some of the pollen mother cells remain in the diploid phase due to a failure of the reduction division and in this way diploid pollen grains arise which are capable of functioning.

In addition, and unexpectedly, some individuals were found with both diploid. and triploid tissue. It must be assumed that this will be the result of a downward adjustment of the triploid condition during the course of development of these plants. This phenomenon will be studied in connection with the autopolyploid nature of these individuals.

The triploids are distinguished morphologically by a relatively large and rounded leaf. The leaves of the diploids vary from a type which is slender and pointed to a rounded and obtuse type. The analysis of the present segregation will be used later in connection with the problem of the origin of grey poplar. — The origin of triploids described above as a result of the presence of diploid pollen appears to provide an explanation of the origin of the spontaneous Triploids of Section *Leuce* which are found in nature.

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Flower Observations and Controlled Pollinations in Fagus

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Contribution from the Hørsholm Arboretum, Denmark

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Introduction

The Danish Government has provided a grant for the breeding of the Danish beech during the 10 years 1948-57. The work is linked with the Royal Veterinary- and Agricultural College's Arboretum at Hørsholm, where it is carried out under the guidance of dr. C. SYRACH LARSEN.

Flower observations on *Fagus sylvatica* L. and controlled self-and crosspollinations within the genus *Fagus* have been undertaken as part of the Programme during the years 1948-52. Investigations into the flower development of *Fagus sylvatica* were already commenced in 1944 with the aid of a grant from the Carlsberg Foundation.

The majority of the pollinations have been carried out using *Fagus sylvatica* as female. Besides *Fagus sylvatica*. *Fagus orientalis* LIPSKY, and *Fagus grandifolia* EHRH. have both been used as pollinators.

Fagus sylvatica, the European beech, has entire margins to the leaves and from five to nine pairs of lateral veins. The cupule is carried on a short stalk and the involucre bears short prickles.

Fagus orientalis, the Oriental beech, is native to the near East and southeastern Europe. It has large leaves with seven to ten pairs of veins. The principle characters distinguishing from the European beech are the lower prickles of the involucre which have been modified into spatulate bracts and the stalk of the cupule which is 2—2½ cm long.

Fagus grandifolia is indigenous to Eastern North America. It has large serrate leaves with 9–14 pairs of veins. The involucre is borne on a very short stalk and bears prickles somewhat similar to those of the European beech.

Flowering specimens of *Fagus grandifolia* could scarcely be found in Denmark, but we have received the greatest kindness and assistance from the staff of the Arnold Arboretum, Mass., U. S. A., who have sent pollen of *Fagus grandifolia* and other *Fagus* species to us on several occasions. The Genetics Section of the Alice Holt Research Station of the Forestry Commission in England has provided us with pollen from the English strain of *Fagus sylvatica*. Dr. C. HEIMBURGER, Ontario, Canada, has sent pollen to us and has also undertaken a few crossing experiments.

In the pollination work we have received much assistance from the administrators of Jægersborg State Forest District and of the Park of Sorgenfri Castle. We are very much indebted for alle the friendliness with which we were met in our work and want to thank all for the assistance we have received. We also wish to thank a number of younger colleagues for their indispensable assistance during the flowering seasons.

Leafing-Out and Flowering Observations

In Denmark beech normally flushes between the 1 st May and 20 th May.

As the buds enlarge and the leaves emerge, the flowers appear from the same buds, both from the short shoots and the long shoots. In the centre of the buds and where they are most protected are found 1–4 female inflorescences which usually contain two, occasionally more flowers, surrounded by an involucre. The occurrence of more than two flowers is characteristic for certain individuals, but the majority of the inflorescences of such trees have only two female flowers. The style is short, and the stigma has three branches which recurve spirally during the flowering. The male inflorescences occur lower down the shoot. They appear in the axils and are long stalked pendulous heads which consist of several flowers, each containing 8–16 stamens. In each flower bud there may be found 1–10 heads of male flowers. Most flower buds have both male and female inflorescences, some, particularly the shaded ones, have only male flowers. Flowers were found on some observed trees which had the male and female characters mixed. One particular tree frequently had in its female inflorescence one ordinary female and one stalkless male flower with only two or three stamens, corresponding to the female organs. A few involucres had developed two abnormal male inflorescences instead of female ones. Such abnormalities were found on several trees.

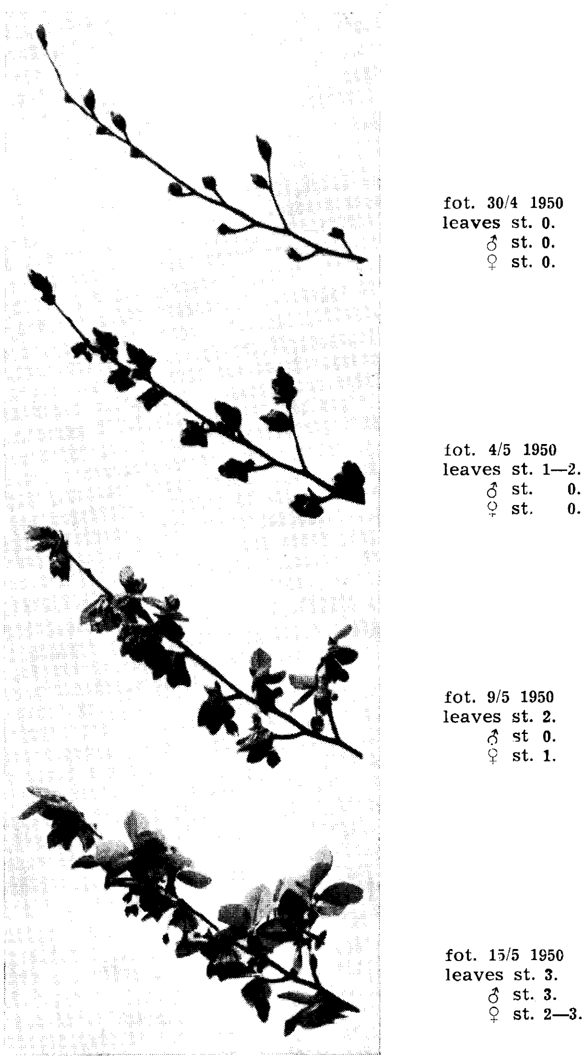

Fig. 1. Leafing-out in Beech. Kew Gardens 30/4 — 15/5 1950. The same branch in different stages. To the right of the photographs the stages of development of the leaves, the male and female flowers are indicated.

