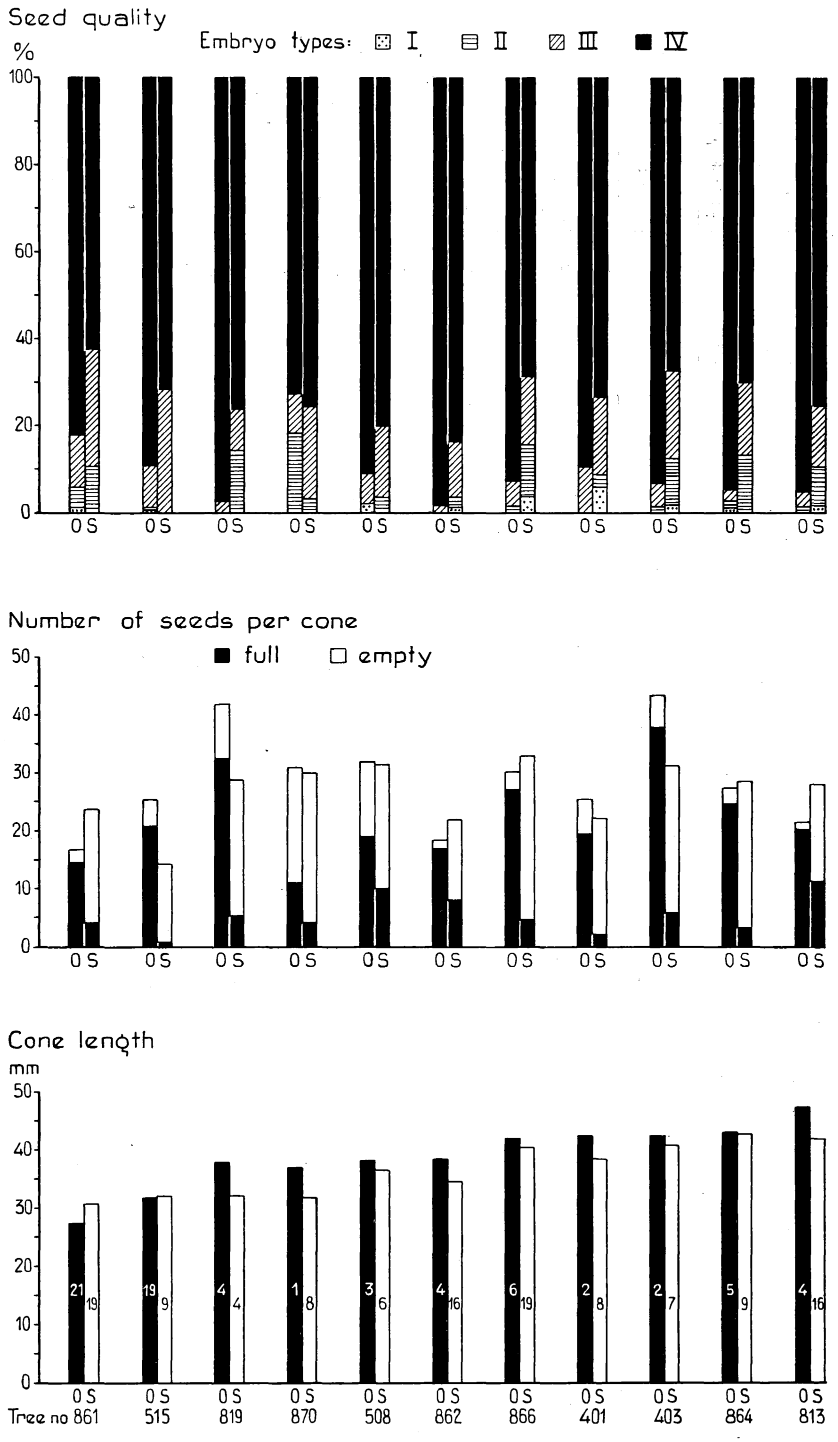

Fig. 2. Seed quality, number of seeds per cone and cone length of seeds and cones obtained after open pollination (O) and self-fertilization (S). The figures in the piles give the number of the cones analysed.

