(Contribution from the Hørsholm Arboretum, Denmark)

Controlled Pollinations in Fagus

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Introduction

Since the issue of the latest paper on controlled pollination in Fagus (NIELSEN and SCHAFFALITZKY, 1954) further experiments have been carried out in this field of research at the Hørsholm Arboretum. The present article deals with some of the results — mainly from experiments in 1953, 1954 and 1956. After the cold and wet summer of 1954, we had a complete off-year for beech in 1955.

Technique of Artificial Pollination of Isolated Flowers

Our technique of artificial pollination by bagging was described in the paper from 1954, and no important changes have been made. However, a few improvements may be mentioned.

We now always use the hecto-spray (SYRACH LARSEN, 1956) for injection of pollen. In 1956 we adopted the method of cutting the downward edge of the outer bag. It is an advantage, because both bags may be fastened simultaneously and removal of the outer bag at pollination becomes unnecessary, thus saving much time.

Table 1. — Harvest of beech nuts from "control bags", in which the twigs were emasculated, but no viable pollen injected

Poll. no./year	Mother tree	Date of isolation	Nuts collected		
			fertile	barren	
78153	Fagus sylv. no. 29	May 1	—	45	
80/53	„ 30	April 30	1*)	25	
81/53	„ 30	May 1	3*)	73	
82—83/53	„ 30	April 28	—	78	injection of dead pollen.
84153	„ 30	April 28	—	74	a small hole pricked in each bag on the day of pollination
101153	„ „ 15	April 29	—	37	
217/54	„ 19	May 4	—	63	injection of dead pollen.
220/54	„ „ 2	May 4	—	20	
221a/54	„ „ 20	May 6	—	14	
221b/54	„ „ 20	May 6	—	16	— „ —
223/54	„ „ 21	May 6	—	12	
224/54	„ „ 9	May 6	—	16	
225/54	„ „ 1	May 7	—	14	
227/54	„ „ 1	May 7	—	12	— „ —
231/54	„ „ 31	May 7	—	2	
300/56	„ „ 21	May 14	—	ca. 130	
305/56	„ „ 30	May 13	2	„ 120	
311/56	„ „ 19	May 11	—	„ 110	
314/56	„ „ 32	May 15	1	„ 60	
315/56	„ „ 23	May 17	—	„ 130	
324/56	„ „ 32	May 15	—	„ 40	
			7	ca. 1091	

*) No. 30 and a few other trees had just begun to shed pollen already on the 29th of April.

In table 1 a view is given of the reliability of our isolation work and in part of the pollination methods.

Our isolation technique is practically completely safe, as there is less than one percent fertile nuts in the "control bags" (table *1)*, the 4 fertile nuts in 1953 may be explained by too late isolation, and the controlled pollinations made on April 30 and May 1 1953 consequently were cancelled. In 1956 we have no explanation of the 3 fertile nuts, as isolation was made early. Perhaps male flowers were forgotten in the bags, however there are other possible sources of error.

In a few cases we have blown into the "control bags" dead pollen in order to see if in this way we were conveying small unwanted lots of viable pollen. There is a slight possibility that by unlucky chance such extraneous pollen could be mixed with other pollen in the laboratory if for instance great care is not taken to avoid mixture. The possibility of pollen from the air entering the bag when the hole was pricked was also investigated. According to table 1 neither of these possibilities seem to be significant, but small scale experiments in 1956 with beech pollen stored from 1952 and 1954 indicate that occasionally extraneous pollen may find its way into the bags (table *2)*. It is difficult to state at which phase of the work such extraneous pollen may be admixed. The possibility cannot be excluded that a small amount of the stored pollen was really still viable, but it is not probable. Further experiments on storage of pollen are desirable.

Table 2. — Experiments, 1956, with pollen stored for 2 and 4 years at 4^0 *C* under dark and dry conditions

no.	Mother tree	Pollen from	Nuts collected	
			fertile	barren
301	Fagus sylv. no. 21	F. sylv. no. 33,1954	2	308
321	„ „ 23	„ 23,1954	9	144
322	„ , 23	„ , 3415		108
	„ 23	F. orient., 1,1952		109
			19	669

Artificial pollination is difficult to carry out in Fagus, but we should like to stress that the control measures are very effective, because the big seeds give quick and early results. We never sow the seeds from "control bags" but crosscut them immediately after the harvest.

It was often suggested that we inject a needlessly large amount of pollen into the bags, because it is necessary to blow in a visible pollen cloud in order to make sure that the blower is really working.

In 1954 we therefore for the first time mixed our pollen with the same quantity of Lycopodium spores.