The relationship between the appearance of the leaves and the development of the flowers varies from tree to tree, as also does the relationship between the flowering of the male and female flowers. Some trees have their leaves quite expanded, before the stigmas of the female flowers commence recurving while others have recurved stigmas when the buds are only half open. This relationship and that between the development of the female and the male flowers were observed while the controlled pollinations were carried out, and more thoroughly in Kew Gardens in England during the spring of 1950. The items of information in tables 2 and 3 are based on observations made by P. Chr. Nielsen at Kew.

Twelve trees which were growing near to each other were chosen for a detailed examination. Simultaneously general observations were made on a rather large number of beeches distributed about the Gardens. The observations were commenced on 4 th — 5 th May, shortly after beeches had started to leaf out, and were brought to an end on 20 th May when nearly all the beeches in Kew Gardens had completed their flushing. Meteorological data for the period are given in table 1.

Table 1
Climatic data during the time of flushing and flowering of beech 1950. Observations from Kew, based on „The Daily Weather Report of the Meteorological Office“, London. Compare table 2.

Date May	Temperature C^0			Rainfall mm	Clouds at noon 0—8	Hours of sunshine
	max.	min.	at noon			
1	17.2	6.1	16.1	trace	7	11.6
2	15.6	8.3	12.2	tr.+3	6	6.3
3	15.0	7.8	12.8	tr.	8	4.6
4	12.2	7.8	12.2	tr.	7	2.4
5	12.2	3.9	10.6	tr.+0.1	8	0.9
6	11.7	7.2	10.0	4+2	8	0.4
7	13.9	6.7	12.8	0.6+1	0	1.2
8	11.7	8.3	10.6	3+1	8	0.0
9	18.3	9.5	16.7	1	0	9.1
10	21.7	10.6	18.9	tr.	1	8.1
11	20.6	10.0	18.9	—	0	14.0
12	21.7	10.6	20.6	—	1	14.2
13	22.2	7.2	17.2	—	0	14.4
14	15.0	6.1	13.9	—	1	9.8
15	12.8	7.8	10.6	—	7	4.3

The following characteristics were used to indicate the stages of leafing-out and flowering.

Flushing. — Further illustrated in fig. 1.

0.—buds completely closed, no green is visible.

1.—buds opening; the male inflorescences are visible — the “cornet stage“.

2.—male and female inflorescences are plainly visible. The leaves still somewhat crumpled up after the folding in the bud.

3.—the leaf blades weakly crumpled or completely straightened out.

Female flowers).* — Further illustrated in fig. 2.

0.—stigmas have not commenced recurving.

1.—stigmas commence to recurve.

2.—stigmas recurved.

3.—withering of the stigmas begun.

Stages 1 and 2 are considered the stages receptive to pollen.

Male flowers.

0.—pollen dispersal has not commenced.

1.—pollen dispersal is commencing.

2.—full dispersal of pollen.

3.—pollen dispersal has ceased.

The detailed observations of the 12 trees are summarized in table 2. The leafing stage of the branch observed is given as well as the leafing stage of the whole tree.

The table shows that a few of the trees had started to leaf-out when the observations began on 5 th May, and that the female flowers of five of them had already reached stage 2. On 20 th May flushing and flowering had finished and only one tree still was releasing pollen. The averages for the 12 trees are:

Period of leafing-out: 5 th — 11 th May.

Flowering of the female inflorescences (stage 1 and 2): 6 th — 13 th May.

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*) In the following »flower« often stands for »inflorescence«.

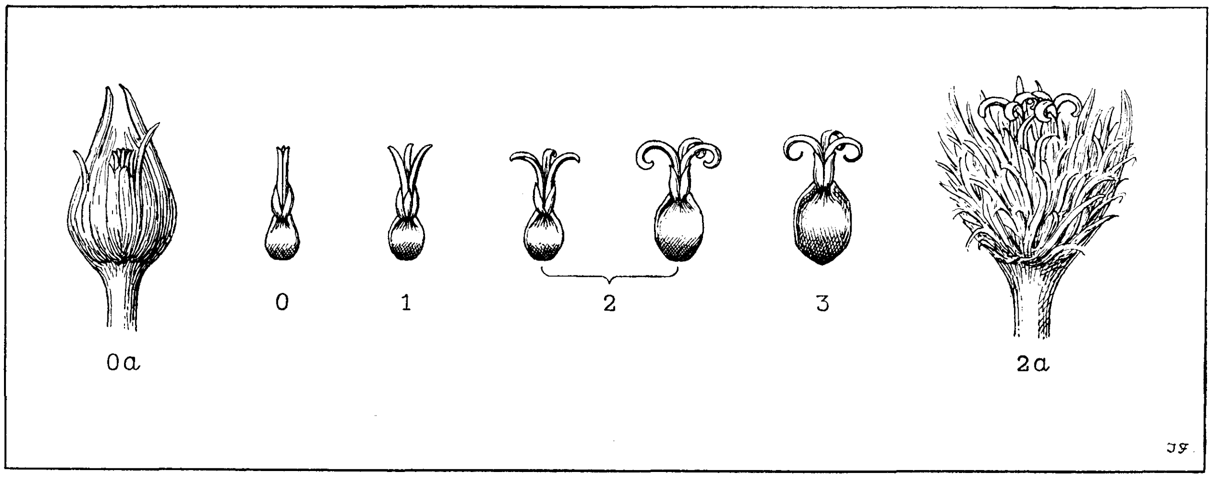

Fig. 2. Sketch of the different stages of development of the female flowers with *Fagus sylvatica* L. In the figures marked (a.) the whole inflorescence is drawn, stage (0) and (2) respectively. In the other cases the individual female flower is shown in the different stages.

Table 2
Observations of leafing and flowering of 12 trees. Kew Gardens, 1950. — Generally showing metandry, but notice the individual variation.