Table 5. Cone and seed yield after open

Tree No.	Type of poll.	Isol. stage	Number of flowers	Number of cones	% cones	Mean cone length	Mean cone weight	Number of total	Number of per cone
43—401	S O	1—2 a	9 —	8 2	88.9 —	38.5 42.5	3.7 5.4	179 51	22.4 25.5
43—403	S O	1—2 a	7 2	7 2	100.0 100.0	40.9 42.5	4.8 5.4	219 87	31.3 43.5
43—508	S O	2 b	15 22	6 3	40.0 13.6	36.7 38.3	5.1 5.6	189 96	31.5 32.0
43—813	S O	2 a	19 6	16 4	84.2 66.7	42.2 47.5	5.7 8.6	449 86	28.1 21.5
43—819	S O	2 a	15 5	4 4	26.7 80.0	32.3 38.0	3.4 6.6	115 167	28.8 41.8
43—861	S O	2 a	31 44	19 21	61.3 47.7	30.8 27.4	3.0 2.5	452 351	23.8 16.7
43—862	S O	2 a	23 10	16 4	69.6 40.0	34.6 38.5	3.4 5.2	352 74	22.0 18.5
43—864	S O	2 b	11 6	9 5	81.9 83.3	42.9 43.2	7.6 9.4	257 137	28.6 27.4
43—866	S O	2 a	54 26	19 6	35.2 23.1	40.5 42.0	5.6 6.1	629 181	33.1 30.2
43—870	S O	2 a	11 6	8 1	72.7 16.7	31.8 37.0	2.9 3.9	240 31	30.0 31.0
49—515	S O	2 a	19 29	9 19	47.4 65.5	32.1 31.8	3.1 3.9	129 484	14.3 25.5
Mean	S O								26.7 28.5

pollen used. The same type of variation was found in cones after open pollination.

Generally the cones after open pollination were longer than those obtained after self-fertilization from the same tree (Fig. 2). That was the case in 9 of the trees whereas in 2 trees (No. 43—861 and 49—515) it was the reverse. However, this superiority of the open pollinated cones as regards cone length is probably not in agreement with fact. The two last mentioned trees were the only ones with a relatively high number of open pollinated cones. This must

pollination (O) and self-fertilization (S).

seeds		Embryo types %					% full seeds I-IV types	No. of cones with seeds	
full	per cone	0	I	II	III	IV		full and empty	empty
34	4.2	81.0	1.1	0.5	3.4	14.0	19.0	8	—
39	19.5	23.5	—	—	7.8	68.7	76.5	2	—
58	8.3	73.5	0.5	2.3	5.9	17.8	26.5	7	—
76	38.0	12.6	—	1.1	4.6	81.7	87.4	2	—
60	10.0	68.3	—	1.1	5.3	25.3	31.7	6	—
57	19.0	40.6	1.0	—	4.2	54.2	59.4	3	—
182	11.4	59.5	0.7	3.6	5.8	30.4	40.5	16	—
81	20.2	5.8	—	1.2	3.5	89.5	94.2	4	—
21	5.2	81.7	—	2.6	1.8	13.9	18.3	4	—
130	32.5	22.2	0.6	—	1.8	75.4	77.8	4	—
77	4.1	83.0	—	1.8	4.6	10.6	17.0	19	—
310	14.8	11.7	0.6	4.3	10.8	72.6	88.3	21	—
129	8.1	63.4	0.3	1.1	4.5	30.7	36.6	15	1
68	17.0	8.1	—	—	1.4	90.5	91.9	4	—
30	3.3	88.3	—	1.6	1.9	8.2	11.7	9	—
124	24.8	9.5	0.7	1.5	4.4	83.9	90.5	5	—
89	4.7	85.9	0.5	1.7	2.2	9.7	14.1	18	1
163	27.2	9.9	—	1.1	5.5	83.5	90.1	6	—
33	4.1	86.2	—	0.5	2.9	10.4	13.8	8	—
11	11.0	64.5	—	6.5	3.2	25.8	35.5	1	—
7	0.8	94.6	—	—	1.6	3.8	5.4	4	5
397	20.9	18.0	0.2	0.2	0.8	80.8	82.0	19	—
	5.8	78.7	0.3	1.5	3.6	15.9	21.3		
	22.3	20.6	0.2	1.5	4.4	73.3	79.4		

be taken into account when comparing the results of the two groups of pollination. As soon as the number of cones from each tree in the two groups are more equal (trees No. 861 and 515) and at the same time rather high, thus giving a more precise mean value of the cone lengths, the mutual position of the mean values of the groups is reverse. Furthermore, the flowers left for wind pollination were in most cases situated on the big top shoots and on the strong uppermost side branches. To what extent the position of the cones in the crown has any influence on the size of the mature cones we don't know but there may be some correlation between cone development and the thickness and the position of the cone-bearing branches. The number of full seeds per cone may have an influence on cone development, too, in this case favouring the open pollinated group. On the other hand, the bagging may be of advantage for the flowers during the first weeks of development (cf. Plym Forshell 1953).

The *mean weight* of the cones from the different trees ran roughly parallel to the mean cone length in both groups, but the total number of seeds per cone as well as the number of full seeds per cone varied independently of cone length and cone weight (Fig. 2, Table 5). *Within* an individual tree the number of seeds per cone is usually rising with the cone size and seems to be characteristic of each mother tree (cf. Simak and Gustafsson 1954 a. o.). In the present material, however, the comparison was made between samples from *different* trees. Thus the typical variation within a tree did not appear and consequently no correlation between cone size and number of seeds per cone was found.