We obtained good results with this 1:1 mixture. In one case we even used a 1:20 mixture. The result was promising, but the material very scanty.

In 1956 we therefore tried out different mixtures, and the results are seen in table 3.

It is evident that in general we obtained better fertilization when not too many Lycopodium spores were mixed in. Consequently it is important to use as much pollen as

Table 3. — Pollination experiments, 1956. Fertilization results when beech pollen was mixed with *Lycopodium* spores in various proportions

Poll. no.	Mother tree	Father tree	Pollen mixture *Fagus/Lyc.*	Number of bags	Beech nuts		
					fertile	barren	% fertile
306	*F. sylv.* no. 30	*F. orient.* no. 3	1 : 1	35	320	180	64
307	— „ — „ —	— „ — „ —	1 : 5	47	296	371	44
308	— „ — „ —	— „ — „ —	1 : 10	34	285	316	47
309	— „ — „ —	— „ — „ —	1 : 20	43	117	382	23
310	— „ — „ —	— „ — „ —	1 : 50	24	57	240	19

possible in pollination experiments in order to hit many stigmas, and some poor results may be caused by the use of too small lots of pollen.

On the other hand mixtures 1:5 and 1:10 render identical and not extremely poor results; the same may be said of mixtures 1:20 and 1:50. When different mixtures thus gave similar results the reason probably is that the various people carrying out the pollination have not all been equally careful. The experiment thus shows that it will be advantageous to mix small quantities of precious pollen with lots of *Lycopodium* spores.

Self-Pollination

On the basis of several experiments from 1949 to 1952 NIELSEN and SCHAFFALITZKY (1954) concluded that *Fagus sylvatica* shows a rather high degree of self-sterility; however individual trees may be fairly self-fertile. On the other hand the degree of self-fertility may vary in different years.

These observations have been further supported by our results in 1953, 1954 and 1956 (cf. *tables 4 and 5*).

Table 4. — Results from self pollination experiments in the years 1953, 1954 and 1956. Observe the generally low fertilization percentages

Year	Mother tree	Nuts collected		
		fertile	barren	% fertile
1953	*Fagus sylv.* no. 15	55	255	18
„	„ „ 1	5	13	(28)
„	„ „ 30	9	52	15
1954	„ „ 19	63	283*)	18
„	„ „ 2	3	107*)	3
„	„ „ 20	14	260	5
„	„ „ 30	20	156	11
„	„ „ 21	13	211*)	6
„	„ „ 9	12	192	6
„	„ „ 1	36	238	13
1956	„ „ 35	8	78	9
„	„ „ 36	1	ca. 180	1
„	„ „ 37	0	16	(0)
„	„ „ 31	0	122	0
„	„ „ 21	5	289	2

*): A few barren nuts had fallen off before collecting but not enough to change the results significantly.
( ): Scanty material.

Table 5. — Results from self pollination experiments on the same trees in different years: —
Tree no. 15 and no. 1 seem rather self fertile. Some trees show great variation in different years (no. 15, 19 and 9); others may be fairly constant (no. 30, 2 and 20)

Mother tree	% fertile nuts in year							
	1948	1949	1950	1951	1952	1953	1954	1956
Fagus sylv. no. 15				40		18		
— „ — no. 1	26		19			28	13	
— „ — no. 30						15	11	
— „ — no. 19					7		18	
— „ — no. 2	2						3	
— „ — no. 20					1		5	
— „ — no. 21					0		6	2
— „ — no. 9		1	10		4		6	

Species Crossings

With our usual pollination technique (confer p. 116) a number of species crossings have been carried out. The results are seen in *table 6*, which also gives a few figures from open pollination of single specimens of introduced species surrounded by *Fagus sylvatica*. In the latter cases there may be a slight possibility of self-pollination.

It is in accordance with the results from 1948—1952 (NIELSEN and SCHAFFALITZKY, l. c.) that fertilization has generally been good when the cross between *Fagus sylvatica* L. and *Fagus orientalis* LIPSKY was repeated.