Tree no.	5. May				9. May				11. May				13. May			
	Leafing		Flowering		Leafing		Flowering		Leafing		Flowering		Leafing		Flowering	
	Tree	Branch	♀	♂	Tree	Branch	♀	♂	Tree	Branch	♀	♂	Tree	Branch	♀	♂
1	1	1	0	0	2	1—2	1—2	0	3	2	2	0	3	3	2—3	1
2	1	1	0	0	1	1	1—2	0	2—3	2	1—2	0	3	3	2	0—1
3	1	1	0	0	2	2—3	1	0	3	3	2	1	3	3	2—3	2—3
4	0—1	0	—	—	1—2	1	—	—	2—3	2—3	—	—	3	3	—	—
5	1	1	0	0	2	2—3	2	0	3	3	2	0	3	3	2—3	2
6	0	0	—	—	0—1	1	0	0	1	1	1	0	2	2	2	0
7	2	2—3	1—2	0	2—3	3	2	2	3	3	3	3	3	3	3	3
8	1	2—3	1—2	0	1—2	3	2	1	2	3	2—3	2—3	2—3	3	3	3
9	1	1	1	0	1—2	1—2	1	0	2—3	2—3	2—3	0	3	3	2	1
10	2	2—3	2	0	2—3	3	1—2	0	3	3	3	2—3	3	3	3	3
11	2	2—3	2	0	2	3	2	0—1	3	3	2—3	2—3	3	3	3	3
12	1—2	2	1—2	0	2—3	3	2—3	0	2—3	3	2—3	2	3	3	3	3

Tree no.	15. May				20. May				Summary, dates		
	Leafing		Flowering		Leafing		Flowering		Receptivity	Release of pollen	Leafing, branch
	Tree	Branch	♀	♂	Tree	Branch	♀	♂	♀	♂	
1	3	3	2—3	2—3	3	3	3	3	8—15	13—16	5—11
2	3	3	2—3	2	3	3	3	3	7—15	13—17	5—13
3	3	3	3	3	3	3	3	3	8—13	11—14	5—11
4	3	3	—	—	3	3	—	—	—	—	9—13
5	3	3	2	2	3	3	3	3	8—16	12—16	5—11
6	2	2—3	2	0	3	3	3	2	11—17	14—21	9—17
7	3	3	3	3	3	3	3	3	4—10	5—10	3—9
8	2—3	3	3	3	3	3	3	3	4—12	9—12	3—9
9	3	3	3	3	3	3	3	3	5—12	13—14	5—13
10	3	3	3	3	3	3	3	3	3—11	10—12	3—9
11	3	3	3	3	3	3	3	3	3—12	9—13	3—9
12	3	3	3	3	3	3	3	3	4—12	10—12	4—9
Averages of summary:									6—13	11—14	5—11

Release of pollen by the male flowers (stage 1 and 2):
11 th — 14 th May.

If only the averages are considered, one would be tempted to draw the following conclusion: Shortly after the leafing-out has begun, the female flowers start their flowering period, while the male flowers do not begin to shed their pollen till the leafing-out has been completed. The first withering of the stigmas begins about a week after the beginning of the recurving. The release of pollen only lasts three days.

If one considers the individual trees, however, it will be clearly seen that great deviations from the averages occur. Special reference is made to tree number 7 in which the period of leafing-out and the flowering of the female and the male flowers occur almost simultaneously.

It should also be noticed that the indication of the female flowers as being in stage 3, generally means that a few of the stigmas have commenced to wither. Even towards the end of the observation period flowers with fresh stigmas were found. Later in this paper the question of the period of receptivity to pollen of the female flowers will be taken up for further consideration.

The general observations of the leafing-out and flowering in Kew Gardens were carried out during walks in the Gardens. The observations on the beeches that were passed were filled into a form with these headings:

Female Flowers — Male Flowers — Leafing-Out
0 1 2 3 0 1 2 3 1 2 3

168 observations were made on about 100 different trees, not including the 12 trees mentioned previously. A sum-

mary of the observations is given in table 3. When working out this table the transitional stages (taken down as 1—2 or 2—3) were in all cases referred to the lower stage.

It appears from table 3 that female flowers in stage 1, which is regarded as the first phase of receptivity, are found in the leafing stages 1, 2 and 3 with a tendency to maximum in leafing stage 2. However, stage 1 of the female flowers only covers a very short period so the number of observations is small. When one considers the leafing stage 3 in which only 18 out of 110 female flowers are found in the stages 0 and 1, it seems to be quite clear that the majority of the female flowers reach their receptive stage at leafing stage 2, i. e. immediately after the flushing. The four observations of female flowers with recurved stigmas (stage 1) while the buds are still in the "cornet stage" (stage 1), also shows that certain female flowers seem to be receptive the moment they emerge from the buds. (When the buds were in stage 1, they were opened a little more by hand in order to observe the condition of the female flowers.) Further it can be seen from table 3 that the recurving of the stigmas of some flowers does not begin until the branch has leafed-out completely, — 18 female flowers being in stage 1, the branch being in leafing stage 3.

None of the male flowers observed began pollen dispersal (st. 1) before the buds were open (st. 2). In leafing stage 2, 7 observations out of 40 show male flowers releasing their pollen, but as it appears from the column of leafing observations in stage 3, 39 out of 110 branches had not started to shed their pollen at the time of full leafing-out. So we have confirmed the conclusion from table 2, that by far the greatest number of the male flowers (161 out of 168 observations) do not begin to release pollen until the branch has completely flushed.

On 4 th May the female flowers on 32 out of 63 observed branches were in the stages 1 and 2, while on 13 th May all 29 observations show female flowers in the stages 2 and 3.

On 4 th May 10 observations show male flowers releasing pollen (st. 1 and 2) and on 13 th May 27 out of 29 observations show that male flowers were shedding or had shed their pollen.

On 20 th May 36 trees were examined. All the female flowers hat withering stigmas; in most cases the withering was so advanced that the flowers were indicated as being in "stage 4" in the notes. In the same 36 observations 34 of the male flowers had completed the release of pollen while 2 were still releasing a little pollen.

By means of the observations summarized in table 2 and 3 it is possible to judge the whole flowering period for beech in Kew Gardens in the spring of 1950. For the female flowers one gets 28 th April to 16 th May and for the male flowers 2nd to 20 th May. The proper flowering period has been 4 th to 12 th May, only lasting about one week. Moreover it can be stated that the beech was metandric the female flowers being receptive (stage 1) about 4—5 days before the male flowers began to release pollen.

However, it should be stressed that the dates and periods given above are averages and that the individual observations deviate considerably from the mean. A detailed examination of the observations that form the basis of table 3 show for example 4 cases of protandry — the female flowers being in stage 1 while the male flowers were in stage 1 and 2.

The conclusions that are drawn on the basis of the material from Kew Gardens 1950 are confirmed by the rather casual observations made in connection with the controlled pollinations 1948-52 and with the flower investigations from 1944.

In 1944 the observations were carried out in the Deer Park near Copenhagen. The investigations started a little late, but it was possible to estimate that the metandry was about 4 days. The observations began 16 th May when most of the female flowers were in stage 2, while only about half of the male flowers were releasing pollen, most of them being in stage 1. The period 10 th to 14 th May was warm with many hours of sunshine. From 15 th to 25 th May there was a cool period with intermittent rain and little sunshine. This cool period which set in just before the pollen was to be released, delayed the flowering period of the male catkins and resulted in a considerable metandry.