With a few exceptions all the cones harvested contained full seeds. The number of *full* seeds per cone (only for cones with both full and empty seeds) varied from 1.8 (tree No. 49—515) to 11.4 (No. 43—813), the percentage varying in about the same degree. The individual capability of selfing in different trees is evident and fully in accordance with the results attained in other experiments with Scots pine (cf. Dengler 1932, v. Wettstein 1940, Plym Forshell 1953).

When comparing the number of full seeds per cone as well as the percentage of full seeds obtained from each tree after selfing and after open pollination, the differences in seed yield between the two types of pollination are very pronounced. For all eleven trees taken together, the mean values after open pollination were: 22.3 full seeds per cone equivalent to 79.4 per cent. The corresponding values after self-fertilization were 5.8 and 21.3, respectively. In every tree the results attained were inferior after selfing, the greatest difference being found in tree No. 49—515. The low ability of the pines tested to inbreeding is clearly shown by these facts as well as by the results attained from the detailed seed analysis.

The quality of the seeds after selfing shows a distinct inferiority when compared with seeds after open pollination from the same trees. 15.9 per cent of the seeds belonged to seed class IV, corresponding to 73.3 per cent after open pollination. This means a poor development of seeds in about 85 per cent of the whole lot of seeds with a small variation between the different trees.

Open pollination

Twenty three trees were included in the open pollination test, eleven of which were used for inbreeding purposes as well (Table 6). Two of the trees, No. 43—509 and 43—810, did not form any cones at all. The remaining pines had a cone setting varying from 7.7 to 100 per cent. The mean percentage of cones that reached maturity was 41.5 and the mean number of seeds per cone was 26.2.

The length and weight of the open pollinated cones varied in about the same way as in the inbred material, *i.e.* the size of the cones seems to be a character mainly determined by the genetical composition of the mother tree. The variation of the number of full seeds per cone ranged from 0.5 to 38.0 and the percentage of full seeds per tree from 20.0 to 94.2, the mean values for the whole open pollinated material being 21.2 and 77.5 respectively. Only four pines had less than 75 per cent full seeds. Among these were the trees No. 43—502 and 43—504, which on the whole, like trees No. 43—509 and 43—810, did not seem to be adapted to cone and seed setting (cf. Wright 1953, p. 28, Ehrenberg et al. 1955).

The quality of the seeds was exceptionally good. About 90 per cent of the full seeds belonged to seed class IV and less than 1 per cent to seed class I.

Parthenocony

Most of the cones after self-fertilization or 114 contained both full and empty seeds. Trees No. 43—862 and 43—866 had one cone out of 16 and 19 respectively with only empty seeds. Tree No. 49—515 had no less than 5 cones out of 9 without any full seeds, *i.e.* more than 50 per cent of the cones developed to normal size in spite of the fact that no full seeds were formed. On the same tree, 82 unpollinated flowers (controls) rendered no cones whatsoever, but from two control flowers, isolated at stage 3 a and thus possibly pollinated before the isolation, 2 cones developed, containing one seed of seed class II and 20 empty ones. 39 control flowers on tree No. 43—502 and 40 on tree 43—518 formed 3 and 1 cone, respectively, without seeds. Looking at the open pollinated material (Table 6) cones developing to maturity without full seeds were rare. On two trees only, No. 43—502 and 43—504, such cones were formed. Among these, 4 contained only empty seeds and 2 no seeds at all. 29 and 12 flowers, respectively, were left for open pollination on these pines, and one cone from each tree contained full seeds.

The occurrence of parthenocony in this material is obvious. Moreover, the importance of the pollination for the further developing of the flowers into cones even without subsequent fertilization of the egg-cells is indicated by the figures. However, the material is too limited to permit any general conclusions, but judging from other experiments in Scots pine (Dengler 1940, Plym Forshell 1953, Wright 1953) and from other species, the mere fact that pollen is applied to a flower stimulates the growth and development of a fruit or a cone.

III. Discussion

The period during which the female flowers are receptive has been delimited to 9—11 days (Dengler 1940) or 6—7 days (v. Wettstein 1940). The former author points out that the flowers used in his experiments probably were receptive one or two days earlier than the first pollinations took place. Cumming and Righter (1948) consider this period to vary from 3 to 7 days for both bagged and unbagged flowers in *Pinus,* and Wright (1953) made pollinations in pine "from complete visibility of the strobili until 1 or 2 days before complete scale closing, a period of 4 of 5 days per tree".

From our own experiences with Scots pine in general we know that the length of the receptive period is very varying (Ehrenberg unpubl.). Above all, the weather prevalent at the flowering period is an influential factor, as mentioned by Cumming and Righter, and others too. If there is a heat wave the development of the flowers is accelerated and the whole process will be over in 3 to 4 days. If, on the other hand, the weather is cold, windy, and rainy or still worse, if it is snowing, which sometimes happens, the pine flowers develop slowly or stop completely, remaining at the stage achieved when they ceased to grow, for many days and even weeks. The subsequent accomplishment of the flowering process can take place in an astonishingly short time; one or two hot days will be enough for the conelets to thicken and start drooping (cf. Scamoni 1938).