Even though before 1953 a few fertile nuts were actually obtained after crossing *Fagus grandifolia* EHRH. with *Fagus sylvatica* L. we had not been able to raise any plants from

Table 6. — Results in fertile and barren nuts from species crossings in 1953—1956

Poll. no. / year	Sow. no. / year	Mother tree	Father tree	Nuts collected	
				fertile	barren
88/53	2514/54	*F. sylv.* no. 30	*F orient.* no. 8	28	18
82/53	—	— „ — no. 30	*F. grand.* no. 1	0	22
83/53	—	— „ — no. 30	— „ — no. 1	0	56
205/54	2722/55	— „ — no. 19	— „ — no. 2	52	3
227/54	—	— „ — no. 1	— „ — no. 2	0	12
233/54	—	*F. grand.* no. 3	*F. sylv.* no. 43	0	24
224b/54	2743/55	*F. sylv.* no. 9	*F. Sieb.* no. 1	9	5
232a/54	—	*F. Sieb.* no. 1	*F. sylv.* open poll.	0	2
232b/54	2746/55	— „ — no. 1	— „ — — „ —	6	16
332c/54	2742/55	— „ — no. 1	— „ — — „ —	3	3
300/56	3171/57	*F. sylv.* no. 21	*F. orient.* no. 8	524	906
313/56	3184/57	— „ — no. 19	— „ — no. 1	569	394
304/56	3175/57	— „ — no. 42	*F. Sieb.* no. 1	192	305
328/56	3177/57	*F. Sieb.* no. 1	*F. sylv.* no. 21	8	30
312/56	3183/57	*F. sylv.* no. 19	*F. grand.* no. 4	90	187
324/56	3193/57	— „ — no. 32	— „ — no. 5	67	126
330/56	—	*F. grand.* no. 3	*F. sylv.* open poll.	0	16

these nuts. However in 1955 we succeeded in raising 23, and in 1957, 27 hybrids of this cross (poll. no. 205/54 and 312/56). In both these plant lots we observed that the size of the cotyledons was small like those of *Fagus grandifolia* (Seed Manual, 1950), much smaller than in seedlings of *Fagus sylvatica*. This is demonstrated in *fig. 1* and *table 7*.

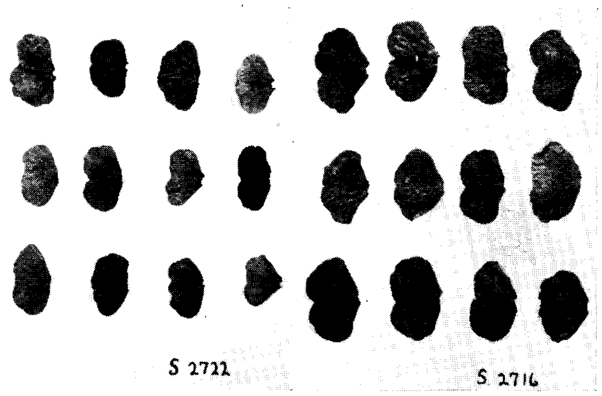

Fig. 1. — *Left:* Cotyledons of sow. no. 2722 *Fagus sylvatica* no. 19 ♀ × *Fagus grandifolia* no. 2 ♂. — *Right:* Cotyledons of sow. no. 2716 *Fagus sylvatica* no. 19 ♀ × *Fagus sylvatica* ♂ open pollination.

a case of real heterosis or simply intermediate vigour in the hybrid *(table 8)*.

Table 6 further shows that we have been able to cross *Fagus Sieboldii* ENDL. and *Fagus sylvatica* L. Four one year old hybrids between these two species exist in the Arboretum (poll. no. 324/56). The number of plants seems very small when compared to the number of fertile seeds. This is due to poor germination. However, there is no reason to believe that poor germination is a general character of this particular hybrid for, in 1957, seed of pure *Fagus sylvatica* also failed to germinate well.

Experiments with Artificial Pollination without Isolation and without Removal of Male Catkins

Isolation and emasculation of beech are both difficult and expensive considering the rather few nuts per bag. We have therefore tried to find a more simple method. A technique has been selected, which will be described below as *"the copper beech control method"*.

The basis of the method is that when a certain copper beech is crossed with a normal green beech some green and some copper beeches will be found in the progeny.

Table 7. — Measurement of leaf size in seedlings of the cross between *Fagus sylvatica* ♀ and *Fagus grandifolia* ♂ compared to seedlings after open pollination of the *Fagus sylvatica* mother tree

no. / year	♀	♂	Cotyledons		Treatment of material
			lenght mm	width mm	
S. 2722/55	*F. sylv.* no. 19	*F. grand.* no. 2	27.7±0.7	15.2±0.3	Average of 16 random cotyledons
S. 2716/55	*F. sylv.* no. 19	*F. sylv.* open poll.	36.1±0.6	19.8±0.3	—„— —„— —„—
S. 3183/57	*F. sylv.* no. 19	*F. grand.* no. 4	27.6±0.4	16.5±0.3	—„— 28 —„—
S. 3185/57	*F. sylv.* no. 19	*F. sylv.* open poll.	36.5±0.5	20.1±0.4	—„— —„— —„—

In 1956 the leaf form of the oldest of the two hybrid lots was compared to that of the progeny from the *Fagus sylvatica* mother tree and to that of six year old seedlings of *Fagus grandifolia* in the Arboretum. Unfortunately we had no seedlings of the father tree itself. In 5 leaves from all 23 hybrid plants and from 23 random plants of both parent species, pairs of nerves were counted. In the same 5 leaves ratios, between length and width were calculated. It appears from *table 8* and *fig. 2*, that the leaf form and the number of nerves of the hybrid are intermediate as to the parent species.