In 1948 the flushing and flowering of the beech started very early because of a very warm April. Most of the trees that were used in the pollination programme had their female flowers in stage 1 and 2 about the 1 st May. The pollen dispersal either began simultaneously or 1—2 days later. The period 13 th — 26 th April was very warm with much sunshine. From 27 th April — 5 th May the weather was somewhat cooler with rain showers. The very fine weather from 13 th — 26 th April forced the female as well as the male flowers to an almost simultaneous flowering about 1 st May.

The same year another flowering observation was carried out on only five trees on the island of Bornholm. There the spring came a little later than in North Zealand where the controlled pollinations took place. On Bornholm there was a distinct metandry of 3—5 days. Thus the cooler weather after 27 th April seems to have influenced the flowering. The number of observations, however, is too small to enable any real conclusions to be made.

Table 3
Relationship between leafing-out and flowering in beech. Kew Gardens, 1950. — Generally showing metandry, but notice the individual variation.

		Leafing stage 1					Leafing stage 2					Leafing stage 3				
Date		4/5	9/5	11/5	13/5	Σ	4/5	9/5	11/5	13/5	Σ	4/5	9/5	11/5	13/5	Σ
Stages of female flowers ♀	0	12	2			14	13	1	1		15	6	2			8
	1	2		2		4	8	5	1		14	4	5	1		10
	2						6	2	1	2	11	12	22	18	11	63
	3												1	12	16	29
		14	2	2		18	27	8	3	2	40	22	30	31	27	110
Stage of male flowers ♂	0	14	2	2		18	24	7	2		33	15	17	5	2	39
	1						2	1	1	2	6	2	7	8	1	18
	2						1				1	4	5	8	10	27
	3											1	1	10	14	26
		14	2	2		18	27	8	3	2	40	22	30	31	27	110

In 1949 only a few trees were observed. They give the impression of metandry of 1—2 days. The flowering began on the 8 th—9 th May during a cool period with some precipitation, but as in 1948 a warm and dry period from 30 th April to 5 th May resulted in almost simultaneous development of the female and male flowers.

From 1950 to 1952 no flower observations were made in connection with the pollinations. For the investigations in the Kew Gardens 1950 a comparison between the weather data in the table 1 and the averages given in table 2 seems to show that the cool and showery period up to the loth May stimulated the flowering of the female flowers, while the male flowers only start their proper release of pollen after some days of warm and dry weather.

In the spring of 1953 we took in branches of one flowering beech tree and placed some of the branches (a) in damp, cool and rather dark conditions, whereas the others (b) were kept in the open. On the 25 th May the flowering stages were as follows:

	Flowering stages		
	Leaves	Male flowers	Female flowers
a	2	0—1	2
b	3	3	2—3

which illustrates the climatic influences.

In accordance with Büsgen 1916 and Syrach Larsen 1937 we have found that *Fagus sylvatica* is normally metandric (comparison between male and female flowers in stage 1). The metandry, however, is closely connected with the weather conditions immediately before and during the flowering period. Drought and heat force the development of the male flowers more than that of the female flowers and will bring about none or a short period of metandry. On the other hand, cool and rainy weather results in a long period between the flowering of the female and the male flowers. (Büsgens statements, ref. to page 11 and our own continued pollination experiments page 11 seem to prove that the metandry of beech has no meaning in the sense of hindering selfpollination.)

So far only the relationship between the development of the flushing and the flowers of the branches has been considered. It is a general experience that the south side of a tree flushes before the north side. On 17 th May 1944 six beeches were observed on the south side as well as on the north side of the crown. The development of the female flowers were roughly described by small scetches which showed that the recurving of the stigmas was more advanced on the south than on the north side. For the male flowers distinction was made between the phases: Not releasing pollen, releasing pollen, pollen release finished. If we number the individual trees 1—6, the flowering table can be set up. It appears that the male flowers take one step forward when we go from the north to the south side of the trees.

	Not releasing pollen	releasing pollen	pollen release finished
North	1,4,5	2,3,6	
South		1,4,5	2,3,6

Observations of the same kind have been made in connection with the controlled pollinations. It can be stated further that the favourable conditions inside the isolation bags force the development of both male and female flowers compared with the flowers outside the bags.

Experiments with the Receptivity of the Female Flowers and the Viability of the Pollen

In connection with the pollination work in *Fagus* the question of the period of receptivity to pollen of the female flowers soon arose.

In 1948 we had already worked with a very early beech — by far the earliest of a stand. Selfing of the tree gave only very few full nuts, while open pollination gave 55%. This led to the view that the receptive period of the female flowers, that had not received pollen, was at least 5—6 days. The metandric flowers of this early flowering tree had to wait 5—6 days to obtain pollination from later trees.

In the later experiments which have been carried out to determine the receptive period of the female flowers, more stress has been laid on the question: “How long are the female flowers receptive?“ rather than on the question: “How soon after the beginning of the recurving of the stigmas (st. 1) are the female flowers receptive?“ The former question is important for making pollinations, while the latter is of mere theoretical interest.

The results of the most important of the continued pollination experiments have been arranged in table 4. The pollination technique is described on page 13. In all cases the most early pollinations were not started till the female flowers had come into flowering stage 2, and very often in a rather late period of stage 2. This is especially the case with tree no. III where the long term experiment only started 19 th May whereas the proper pollination of the same tree was carried out 15 th May. We wanted here to concentrate on very late pollinations in order to find out how long we had to leave the isolation bags on the trees to secure the isolated female flowers against foreign pollination.

The pollination on tree no. II 1950 started actually on 8 th May, but the mixture of pollen that was used on 8 th and 10 th May was moist, and as it did not seem to work, a new mixture was prepared for the rest of the experiment. On 10 th May the female flowers had reached stage 1, so the receptive period may be set to lo th to 23 rd May, possibly still longer. Pollen dispersal began 11 th May and lasted till about 15 th May. As a result of the pollination 21 st May 19 barren and 0 good nuts were collected. This special pollination was carried out immediately after a rainshower and thus the pollen injected adhered to the damp inner sides of the bags. The high fertilization percent after the pollination 23 rd May proves that the female flowers were receptive 21 st May. The most thorough experiment was made in 1952 on tree no. I, the same tree that was used in 1949. The column with percent of good nuts show high fertilization percents from 5 th to 14 th May, while the following pollinations have only given a few good nuts.