The time for removing the bags has in our experiments been fixed to 10—14 days after pollination or when the pedicels have bent. The cone scales thicken before this happens but from experiments with very "late" pollination we have the experiences that it is not absolutely "safe" as regards outcrossing to expose the conelets to the possibilities of open pollination even then. Here too, the weather conditions are a predominating factor.

Unwarranted outcrossings are avoided if the bagging of the female flowers is carried out as soon as the flower buds have emerged above the vegetative bud and before the bud scales have opened up, *i.e.* the top of the red or green conelet ought not to be visible from above. In two cases (3 *control* flowers out of 1 033, Tables 3 and 4), full seeds were obtained, when the flowers had been isolated at stages 1—2 b. Either the stage reported as "bagging stage" was erroneous or the bags used were not perfect, or some pollen may have reached

Table 6. Cone and seed yield after open pollination.

Tree No.	Number of		% cones	Mean cone		Number of seeds				Embryo types %					% full seeds I—IV types	No. of cones with		
	flowers	cones		length	weight	total	per cone	full	per cone	0	I	II	III	IV		full and empty seeds	empty seeds	no seeds
42—808	—	2	—	43.5	8.4	73	36.5	65	32.5	11.0	—	1,4	4.1	83.5	89.0	2	—	—
43—221	13	1	7.7	40.0	7.0	28	28.0	23	23.0	17.9	—	—	3.6	78.5	82.1	1	—	—
43—401*	—	2	—	42.5	5.4	51	25.5	39	19.5	23.5	—	—	7.8	68.7	76.5	2	—	—
43—403*	2	2	100.0	42.5	5.4	87	43.5	76	38.0	12.6	—	1.1	4.6	81.7	87.4	2	—	—
43—502	29	4	13.8	23.8	1.6	10	2.5	2	0.5	80.0	—	—	—	20.0	20.0	1	1	2
43—504	12	4	33.3	27.0	1.8	34	8.5	12	3.0	64.7	—	8.8	5.9	20.6	35.3	1	2	1
43—508*	22	3	13.6	38.3	5.6	96	32.0	57	19.0	40.6	1.0	—	4.2	54.2	59.4	3	—	—
43—509	8	0	0.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
43—518	8	4	50.0	40.0	5.7	147	36.8	128	32.0	12.9	1.4	1.4	2.0	82.3	87.1	4	—	—
43—615	35	16	45.7	27.9	2.6	363	22.7	320	20.0	11.8	0.3	1.7	3.0	83.2	88.2	16	—	—
43—621	21	2	9.5	42.5	8.6	66	33.0	62	31.0	6.1	—	—	4.5	89.4	93.9	2	—	—
43—804	4	2	50.0	30.0	4.0	38	19.0	32	16.0	15.8	2.6	—	21.1	60.5	84.2	2	—	—
43—806	9	4	44.4	32.0	3.8	123	30.8	104	26.0	15.4	—	0.8	4.1	79.7	84.6	4	—	—
43—810	7	0	0.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
43—813*	6	4	66.7	47.5	8.6	86	21.5	81	20.2	5.8	—	1.2	3.5	89.5	94.2	4	—	—
43—819*	5	4	80.0	38.0	6.6	167	41.8	130	32.5	22.2	0.6	—	1.8	75.4	77.8	4	—	—
43—861*	44	21	47.7	27.4	2.5	351	16.7	310	14.8	11.7	0.6	4.3	10.8	72.6	88.3	21	—	—
43—862*	10	4	40.0	38.5	5.2	74	18.5	68	17.0	8.1	—	—	1.4	90.5	91.9	4	—	—
43—864*	6	5	83.3	43.2	9.4	137	27.4	124	24.8	9.5	0.7	1.5	4.4	83.9	90.5	5	—	—
43—866*	26	6	23.1	42.0	6.1	181	30.2	163	27.2	9.9	—	1.1	5.5	83.5	90.1	6	—	—
43—870*	6	1	16.7	37.0	3.9	31	31.0	11	11.0	64.5	—	6.5	3.2	25.8	35.5	1	—	—
49—507	5	4	80.0	34.2	5.1	73	18.2	65	16.2	11.0	—	2.7	—	86.3	89.0	4	—	—
49—515*	29	19	65.5	31.8	3.9	484	25.5	397	20.9	18.0	0.2	0.2	0.8	80.8	82.0	19	—	—
23		114	41.5	—	—	—	26.2	—	21.2	22.5	0.4	1.5	4.6	71.0	77.5	—	—	—

* Used in inbreeding tests as well.

the buds before the bagging took place and remained there, afterwards coming into contact with the cone scales. This apparently happens very seldom, however, and the risks of contamination after bagging at the early stages 1—2 a must be considered small, provided the technical equipment is good. Furthermore, the seed setting after pollination at stages 2 and 3 is very poor (cf. Table 2). As regards bagging at stage 3 there were, in this material, very few *control* flowers developing into cones (5 out of 275) giving a rather poor seed yield (Table 3).