The height growth of the hybrid was compared to that of the progeny after open pollination of the *Fagus sylvatica* mother tree. A tendency towards greater juvenile vigour appeared in the hybrids in 1956, and was even stronger in 1957. However, as the material is limited and progeny after open pollination from the *Fagus grandifolia* father tree is lacking, we can not make out if it is

Now when the stigmas of a selected green beech are judged to be just receptive and before much pollen dispersal has begun, hand-pollination is done without bags, and with pollen from a selected tree and on the same day with pollen from a copper beech. Furthermore, the green mother tree is pollinated with the copper beech pollen by our usual bagging-technique.

This procedure gives information on the exact segregation of green and copper plants in the progeny from the crossing of green × copper. From segregation in the offspring after green × copper, without bags, we can now test how well this method has worked. If, for instance, the segregation is the same as with bagging the method is 100 percent good. In this way it is possible to test the purity of a progeny. Finally we calculate that the progeny after crossing of green × green is of the same purity.

The viability of the green father tree pollen should be tested in a few bags.

Table 8. — Leaf form of the 23 hybrids between *Fagus sylvatica* ♀ and *Fagus grandifolia* ♂ compared to that of 23 random plants of the parent species, Height growth comparison only between the hybrid and pure *Fagus sylvatica*

Sow. no. / year	Progeny	Number of lateral pairs of veins	Ratio between length and width of leaves	Height cm	
				1956	1957
S. 2716/55	*F. sylv.* no. 19 ♀ open poll.	8.02±0.06	1.56±0.02	35.3±1.4	52.9±2.1
S. 2722/55	—„— „— ♀ × *F. grand.* no. 2	9.17±0.31	1.75±0.02	39.0±1.8	66.7±4.2
—	*F. grand.* random seedlings	12.49±0.14	2.30±0.03	—	—

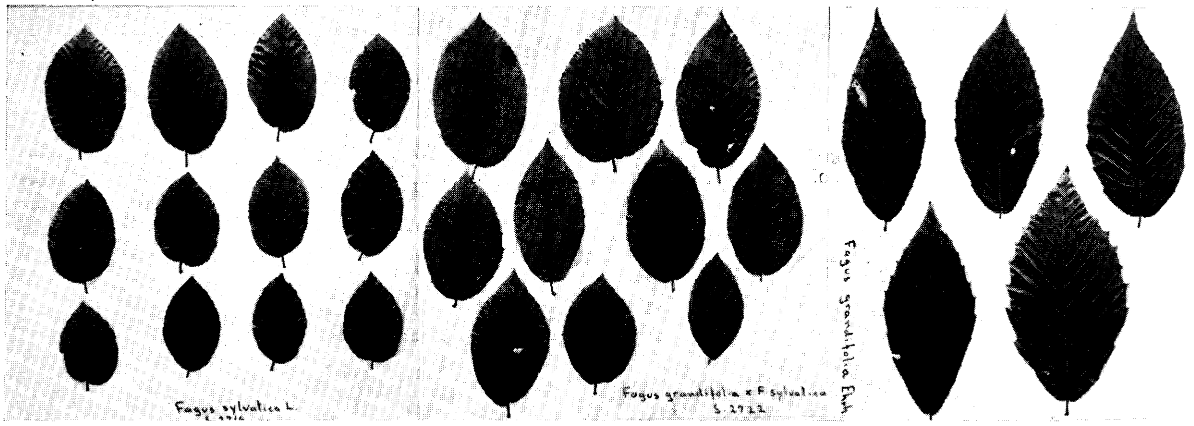

Fig. 2. — Comparison of leaf form of *Fagus sylvatica* ♀ × *Fagus grandifolia* ♂ with the parent species. — *Left:* Sow. no. 2716 *Fagus sylvatica* no. 19 ♀ × *Fagus sylvatica* ♂ open pollination. — *Centre:* Sow. no. 2722 *Fagus sylvatica* no. 19 ♀ × *Fagus grandifolia* no. 2 ♂. — *Right:* Random seedlings of *Fagus grandifolia.*

Table 9. — Survey of segregation of green- and copper-plants originating from artificial crossings between green and copper beeches — normal bagging technique

Experiment year	Sow. no.	*Fagus sylv.* Mother tree	*Fagus sylv.* Father tree	Plants			
				number			% copper
				total	green	copper	
1952	2362	no. 23, copper	no. 9, green	76	43	33	43
1952	2357	no. 9, green	no. 23, copper	61	32	29	48
1953	2511	no. 30, green	no. 38, copper	176	75	101*)	57
1953	2512	no. 30, green	no. 23, copper	18	9	9*)	50

*) Including a few plants with green and copper leaves.