Both in 1951 and 1952 single full nuts were found as results of the late pollinations. The presence of these nuts is no doubt due to the fact that single female flowers are much later than the female flowers of the tree in general. (A parallel phenomenon also appears for the male flowers where single pollen shedding heads may be found very late.)

Some supplementary experiments have also been undertaken none of which gave results contrary to the larger experiments referred to in table 4.

For the long term pollination experiments a mixture of pollen from 2—4 individuals of *Fagus sylvatica* has been

Table 4
Long term pollination experiments. Pollination was undertaken at different dates on the same trees in order to determine the length of the receptive period of the female flowers. Obs.: The same tree was used in 1952 and 1949

Pollination		Number of nuts collected		Percent of good nuts	Receptive period minimum
Date	Number of flowers	good	barren		
1949: no. I (alias nr. 9)					
9. V.	30	14	0	100	9—18 May
14. V.	?	26	2	93	
18. V.	28	10	4	71	
1950: no. II (alias nr. 12)					
12. V.	10	7	3	70	12—23 May
14. V.	22	17	5	77	
16. V.	34	28	6	82	
19. V.	26	17	7	71	
21. V.	22	0	19	0	
23. V.	26	24	2	92	
open		430	576	43	
1951: no. III (alias nr. 16)					
19. V.		39	6	87	?
22. V.		6	65	8	
25. V.		1	97	1	
28. V.		1	41	2	
7. VI.		1	17	6	
open		263	260	50	
1952: no. I (alias nr. 9)					
5. V.	92	76	11	87	5—14 May
8. V.	50	34	2	94	
11. V.	116	105	8	93	
14. V.	102	79	11	88	
17. V.	100	0	92	0	
20. V.	152	1	139	1	
23. V.	132	0	134	0	
26. V.	166	2	108	2	
29. V.	104	0	106	0	
open		234	488	32	

used. (In 1952 only pollen from one father tree.) In some cases the pollen has been blown into the bags, in other cases pollination has been made with a small brush. In all cases double bags have been applied.

The conclusion of the long term pollination experiments must be the following: *Female flowers which have not been pollinated are receptive to pollen during a period of 10—14 days. It is certain that they are receptive during stage 2,* and probably already in stage 1, although this was not proved.

The flower observations in 1944 had already made it clear that, it was impossible to determine by eye whether a female flower had been fertilized or not during the period immediately after pollination. According to the flower observations described, withering of the stigmas begins about a week after the flowers have opened. Some observations of the commencement of withering of the stigmas inside and outside the isolation bags were undertaken along with the controlled pollinations. The observations were somewhat casual, and it has not been possible to draw any definite conclusions. It appears that the withering begins after a variable period which differs for the various trees both in pollinated and in unpollinated flowers. The protection of the isolation bags against hard weather conditions makes the withering of the stigmas occur later inside than outside the bags.

In connection with the investigations of the receptivity of the female flowers it should be stated that twice we have tried pollination with one year old pollen stored in a dessicator, but without any special storage preparations (ref. to table 6). No regular pollen germination tests were carried out, but pollinations with the one year old pollen on trees, which gave good results with fresh pollen did not produce any full nuts. It is possible that storage in darkness at low temperature, and a certain humidity would keep the germination ability of beech pollen as has been the case for other tree species.

Our usual technique of storing beech pollen is described on page 13. Even by this simple method good fertillization percents have been obtained with pollen 3 weeks old.

The Development from Flower to Fruit

In connection with the controlled pollinations we made a few simple investigations of the development of the involucre and the nuts.

During the flowering the involucre begins to enlarge and about one month after it has attained its full size. At this time an examination of the ovary shows 6 ovules situated at the end of the ovary. About 5—7 weeks after the flowering it is evident that one of these ovules has increased in size in part of the ovaries. After 5—7 weeks more the ovule has increased so much that the whole nut has been filled.

In his 1916 treatise M. Büsgen describes this development in detail. In order to give a background for the understanding of the development from flower to nut some of Büsgen's investigations are now referred to briefly: On 8 th May the male catkins begin to release pollen and simultaneously it is observed that the pollen grains germinate on the stigmas. However, the ovules are not completely developed and the pollen tubes rest for about 3 weeks in the styles until the ovules are ready for fertilization. On 28 th May Büsgen observed one pollen tube that had reached down to the ovules which are now one mm long. On 16 th June Büsgen found that one of the ovules had increased to double the size of the remainder which usually do not become larger and gradually decompose. On 30 th June the embryos can be recognized in the fertilized ovules, and then the enlargement of the kernel really starts.

When picking beech mast one often finds barren nuts, and it appears also clearly from our tables of controlled pollinations that barren nuts are quite frequent in *Fagus sylvatica.* To test the security of our isolation bags emasculated twigs have been isolated. An account of these control bags is given in table 6. It appears that the nuts are barren in these bags and the results thus prove the parthenocarpy of *Fagus sylvatica.*

In this connection it may be of interest to mention that in our control bags we have found nuts which had been attacked by the larvae of *Tortrix carpocapsa* L. which consequently have been forced to feed on the small unfertilized ovules and the inner walls of the ovaries which are rather fleshy at the beginning of the season.

Selfpollination Experiments

The purpose of the selfpollination experiments was to determine to what extent *Fagus sylvatica* is selffertile. This is an important factor for long term breeding work. We only know of one previous experiment in this field dating from 1935 when C. Syrach Larsen (1937) selfed a freak beech "Fasanbøgen". This selfpollination resulted in 54 good and 789 barren nuts, i. e. a selffertilization percent of about 6.

Where no other method is mentioned the technique applied in the experiments from 1948—52 was as follows: Before the beeches began to shed their pollen and before the stigmas had emerged from the buds, double bags of

Table 5

Comparison between selfpollinations, open pollinations, and successful controlled cross pollinations. Showing a high degree of selfsterility in most cases, but there is individual variation.