Naturally the number and the vicinity of male flowers shedding pollen at the time of bagging the female flower buds are of importance and the opportunities for open pollination to occur are depending on these factors. As the experiments were carried out in a provenance testplot, pollen from some early flowering provenances was already in the air at the time of bagging and the possibilities of open pollination were at hand.

The occurrence of parthenocony has been proved for many of the pine species, but generally pollination is considered necessary for the development of cones without full seeds (Ernst 1918, Dengler 1932, 1940, v. Wettstein 1940, Langner 1951, Wright 1953). However, Wright (l. c.) reports autonom parthenocony, *i.e.* cone development without preceding pollination, to occur occasionally in *P. griffithii, P. rigida,* and *P. strobus.* Plym Forshell (1953) mentions some similar cases in *P. silvestris.* The criterion of this type of parthenocony is cone development without any seeds or seed scales whatsoever but often with fully developed seed wings. In the present material four control cones from two trees, containing neither seeds nor any seed scales, were obtained. Autonomous parthenocony may be the explanation of this phenomenon. The stimulating effect of pollination without subsequent fertilization on cone development (induced parthenocony, cf. Ernst 1918 p. 407) has not been specially studied in the present experiments, but 7 cones containing only empty seeds were found in the inbred material (Table 5) as well as 3 cones of the same kind from two trees after open pollination (Table 6), indicating the occurrence in Scots pine of this type of parthenocony, too.

To what extent genetic factors are responsible for the varying occurrence of parthenoconic cones in *P. silvestris* is impossible to tell without further studies, many accidental and unaccountable factors playing an important role during the development of the flowers and cones. The 27 pines, selected for our crossing experiments on a large scale (cf. Plym Forshell 1953), have continually, every year up to 1954, been tested as to their capacity of forming parthenoconic cones. Very few control flowers develop into cones on the whole and no regular distribution of such cones on the different trees can be traced.

In *P. silvestris* forced self-fertilization is possible to a varying degree (Dengler 1932, 1939, 1940, v. Wettstein 1940, Johnson 1945), certain trees being more fit for inbreeding than others, owing to differences in the genetic constitution (cf. Plym Forshell 1953). Usually the number of *full* seeds per cone is markedly lower after selfing than after cross pollination or open pollination, the quality of the full seeds poorer and consequently the rate of germination as well as the first year growth low. The vigour of 6 year old inbred plants is at present still inferior to that of plants of the same age originating from open pollination and cross pollination (Ehrenberg et al. 1955). Lethal and semilethal genes frequently occur in populations of conifers (Gustafsson 1952, Eiche 1955) showing their effects as selective factors on pollen and egg cells from the very start of the pollination and, later on, on the fertilization process (Stockwell 1939), continually influencing the growth of embryos and plants. In the present material cones containing full seeds after selfing of the flowers were formed on all the twelve pines included in the test, *i.e.* forced self-fertilization was successful in every tree tried. Similar results have been obtained in our experiments with other Scots pines (Plym Forshell 1953). This indicates that the capability of self-fertilization is rather a widespread phenomenon in Scots pines growing in Sweden. The signs of the deleterious effects of inbreeding on seed setting, however, are very pronounced and, to a great extent, varying from tree to tree.

Regarding the number of *full* seeds per cone, the percentage of *full* seeds, and the distribution of the seeds to the different embryo classes there is a marked inferiority in the selfed material as compared with the material obtained after open pollination. As regards cone length and cone weight the difference between the two pollination types is less pronounced, though the cones after open pollination mostly are larger and heavier. When the *total* number of seeds per cone is considered, the outbred material is less superior to the inbred one.

The variation between the different trees in respect of successful selfing is clearly shown in the present experiment. In tree No. 49—515 for example there were only 7 *full* seeds in 4 cones out of 9, *i.e.* 0.8 per cone, and the percentage of *full* seeds was 5.4, the corresponding figures for tree No. 43—813 being 11.4 and 40.5 respectively. Surely this variation in caused by genetic differences between the trees, some individuals being more suited to selfing than others.

The distribution of seeds to different embryo types after selfing is very characteristic and in full agreement with the results obtained in previous experiments. The amount of empty seeds is about 4 times higher in the inbred material than in the open pollinated material of seeds from the same trees. The explanation of this is discussed by Ehrenberg et al. (1955). As pointed out by them, self-fertilization arrests embryo development, many embryos remain in stage I, II and III and polyembryony occurs even in trees where it never is found after open pollination. As mentioned above the occurrence of lethal and semilethal genes is far from rare in populations of Scots pine and the increased homozygosis of such genes affects the development of embryos and plants.