In order to be well in advance of the time of maximum pollen dispersal rather early flowering and protogyn mother trees should be used.

In *table 9* a survey is given of the results by crossings green × copper using normal bagging technique. It is striking how close the segregation percents are to 50. We have also observed the segregation after open pollination from some of the copper beeches, which have been pollinated almost exclusively by green trees in the neighbourhood. Self-pollination will hardly play any rôle and we always used copper beeches which were more or less surrounded by green trees and never close to other flowering copper beeches. *Table 10* shows that also in these tests the segregation ratio is never far from 1:1.

Admitting that "the copper beech control method" involves a number of minor sources of error, we have in our experiments roughly calculated that green × copper generally renders a 1:1 segregation. Consequently the purity of the progeny after green × copper without bagging — and hence of the crossing green × green — is calculated in the following way: The number of copper plants in the progeny is multiplied by 2, which gives the approximate number of plants with "copper father"; consequently the others originate after open pollination from green trees in the neighbourhood.

Table 10. — Survey of segregation of green and copper plants in progenies originating after open pollination of copper beeches. It is believed that the fathers were all green beeches

Experiment year	Sow. no.	*Fagus sylv.* Mother tree	Plants			
			number			% copper
			total	green	copper	
1952	2363	no. 23, copper	174	88	86	49
1953	2540	no. 38, copper	41	25	16	39
1953	2523, 24, 31	no. 39, copper	290	155	135	47
1954	2759	no. 39, copper	900	430	470	52
1956	3248	no. 39, copper	200	101	99	50
1956	3243	no. 24, copper	37	18	19	51
1956	3252	no. 40, copper	287	142	145	51

The results from the experiments are seen in *table 11.* We have produced plant lots, the purity of which is about 57, 26, 17 and 44%. This is fairly satisfactory, although still better results may be gained, for instance by using more isolated mother trees. In one case we only obtained 9 percent, a probable explanation of the two poorest results, 0 and 3%, is given in *table 11.*

In 1952 the pollen was conveyed to the stigmas by a hair-pencil, but in the following years by blowing a small pollen cloud directly on the stigmas. Experiments in 1952 had shown that merely blowing the pollen cloud away over the female flowers was insufficient; at any rate this method requires much more pollen than is generally at our disposal.

In 1954 an experiment was made on a fairly large scale to obtain progenies from some of our selected beeches. We succeeded in getting much greater quantities of nuts than by our bagging methods, but germination — probably due to bad storage — was too poor to obtain the expected big progenies. However, this was not due to a defect in the "copper beech control method", and the experiment may be repeated.

Finally we draw attention to the fact that similar methods may be used within other tree species, where special and easily identifiable marker genes exist. Here it should be remembered that Langner (1953) has used aureaforms in *Picea Abies* as a means of establishing fertilization relationships in a forest stand. In studies of contamination of seed crops similar methods with tracer pollen from red varieties have been used (f. inst. Bateman, 1947).

Table 11. — Survey of experiments with early artificial pollination without isolation

Experiment year	Sow. no.	Mother tree green beech	Pollen from copper beech	Plants					Remarks
				number				%	
				total	green	cop-per	with cop-per father	with cop-per father	
1952	2358	no. 9	no. 23	88	63	25	50	57	Careful pollination of each stigma.
1952	2359	no. 9	no. 23	43	43	0	0	0	Pollen clouds blown away over the female flowers. The stigmas were not sought out separately.
1953	2502—3	no. 18	no. 38	129	112	17	34	26	Careful pollination of each stigma.
1953	2505—7	no. 29	no. 38	482	440	42	84	17	do.
1953	2513	no. 30	no. 38	65	62	3	6	9	do.
1954	2668b	no. 41	no. 23	55	43	12	24	44	do.
1954	2689	no. 16	no. 23	59	58	1	2	3	do. Pollination too late as no. 16 and other trees were at their climax of pollen dispersal.

The fact that we seem to get a 1:1 segregation when copper beech is crossed with green beech indicates a case of monofactorial segregation. We believe that our copper beech material were heterozygotes mutation with the formula *Cg*.