Year	Mother tree no.	Selfpollination			Open pollination			Controlled cross pollinat.			Remarks
		nuts collected			nuts collected			nuts collected			
		good	barren	% good	good	barren	% good	good	barren	% good	
1948	1	79	221	26*)	304	130	70	291	738	28	*) emasculated
1948	2	1	41	2	—	—	—	—	—	—	
1948	3	4	106	4	69	60	53	118	60	66*)	*) *Fagus sylv.* × *F. orient.*
1948	4	10	298	3	286	234	55	—	—	—	
1949	5	0	48	0	48	67	42	—	—	—	
1949	6	1	123	1	74	150	33	—	—	—	
1949	7	0	59	0	2	70	3*)	—	—	—	*) small female flowers, late flowering
1949	8	0	11	0	10	12	45	—	—	—	
1949	9	1	187	1							*) pollen injected
1949	9	0	46	0*)	31	86	26	60	6	89	
1950	1	80	336	19	—	—	—	—	—	—	
1950	8	5	119	4	440	114	79	—	—	—	
1950	9	20	182	10	397	352	53	—	—	—	
1950	10	8	160	5	558	77	88	—	—	—	
1950	11	7	453	2	1083	89	92	—	—	—	
1950	12	4	61	6*)							*) pollen injected
1950	12	23	251	8	430	576	43	93	23	80	
1951	13	22	226	9	80	20	80	—	—	—	
1951	14	32	181	15	15	85	15*)	—	—	—	*) late flowering
1951	15	42	64	40*)	81	19	81	—	—	—	*) highest selffertilization per cent
1951	16	21	94	18	263	260	50	138	191	42	
1951	17	9	57	14	97	124	44	12	55	18	
1952	8	—	—	—	92	8	92	—	—	—	
1952	9	33	882	4	234	488	32	294	32	90	
1952	18	27	257	10	453	394	53	—	—	—	
1952	19	10	135	7	75	21	78	289	65	82*)	*) *F. sylv.* × *F. orient.*
1952	20	2	228	1	106	55	66	546	81	87*)	*) *F. sylv.* × *F. orient.*
1952	21	0	75	0	400	35	92	10	3	77*)	*) *F sylv.* × *F. orient.*
1952	22	2	98	2	—	—	—	—	—	—	
1952	23	1	103	1	142	239	37	103	18	85	

grease-proof paper were tied around the twigs (in 1948 single bags). No emasculation was done and pollen was only injected into the bags in 1948 and 1950. This technique and the certainty of the isolation are discussed on page 14.

The results of the 5 years selfpollination experiments appear in table 5. The table also includes the fertilization percentages from open pollination and, where possible, the best percentages of good nuts which were obtained by artificial crosspollinations. In this way it is possible to compare the degree of selffertilization with the fertilization by natural pollination and by the most complete crosspollination.

The caprices of Nature make it very difficult to calculate how many isolation bags one should put up to get a sufficient quantity of beech nuts, and so table 5 shows experiments of very different sizes. We have decided to publish our results in this way so that the reader himself will be able to estimate the value of the experiments as is apparent from the columns giving the numbers of good and barren nuts.

The most important information which can be read from the results is that most of the individuals in question of *Fagus sylvatica* show *a relatively high degree of selfsterility*. Only 5 trees had more than 10 percent of selffertilized nuts. Even a selffertilization percent of 10 is small compared with the open pollination and the most successful controlled cross-pollinations. It should be remembered that there is always plenty of pollen in the selfpollination bags and that the female flowers are receptive for a considerable period.

Simultaneously it should be stressed that *the degree of selfsterility may to some extent vary for an individual tree from one year to another*. In 1949 tree no. 9 only yielded 1 good nut out of 233 nuts whereas in 1950 and 1952 the selffertilization percentages are 10 and 4. It is evident that *a few trees show a considerable degree of selfing ability*. Tree no. 15 is outstanding with 40 percent (1951) while tree no. 1 in 1948 has 26 percent and in 1950 19 percent good selffertilized nuts.

Even if individual differences are important, it seems probable that selffertilization takes place more easily in some years than in others. Apart from tree no. 1 selffertilization percentages were small in 1948, very small in 1949, small in 1950 (again apart from no. 1), relatively high in 1951 while 1952 again gave small percentages.

The rather few investigations concerning selfsterility in other species of forest trees have given results which — like ours in beech — indicate a rather high degree of selfsterility, while, on the other hand, some species have proved to be fairly selffertile. Some investigations suggest the existence of individuals with a selffertilization ability which differs greatly from the normal for the species.

A method that now and then has been proposed to determine the selffertility of a tree species consists in an examination of the fruit setting of single individual trees in such positions that only very little crosspollination can be expected. H. Geyr (1930) mentioned a single beech which always bore barren nuts, and Jahn (1934) gave a corresponding example from the Botanic Garden in Hann. Münden.

Accordingly we in 1948 decided to examine isolated beeches in Denmark, but only two suitable trees were found, one of them 1200 m and the other 2000 m from the nearest beeches. The fertilization percentages were 6 and 0.

Following a request in 1948 to New Zealand where *Fagus sylvatica* is an exotic, we had a reply from A. L. Poole, who maintained that one *Fagus sylvatica* which was examined for our purpose had only given 2 percent good nuts. According to mr. POOLE's reply other isolated beeches also gave very poor percentages of good nuts, whereas trees in groups in good flowering years had borne a good germinating crop. A considerable drawback to this method is that it cannot be known how much pollen comes from far distant trees. However, when we get small fertilization percentages, even when the tree in question has shed a lot of pollen, the degree of selfsterility must be significant. The male flowers of such a tree will almost certainly be releasing pollen within the long receptive period of the female flowers, and consequently the selfsterility cannot be due to dichogamy.

It is not yet possible to make any statements about the plants that have been raised from the selfed nuts, because the material Januar 1953 only consisted of 2 plants from 1948, 17 plants from 1950 and 27 plants from 1951.

The germination percentages in the nursery have often been low, but in some cases they have been quite normal. The losses of plants in the first years have frequently been very great. There are indications of an inbreeding depression which, on the other hand, is not disastrous. A comparison between the plants originating from self- and open pollination from the same mothertree has not yet given any clear picture of the relationship.

Open Pollination

To compare the results of the selfpollinations we have brought fertilization percents after open pollination into table 5. However, the figures, themselves, give some information. In 1949 tree no. 7 is the only tree which gives the very small fertilization percent 3; this being probably due to the very small female flowers of that tree and to its late flowering. Tree no. 14, 1951, is also a late flowering tree in a year with moderate flowering.

For the rest the fertilization percentages vary from 23 to 92. One may wonder why the only abundant flowering year, 1948, has not given the highest, and the bad flowering year, 1949, the lowest percentages. The weather conditions and the position of the individual tree may be of great significance.