The present experiments, carried out on the rather limited number of trees available at Ramningshult, cannot in themselves permit too far-reaching conclusions as to the genetic background of the events, but the agreement between the results obtained here and those from other inbreeding tests, is very good. In the main they confirm those results, indicating that the statements and conclusions are of general validity.

Summary

1. Detailed analysis of cone and seed yield and seed quality after self-fertilization and open pollination in Scots pine, Pinus silvestris L., were performed. The occurence of parthenocony was studied and testings of the cross-breeding technique were made.
2. The earlier the bagging of the female flower buds was done after they were clearly visiable (stage 1) the less the risk of contamination through foreign pollen.
3. The earlier the isolation and pollination of the female flowers were done, the smaller the cones and the inferior the cone and seed setting. Only pollination at the optimum stage (stage 4) rendered well developed cones and a seed yield equal to that obtained after open pollination.
4. Washing the buds and conelets at the time of bagging seemed to diminish the risks of late isolation.
5. Control flowers, i.e. isolated but unpollinated flowers, occasionally developed into cones, mostly without seeds or with only empty ones. If the isolation was made as late as stage 2b and following, cones with full seeds were obtained.
6. In every tree tested forced self-fertilization was successful. The yield of cones and seeds varied from tree to tree, indicating genetic differences as to the capability of inbreeding. The quality of the seeds obtained after selfing was inferior to that of the seeds obtained after open pollination.
7. The occurence of parthenocony was established. The stimulating effect of the pollination for the further development of the flowers into cones even without subsequent fertilization of the egg cells is indicated by the figures.
8. To what extent genetic factors are responsible for the varying occurence of parthenoconic cones in P. silvestris is discussed.

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Sammanfattning

Blomning och pollinering hos tall (Pinus silvestris L.)

Kontrollerade korsningar mellan utvalda individer av tall (*Pinus silvestris* L.) har sedan 1948 utförts av genetiska avdelningen vid Statens skogsforskningsinstitut. 27 tallar från 58:e breddgraden i Sydsverige upp till polcirkeln i norr ingår som föräldraträd i dessa korsningar, vilka omfattar kombinationer av olika talltyper inom samma bestånd (plus × plus, minus × minus, plus × minus och minus × plus) eller från skilda provenienser. Förmågan till självbefruktning hos de olika träden har undersökts, likaså deras förmåga att utbilda kottar utan föregående pollinering.

För att närmare studera förekomsten av självfertilitet och partenokoni hos tallen utfördes våren 1953 en del försök i en yngre kultur. Denna anlades 1933 med plantor från 39 olika provenienser på Ramningshults kronopark ca 10 mil norr om Stockholm (Langlet 1936). Försöksmetoderna prövades på sådana detaljer som t. ex. vid vilka stadier i honblommans utveckling isolering bör ske för undvikande av inkorsning med obehörigt pollen, vid vilka stadier pollineringen ger största utbytet av frö etc.[1]

[1] Termen »blomma» använd i vid bemärkelse för att beteckna de reproduktiva organen.

28 tallar från 6 provenienser valdes som moderträd (tab. 1). 2 av träden, nr 3—103 och 49—502, användes för detaljstudier av försöksmetoden medan de övriga 26 prövades på förmågan av inavel samt förmågan att utveckla kottar utan pollinering (partenokoni, Söderberg 1953). Honblommornas utvecklingsstadium vid isoleringen kontrollerades. De olika stadierna i honblommans utveckling klassificerades som följer:

0. honblomknoppen nätt och jämnt urskiljbar,
1. honblomknoppen tydligt synlig, spetsig, dess översta del når upp till den vegetativa knoppspetsen men ej över den,
2 a. honblomknoppen når över den vegetativa knoppspetsen, smal, spetsig,
2 b. honblomknoppen tydligt längre än den vegetativa, rundad, knoppfjäll slutna,
3 a. knoppfjäll öppna i knoppspetsen, den röda eller gröna blommans översta del något synlig,
3 b. honblomman fullt synlig ovanför knoppfjällen,
4. honblomman fullt utvecklad, kottfjäll i rät vinkel mot kottaxeln. Det optimala stadiet för pollinering.

Försöksmetodiken var i stort sett densamma som allmänt användes vid korsningsarbete med skogsträd i Sverige: isolering av honblomknopparna med dubbel pergamynpåse; etikett med nummer under varje påse; insamling av hanblommor från bestämda faderträd och extraktion av pollen från dessa; pollinering med hjälp av pipett med pollen, vilket sprutas in genom ett hål i påsen, varefter hålet klistras igen och ytterligare en påse sättes ovanpå den första. Avtagning av påsarna 10—12 dagar efter pollineringen. Insamling av kottarna följande år, varje kotte med tillhörande etikett.