The gene for copper *(C)* seems dominant over the gene for green *(g)*. The homozygotic copper beech *(CC)* may not exist, as it must necessarily originate by self-pollination of a single copper beech or by crossing two. Consequently nearly all existing copper beeches may be given the same formula *Cg*.

Open Pollination Studies

Many of the pollination experiments were carried out in the Deer Park of Jaegersborg State Forest District. In the Deer Park the old scattered beeches are mostly very broad trees with large crowns, of which from short ladders or the roof of a car it was possible to reach the lowest branches.

In 1953, 1954 and 1956 we assessed the fertilization percentages of 31 of these beeches after open pollination. This was done by cross-cutting samples of 100 beech nuts — the number of fertile nuts thus directly giving the fertilization percent. In 1953 the samples were numbered and their location in the crown described by giving their approximate adjustment. In 1954 and 1956 samples were taken as near as possible to the old samples — in a few cases the original branches had been broken and 2 of the trees had been felled. In this investigation we only consider samples and trees which were used in all 3 years.

The main object of these studies was to find out to what extent fertilization percentage varied from tree to tree and from one crown section to another of the same tree.

The position of the trees is seen in *fig. 3; tables 12 and 13* give a view of the results, which are presented in the headings.

As the studies were of informative character and consequently not followed up by detailed flowering and pollen shedding observations, it is impossible to give more definite explanations of all the results. It should be noted, however, that in years with a heavy beech mast about 90 percent of all female flowers are fertilized in such an open beech forest; this shows the effectivity of wind pollination for this species.

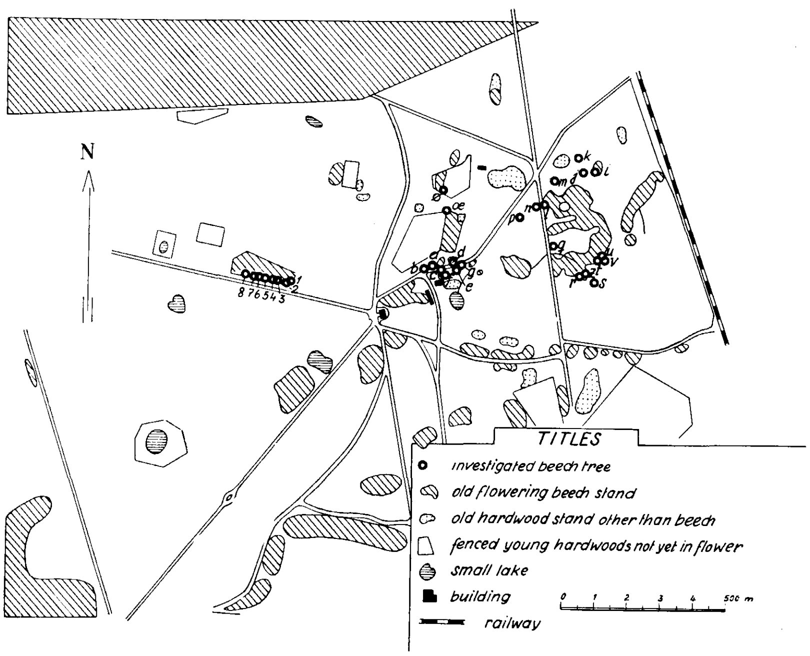

Fig. 3. — View of the position of the investigated beeches in the Deer Park of Jaegersborg State Forest District.

Summary

In the Hørsholm Arboretum pollination experiments in *Fagus* have continued along the lines of the paper published in this journal by Nielsen and Schaffalitzky (1954).

The isolation technique has scarcely been changed and was usually completely safe.

Experiments with pollen mixtures showed that it will be advantageous to mix great quantities of *Lycopodium* spores into the small quantities of valuable *Fagus* pollen usually available.

Further self-pollination experiments confirmed that *Fagus sylvatica* is generally highly selfsterile, although there are certain exceptions.

Seedlings have been raised of the cross *Fagus sylvatica* ♀ × *Fagus grandifolia* ♂. The hybrids show intermediate leaf characters and tendency towards hybrid vigour in comparison with *Fagus sylvatica.* Four one year old hybrids of the cross *Fagus sylvatica* ♀ × *Fagus Sieboldii* ♂ were also obtained.

Table 12. — Fertilization percentages in 1953, 54 and 56. Open pollination in the Deer Park, comp. *fig. 3.* — Samples of 100 nuts from the crowns of 31 old beech trees. Note the variation from tree to tree and within the individual crowns. From a few trees several samples were taken, especially where the first samples showed poor fertilization. Of these more detailed examined trees f each year shows extremely low percentages; also k and æ display rather poor fertilization. As we have found these 3 trees to flower very early, it is probable that many of their female flowers are not receptive when pollen shedding is at its height.