Controlled Cross-Pollination

A. Technique, Description and Criticism

As the techniques of the controlled cross-pollination closely correspond to the well known methods, only a summary description will be given: As soon as possible the male catkins and some of the leaves were removed. The twigs with the female flowers were isolated against foreign pollen by 2 grease-proof paper bags (double bags), the one tied around the twig, the other outside the first one (1948 only single bags). A ring of hydrophobic cotton wool was placed around the twig before and where the bags were tied on. The isolations were finished before the female flowers were considered receptive and usually before pollen shedding started from the surrounding beeches. The pollen used for the pollinations was produced in the following way. Branches about 1 m long were placed in water and as far as possible each fathertree was kept in a separate room. Shortly before the pollen was shed, small twigs with catkins were cut off and put into grease-proof paper bags which were placed in the field laboratory of the Arboretum at about 25° C. After 2—4 days at this temperature the pollen was released and the pure pollen was sieved from the remnants of the pollensacs etc. The cleaned pollen was put into glass tubes which were stored in a dessicator with calcium chloride. The cleaning of the pollen from the various fathertrees often had to be undertaken in the same room, but was never carried out simultaneously. For each sample every possible care was taken to avoid mixture with foreign pollen.

When the female flowers seemed receptive, the pollination took place. The outer bag was removed, a hole was pricked in the inner bag, and pollen was injected by sprinkling or blowing it into a bag through a fine glass tube. The hole was covered with adhesive tape and the outer bag was replaced.When the receptive period of the female flowers was considered finished, the 2 isolation bags were removed.

The bags were looked after during the period of isolation. If the outer bag was damaged it was replaced with a new one. If the inner bag was damaged, the isolation in question was left out of the experiment.

Table 6
Nuts from „control bags", i. e. bags containing emasculated unpollinated flowers. Criticism of the technique.

Year	Mothertree no.	Nuts collected		Remarks
		good	barren	
1948	17	4*)	2	*) Pollen releasing started before isolation. Experiment left out
1948	25	11*)	15	*) Female flowers receptive when isolated. Experiment left out
1949	8	0	20	
1949	9	0	29	
1949	9	0	28*)	*) One year old pollen injected
1951	26	0	2	
1951	16	(5)*)	50	*) The 5 good nuts were found in bags with forgotten male catkins, - consequently selfed nuts
1951	17	1*)	23	*) Must be due to mistake: e. g. hole in the bag, forgotten male catkins, - consequently selfed nuts
1952	18	0	25	
1952	19	0	225*)	*) Single bags
1952	19	0	290	
1952	20	0	86	
1952	20	0	36*)	*) One year old pollen injected
1952	9	0	116	
1952	9	0	85	
1952	8	0	14	
1952	23	0	35	

At various points the technique in 1948 was little different from the description above, and therefore this year's results are considered separately in the following account.

Socalled "control-bags" in which the twigs were emasculated in the normal way, but no pollen injected, were used to determine if the method was safe. In 1948 and 1949 we had only a few "control-bags", while many were used in 1951 and 1952. The theoretical possibility, that the pricking of the hole in the inner bags, which is necessary to carry out the pollination, should give admittance for air borne pollen, is considered insignificant. A glance at the pollinations with one year old pollen in 1949 and 1952 will confirm this point of view. These pollinations gave no good and respectively 28 and 36 barren nuts (table 6).

As appears from table 6 the method can be considered quite safe. When foreign nuts can be kept down at a quantity of about 1 per thousand, the results will not be affected for all practical purposes. It is an omission that only a few control-bags were used in 1948 and were lacking in 1950. In this paper, however, we have left out some experiments from 1948 in which the female flowers proved receptive before the isolation. The few control-bags were actually used in doubtful cases and proved by giving some nuts with kernel that the isolation had been too late (table 6).

The fact that single bags, mostly without control-bags, were used in 1948, and the fact that hard weather conditions made it necessary to change some of the bags, when the pollination took place, introduces a point of uncertainty. That single bags may be adequate appears from the results from tree no. 19, 1952, given in table 6. We judge that the possibilities of foreign open pollination during the changing of the bags are small, at least not big enough to alter the main result. This appears e. g. from the fact that selfpollination bags, which, following table 5, had small fertilization percentages were also changed. Even if we do not think that the said points of uncertainty are sufficient to change the conclusions of the experiments, we have only included such controlled pollinations from 1948 showing high fertilization percentages. The results of the countings of lateral leaf veins in table 9 do not indicate foreign nuts in the crossings *Fagus sylvatica* × *Fagus orientalis* from 1948.

In spite of the fact that no control-bags were used in 1950, the isolation must be regarded as certain, because it took place before the pollen dispersal of beech began. With the background of our experience with double bags from 1951 and 1952 no doubt exists about the certainty of the 1950 pollinations.

B. Species Crossings

Fagus sylvatica × *Fagus orientalis:*

The method described has particularly been applied to species crossings with the object of obtaining heterosis. Most of the crossings were between *Fagus sylvatica* and *Fagus orientalis.* Table 7 gives the results of the most important experiments.

It appears that the two species cross easily, a fact which is in accordance with statements from the literature about the occurrence of intermediate forms at the merging of the natural ranges of the two species.

When the column giving numbers of plants in 1950 from the 1948 pollinations is studied, the great difficulty of making progeny tests from controlled beech pollinations is evident because of the limited number of plants one gets even from rather large scale and time-consuming experiments. This is mostly due to the small number of seeds per isolation bag (in contrast to the conifers), but also due to difficulties of storing the nuts, and to losses of plants in the nursery and at transplanting. In spite of great care beech has proved to be a rather difficult species to handle.

The progenies from the crosses are now being tested in comparison with open pollinated progenies of the same mothertrees. Unfortunately we did not get sufficient open pollinated plants from the rather young fathertrees to make the test complete. It is yet too early to judge the value of the hybrids in cultivation. The material will only be large enough to prove this if there are striking differences in vigour. Nevertheless we have measured the heights of

Table 7

Controlled cross pollinations. — *Fagus sylvatica* × *Fagus orientalis.* — To compare efforts (number of bags) to results (number of good nuts and plants). Notice per cent fertilization.