Fröna analyserades med hjälp av röntgenmetoden, beskriven av Simak och Gustafsson (1953 och 1954).

I. Pollinering och isolering vid olika stadier hos honblomman

På träd nr 3—103 och 49—502 isolerades 115 respektive 122 blomknoppar i olika utvecklingsstadier från 0 till 4 (tab. 2). Omedelbart före isoleringen utfördes pollinering för att säkra tillförsel av pollen till varje knopp. Honblommorna indelades i två grupper, A och B. Grupp A: blommorna pollinerades och isolerades omedelbart därefter. Grupp B: blommorna pollinerades, kvisten med de pollinerade blommorna doppades i vatten i avsikt att skölja bort det pollen, som artificiellt placerats där eller förts dit med vinden, varefter påsar bands över.

En blandning av pollen från närstående träd användes vid pollineringen.

De båda träden gav likartade resultat vad beträffar kott- och fröutbyte samt fröets kvalitet efter pollinering i olika stadier. Inga kottar utvecklades från blomknoppar pollinerade och isolerade i stadierna 1—2 a. Pollinering i stadium 2 b resulterade i matade kottar på träd 49—502 men antalet frö per kotte var lågt och frökvaliteten dålig. Från samma träd skördades kott även efter pollinering i stadium 3 a medan båda träden gav kott och frö efter stadierna 3 b—4. Endast utbytet av kott och frö efter pollinering i stadium 4 var i paritet med det, som erhölls efter fri avblomning på samma träd.

Intressant är den skillnad, som framträdde mellan grupperna A och B inom båda träden vad beträffar kott- och fröutbytet samt frökvaliteten. En allmän tendens till lägre utbyte och till sämre kvalitet var märkbar i grupp B, där blommorna doppats i vatten efter pollineringen.

Att döma av här erhållna resultat bör honblommorna isoleras redan i stadierna 1—2 b för undvikande av inkorsning med obehörigt pollen. Så snart knoppfjällen öppnat sig och honblommornas översta del blivit synlig, är pollinering möjlig.

Som ovan nämnts utfördes den artificiella pollineringen för att säkra tillförsel av pollen till blommorna. Det var viktigt för försökets ändamål att pollinering verkligen skedde. Genom att före isoleringen skölja blommorna i vatten infördes en faktor, som man ofta måste räkna med i det praktiska korsningsarbetet, nämligen nederbörd under blomningstiden. Jämför man resultaten, som erhållits i de båda grupperna, är utbytet över lag sämre i grupp B. Det artificiellt anbragta pollenet tvättas antagligen till största delen bort men dessutom tycks möjligheterna för det pollen, som redan förut tillförts honblommorna, att nå pollenkamrarna bli mindre. Pollenet förlorar snabbt sin vitalitet i fuktighet eller börjar gro, innan det nått in till pollenkammaren och förstörs sedan. Fuktig väderlek hindrar alltså inte bara själva pollenspridningen, vilket är ett känt faktum, utan minskar också tillfällena till befruktning av redan förefintligt pollen.

Välutvecklade kottar erhölls endast från blommor, pollinerade och isolerade i stadium 4. Ju tidigare pollineringen och isoleringen ägde rum, desto sämre blev kott- och frösättningen och desto mindre kottarna.

Procenten matat frö varierade mellan 80 och 100 inom båda grupperna. Inom grupp B var procenten matat frö något lägre än i motsvarande stadier i grupp A, vilket tyder på att behandlingen med vatten — jämförbar med regnig väderlek — haft en försämrande effekt på fröutbytet. Isolering av honblommorna torde vid sådan väderlek kunna ske även något senare än i stadium 2 b.

Med få undantag tillhörde de erhållna fröna embryoklass IV. Naturligt nog gav pollinering i stadium 4 de bästa resultaten, men fullgott frö erhölls även efter pollinering vid tidigare stadier (3 a och 3 b). Fröutbytet och i någon mån frökvaliteten blev dock sämre i detta fall.

II. Isolering vid olika stadier, kontroller, självfertilitet och fri avblomning

På 26 träd isolerades honblommorna i stadierna 1—3 a (tab. 3). Pollen samlades från 11 av träden. På 23 av träden lämnades även honblommor att fritt avblomma.

Kontroller

Antalet kontroller, d. v. s. isolerade men ej pollinerade blommor, uppgick till 1 033, isolerade i stadierna 1—2 b, och 275 i stadierna 3 a—3 b, fördelade med varierande antal på de olika moderträden. Sammanlagt 12 kottar skördades från 6 av träden, en kottsättning på 0,9 %. 7 av kottarna utvecklades från blommor, isolerade i stadierna 2 a—2 b (4 moderträd), de övriga 5 från blommor i stadiet 3 a. 0,7 % av kontrollblommorna, isolerade i stadierna 1—2 b, utvecklade kottar men endast 0,3 % utvecklade kottar med matat frö. Motsvarande värden för de blommor, som isolerats i stadium 3 a, var 1,8 respektive 1,5 %. Risk för inkorsning föreligger, även om isoleringen sker vid stadium 2 a, men är ytterligt reducerad, i detta fall uppgår den till ung. 1 % i hela materialet.