Tree marked	Sample		Per cent fertile nuts		
	No.	Adjustment in crown	1953	1954	1956
a.	1	SE	75	91	98
	2	S	88	90	96
	3	NE	64	92	93
b.	1	SE	78	95	100
	2	SSE	63	97	97
	3	W	81	90	90
	4	SW	83	92	97
c.	1	W	82	94	99
	2	NW	87	98	95
d.	1	S	93	96	95
e.	1	W	83	92	91
	2	S	85	91	90
f.	1	SE	15	85	52
	2	SSE	13	60	55
	3	SSE	15	55	56
	4	SSE	16	59	59
	5	SSE	13	54	39
	6	SSW	30	30	55
	7	SW	37	41	56
	8	SW	57	45	74
g.	1	S	64	95	94
i.[1]	1	S	56	96	91
	2	S	48	95	97
j.[2]	2	W	74	81	91
	3	N	59	90	99
k.	1	S	74	88	85
	2	S	72	82	88
	3	W	67	87	85
	4	N	51	78	79
	5	N	49	74	85
	6	E	61	79	88
	7	NE	65	80	80
	8	N	47	78	83

Tree marked	Sample		Per cent fertile nuts		
	No.	Adjustment in crown	1953	1954	1956
l.	1	W	86	100	100
	2	S	84	100	96
m.	1	SW	63	89	97
	2	S	75	85	89
	3	SE	88	97	96
	4	ESE	84	98	98
	5	NE	73	95	95
	6	N	74	84	77
n.	1	SE	37	93	89
	2	WSW	63	92	93
	3	WSW	50	95	93
	4	SSW	56	91	94
p.	1	E	74	91	94
q.	1	SW	98	95	96
r.	1	S	83	85	95
s.[3]	1	E	85	92	86
t.	1	S	83	88	99
u.	1	SE	81	95	97
v.	1	SSW	34	71	89
	2	SSE	39	82	79
z.	1	SW	44	84	76
ø	1	S	35	80	90
æ	1	NE	55	85	90
	2	E	31	88	57
	3	N	70	91	81
	4	W	64	84	60
	5	SW	28	79	73
	6	SW	39	58	67
	7	S	17	66	79
	8	SE	24	68	82
	9	SW	35	77	63
	10	SSE	30	78	87
	11	S	12	77	86
	12	S	17	72	86

[1]) In 1956 sample no. 1 and 2 were taken to ESE.
[2]) In 1956 sample no. 2 and 3 were taken to SW.
[3]) In 1956 sample no. 1 was taken to W.

Table 13. — Average fertilization percentages for the 31 old trees, which are distributed among 10 percentage classes. Note that the great flowering years of 1954 and 1956 show nearly the same and definitely better fertilization than the rather poor year of 1953

Fertilization per cent classes	Number of trees per class		
	1953	1954	1956
> 90	2	19	25
80—89	9	9	3
70—79	6	2	2
60—69	4	—	—
50—59	2	1	1
40—49	3	—	—
30—39	4	—	—
20—29	1	—	—
	31	31	31

A method was devised to test the purity of progeny after early artificial pollination without bagging. Copper beech pollen was used in this test, hence called "the copper beech control method". An approximate 1 : 1 segregation in the progeny after crossing green with copper beech indicates a case of monofactorial segregation.

In 1953, 1954 and 1956 open pollination studies in a deer park with scattered groups of old beech trees showed the great effectivity of wind pollination. It is suggested that poor fertilization in a few trees was due to early flowering.

Résumé

Titre de l'article: *Pollinisations contrôlées chez le hêtre.*

Les expériences de pollinisations contrôlées du hêtre ont été poursuivies à l'Arboretum de Hörsholm suivant les grandes lignes de l'article dans ce journal par Nielsen et Schaffalitzky (1954).

La technique d'isolation n'a pratiquement pas été changée et se révéla normalement tout à fait sûre.

Les expériences portant sur des mélanges de pollen ont montré qu'il est intéressant de mélanger à de grandes quantités de spores de lycopode les petites quantités de pollen de hêtre de valeur que l'on peut habituellement obtenir.

De nouveaux essais d'autofécondation ont confirmé que *Fagus sylvatica* est presque complètement autostérile, bien qu'il y ait quelques exceptions.