Inavel och fri avblomning

Elva träd analyserades med hänsyn till förmågan av självbefruktning. Av dessa skördades även kott efter fri avblomning som jämförelsematerial.

Samtliga blommor eller 214 isolerades i stadierna 1—2 b och pollinerades i stadium 4. Antalet skördade kottar var 121, d. v. s. ca 57 % av blommorna utvecklade kottar.

Kottsättningen varierade från träd till träd, från 26,7 till 100 %. Kottarna var med få undantag väl utvecklade. Variationen i kottlängd inom ett träd var mindre än samma variation mellan träden. Detta är i överensstämmelse med de resultat, som erhållits i andra undersökningar med tall, där kottlängden visat sig vara karakteristisk för moderträdet och ej beroende av t. ex. det pollen, som använts. Samma variation förekom hos kottar efter fri avblomning.

Kottar efter fri avblomning var vanligen längre än inavelskottarna från samma träd. Denna överlägsenhet i kottlängd hos det fritt avblommade materialet är förmodligen endast skenbar, då värdena i detta försök baserar sig på ett relativt litet antal kottar från varje träd. Dessutom lämnades i de flesta fall toppskottets och de översta kraftiga sidogrenarnas honblommor oisolerade. I vad mån den kottbärande grenens belägenhet i kronan inverkar på kottarnas tillväxt kan inte sägas med bestämdhet, men det är möjligt, att en korrelation mellan dessa två faktorer existerar. Antalet matade frö per kotte inverkar möjligen också på kottutvecklingen.

Kottarnas medelvikt varierade parallellt med medelvärdena för kottlängden i båda pollineringsgrupperna, men det totala antalet frö per kotte liksom antalet matade frö per kott varierade oberoende av kottlängd och kottvikt. *Inom* ett träd ökar vanligen kottstorleken med ökat antal frö per kotte, och är antagligen karakteristisk för varje moderträd. I föreliggande material gjordes emellertid jämförelse mellan olika träd, varför den typiska variationen inom träden täckts av mellanträdsvariationen.

Matat frö erhölls från så gott som samtliga inavelskottar. Antalet matade frön per kotte varierade från 1,8 till 11,4 och procenten matat frö i samma utsträckning. Inavelsförmågan hos de enskilda träden i detta försök synes vara mycket varierande.

Skillnaderna i fröutbytet mellan de två grupperna självpollinering och fri avblomning var markanta beträffande antalet matade frön per kotte och procenten matat frö. Hos samtliga träd var resultatet sämst efter inavel, där medelvärdena var 5,8 frön per kotte respektive 21,3 % matat frö. Motsvarande värden efter fri avblomning var 22,3 respektive 79,4.

Totalantalet frö, som skördades efter inavel, uppgick till 3 210. 21,3 % innehöll endosperm och embryo eller enbart endosperm. Kvaliteten hos detta frö var underlägsen kvaliteten hos motsvarande frö efter fri avblomning.

Av de 23 träd, som undersöktes på kottsättning efter fri avblomning, gav 2 träd ingen kott alls. Hos de övriga var utbytet av kott i genomsnitt 41,5 % och medeltalet frö per kotte 26,2.

Medelvärdena för kottlängd och kottvikt varierade på samma sätt som vid inavel. Antalet matade frön per kotte låg mellan 0,5 och 38,0 och procenten matat frö mellan 20,0 och 94,2. Endast 4 av träden hade mindre än 75 % matat frö. Bland dessa var träd nr 43—502 och träd nr 43—504, vilka liksom tall nr 43—509 och 43—810 överhuvudtaget hade dålig kottsättning.

Kvaliteten på fröna var god med omkring 90 % i embryoklass IV och mindre än 1 % i klass I.

Partenokoni

7 kottar av de 121, som erhölls efter inavel, innehöll endast tomma frön. Antalet kontrollkottar helt utan frö uppgick till 5 av 12 skördade. I materialet efter fri avblomning (114 kottar) var kottar utan matat frö sällsynta. Endast från 2 träd erhölls dylika antingen med enbart tomma frön (4 st.) eller helt utan frö (2 st.). Procentuellt sett erhölls fler kottar från pollinerade än opollinerade blommor, d. v. s. närvaron av pollen stimulerade kottutvecklingen även om icke befruktning skedde. I vilken grad variationen i förekomsten av partenokona kottar är ärftligt betingad är omöjligt fastställa utan vidare undersökningar. Hos de ovannämnda 27 tallar (s. 1), som utvalts för korsningsförsök i stor skala, har hittills ingen lagbundenhet i fråga om förekomsten av partenokoni kunnat konstateras.