Le croisement *Fagus sylvatica* ♀ × *F. grandifolia* ♂ a donné des semis. Les hybrides ont des caractères foliaires intermédiaires et une tendance à l'hétérosis par compa-

raison avec *F. sylvatica*. Le croisement *F. sylvatica* ♀ × *F. Sieboldii* ♂ a donné quatre semis de un an.

Une méthode fut mise au point dans le but de tester la pureté d'une descendance obtenue par pollinisation artificielle précoce, sans ensachage. Du pollen de hêtre pourpre fut employé pour ces tests, d'où le nom de «méthode de contrôle au hêtre pourpre». Une ségrégation voisine de $^1/_1$ dans la descendance issue du croisement du hêtre vert avec le hêtre pourpre indique qu'il s'agit d'un cas de ségrégation unifactorielle.

En 1953, 1954 et 1956 des études sur la pollinisation libre, faites dans un parc contenant des bouquets épars de vieux hêtres, ont montré l'efficacité de la pollinisation par le vent. On pense que la mauvaise fertilisation constatée sur quelques arbres était due à une floraison trop précoce.

Zusammenfassung

Titel der Arbeit: *Künstliche Kreuzungen in der Gattung Fagus.*

Im Arboretum Hørsholm wurden Kreuzungsexperimente mit Buche nach den Richtlinien der in dieser Zeitschrift von NIELSEN und SCHAFFALITZKY (1954) veröffentlichten Arbeit fortgesetzt. Die Isoliertechnik wurde kaum verändert und war i. a. zuverlässig. Als vorteilhaft stellte sich heraus, die gewöhnlich nur geringen zur Verfügung stehenden Mengen wertvollen *Fagus*-Pollens mit großen Mengen *Lycopodium*-Sporen zu mischen.

Weitere Selbstungsversuche bestätigten trotz einiger Ausnahmen die Tatsache, daß *F. silvatica* in hohem Maße selbststeril ist. Von der Kreuzung *F. silvatica* × *grandifolia* zog man Bastarde mit intermediären Blattmerkmalen und einer Tendenz zu überlegenem Wuchs gegenüber *F. silvatica* heran. Außerdem erhielt man vier einj. Sämlinge der Kreuzung *F. silvatica* × *F. Sieboldii.*

Es wurde eine Methode entwickelt, um die „Reinheit" einer Nachkommenschaft von sehr früh bestäubten und nicht eingetüteten Blüten festzustellen. Wegen der Verwendung von Blutbuchenpollen erhielt dieser Test den Namen „Copper Beech Control Method". Eine Aufspaltung etwa im Verhältnis 1 : 1 in der Nachkommenschaft einer Kreuzung zwischen normaler Buche und Blutbuche läßt auf einen Fall monofaktorieller Vererbung schließen.

Die ausgeprägte Wirksamkeit der Windbestäubung geht aus Studien der Jahre 1953, 1954 und 1956 an einigen verstreuten Altbuchengruppen in einem Wildpark hervor. Es wird vermutet, daß der geringe Samenansatz einiger Bäume auf die frühe Blütezeit zurückgeführt werden muß.

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Possibilities for Genetic Improvement in the Utilization Potentials of Forest Trees

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Introduction

The improvement of forest trees must be considered not only from the viewpoint of the producer, the landowner or forester, but also from the viewpoint of the consumer, the industry that uses the wood. The distinction between "forest requirements" and "use requirements" must always be recognized even where industry owns the land and grows its own timber.

Because the word "requirement" has been given some special meanings in some disciplines, a clear definition is in order here. In this paper, "requirement" is used in one of its most common meanings: "that which is needed . . . a required quality".

"Forest requirements", the characteristics and qualities of the tree that are of primary interest to the forester, can be quite clearly defined. In general, most importance will be placed upon hardiness in the region where the trees are to be grown, rapidity of growth, resistance to diseases and insects, and low cost of propagation and plantation establishment. Improvement of these characteristics will go far to reduce the investment risk and to increase the profit from the timber harvest.

"Use requirements" are the characteristics and qualities of the tree that determine its value for special uses. Many of these use requirements have not yet been defined.

The wood-using industries' rapidly increasing interest in forest tree improvement is aimed primarily at the possibilities for improving characteristics and qualities of wood that are reflected in the cost and quality of the finished products. Different wood-using industries have different use requirements. Even in the same industry, for example the paper industry, the requirements differ between individual companies; and in mills making a variety of pulp or paper grades the wood requirements depend on the particular end product.

For genetic improvement we need information on the effect that the individual characteristics of wood have on the manufacturing processes and on the finished products; and we must also have rapid methods for evaluating these characteristics in the living tree. Such methods have recently been developed for the determination of density, percentage of summerwood, and fibril angle; but more information is needed for the genetic improvement of

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