S.-no	Year of Pollination	Mothertree	Fathertree	nuts collected			number of bags	plants 1950	Remarks
				good	barren	% good			
S. 1645/49	1948	F. s. no. 3.	F. o. no. 2.	118	60	66	30	11	
S. 1650/49	1948	F. s. no. 23.	F. o. no. 1.	62	11	?*)	65	21	*) many nuts lost
S. 1653/49	1948	F. s. no. 27.	F. o. no. 4.	424	79	84	100	110	
S. 1659/49	1948	F. s. no. 28.	F. o. no. 3.	79	14	74	27	35	
								1953	
S. 2351/53	1952	F. s. no. 19.	F. o. no. 1.	444	377	54	150	459	*) single bags
	1952	F. s. no. 19.	F. o. no. 1.	289	65	82*)	40		
S. 2352a/53	1952	F. s. no. 19.	F. o. no. 2.	24	170	12	30	12	

Table 8

Heights of hybrids of *Fagus sylvatica* × *Fagus orientalis* compared to those of plants originating from open pollinations of the same mother-tree of *Fagus sylvatica.*

S. no.	mother-tree *F. sylv.* × father-tree *F. ortl.*	1950				1953			
		number of plants	mean height cm	height difference	3 × mean error in height differences	number of plants	mean height cm	height difference	3 × mean error in height differences
S. 1653/49	no. 27 × no. 4	110	20.6	3.4	2.5	75	57.2	13.1	10.5
S. 1654/49	no. 27 × open poll.	173	17.2			74	44.1		
S. 1650/49	no. 23 × no. 1	21	36.0	1.0	6.9	20	76.2	—15.4	20.6
S. 1651/49	no. 23 × open poll.	26	35.0			20	91.6		
S. 1659/49	no. 28 × no. 3	35	20.8	—4.1	4.2	23	40.1	0.6	12.3
S. 1660/49	no. 28 × open poll.	60	24.9			30	39.5		

Table 9
Countings of lateral pairs of veins of leaves on hybrids of *F. sylvatica* × *F. orientalis* to compare with parent trees and their progenies after free pollination. Showing intermediate numbers of veins on hybrids.

Fathertree or Mothertree or Progeny	Number of lateral pairs of veins	Character and treatment of the material
F. sylv. no. 27	7.0 ± 0.2	50 leaves, 5 from the tips of 10 shoots*)
F. ortl. no. 4	9.9 ± 0.5	14 „ , all from one shoot*)
S. 1653/49. *F. sylv.* no. 27 × *F. ortl.* no. 4	8.7 ± 0.3	100 „ , 5 from 20 plants, tips of shoots**)
S. 1654/49. *F. sylv.* no. 27 × open poll.	7.2 ± 0.2	100 „ , 5 „ 20 „ , „ „ „ **)
S. 1686/49. *F. ortl.* no. 4 × open poll.	10.1 ± 0.3	51 „ , 17 „ 3 „ , „ „ „ *)
F. sylv. no. 23	6.6 ± 0.3	50 „ , 5 „ the tips of 10 shoots*)
F. ortl. no. 1	10.3 ± 0.3	50 „ , 5 „ „ „ „ 10 „ *)
S. 1650/49. *F. sylv.* no. 23 × *F. ortl.* no. 1	8.8 ± 0.3	100 „ , 5 from 20 plants, tips of shoots**)
S. 1651/49. *F. sylv.* no. 23 × open poll.	7.3 ± 0.2	100 „ , 5 „ 20 „ , „ „ „ **)
F. ortl. no. 1 × open poll.	lacking	
F. sylv. no. 28	7.0 ± 0.3	50 „ , 5 „ the tips of 10 shoots*)
F. ortl. no. 3	9.6 ± 0.3	50 „ , 5 „ „ „ „ 10 „ *)
S. 1659/49. *F. sylv.* no. 28 × *F. ortl.* no. 3	8.5 ± 0.3	50 „ , 5 „ 10 plants, tips of shoots*)
S. 1660/49. *F. sylv.* no. 28 × open poll.	7.4 ± 0.2	50 „ , 5 „ 10 „ , „ „ „ *)
F. ortl. no. 3 × open poll.	lacking	

**) Counting only on one side of the midrib
*) Counting on both sides of the midrib

the progenies in 1950 and 1953. The results of these measurements appear in table 8. At present it can only be said with certainty that the mean height of the cross, S. 1653, is bigger than that of the pure *Fagus sylvatica*, S. 1654. Our most numerous material happens to consist of S. 1653 and S. 1654, and even if we get no certain height differences in the two other cases, there seems to be a possibility of a moderate heterosis which, however, does not compare with well known examples of forest tree breeding. On the other hand the height differences obtained here may not be due to a species cross heterosis. The combining abilities of the individuals in question are also of great significance.

From previous small introductions of *Fagus orientalis* to Western Europe it has been reported that the juvenile growth is faster than that of *Fagus sylvatica*. In the Hørsholm Arboretum we have had the same experience from seedlings and plants lined out in the nursery. As mentioned above the hybrid has not shown strikingly faster juvenile growth than *Fagus sylvatica*, and so should be expected to be inferior to *Fagus orientalis* in this respect.

In the summer 1952 it was found that the number of lateral leaf veins of the hybrids were intermediate between those of the parent trees. The same relationship was found to the open pollinated offspring from the father- and the mothertrees. The results of these veincounts appear in table 9. The counts were carried out as accurately as possible on the often rather scarce material.

Fagus grandifolia × Fagus sylvatica (Also Fagus sylvatica × Fagus grandifolia and Fagus grandifolia × Fagus orientalis): —

In 1948, 50 and 52 pollen of *Fagus grandifolia* was received from U. S. A. Each time, however, it arrived a little late in the season, and the crossing experiments did not succeed.

In 1948 samples of pollen of *Fagus sylvatica* and *Fagus orientalis* were sent to dr. C. Heimburger, Southern Experiment Station, Ontario, Canada, who kindly carried out controlled pollination of 100 female flowers of one *Fagus grandifolia*. Five nuts with kernel were obtained and one nut of each cross germinated, but the plants died rather soon. For various reasons it might be suspected that the nuts were open pollinated. — Dr. Heimburger reckoned, that the female flowers were only receptive for 6 days, and thus it is not certain that the crosses were actually obtained.

In 1951 2 young grafts of one *Fagus grandifolia* from Connecticut, U. S. A., flowered at Hørsholm with about 20 female flowers. Unfortunately these were noticed too late for making pollinations. There was a faint possibility of open pollination with *Fagus sylvatica* as father. 1 nut with kernel was harvested, but it did not germinate.

In 1952 3 grafts of the same clone flowered again and the female flowers were pollinated with *Fagus sylvatica* without isolation in bags. The small male flowers seemed to be abnormal and did not release pollen although the pollensacs contained pollen. 24 female flowers were pollinated resulting in 16 barren and 8 good nuts. 2 out of the 8 good nuts were cut through in oder to make sure that they contained a sound kernel. The rest were sown, but none germinated.

So, although the two species seem interfertile to a limited extent, no plants exist of the cross.

C. *Crosses within Fagus sylvatica*

Although the main purpose of the pollinations was to produce the above mentioned species crosses, controlled pollinations were also carried out between individuals of *Fagus sylvatica*. The purpose of these was mostly to solve problems about the pollination technique. Table 5 gives fertilization percentages of some of the technically best experiments. It appears that it is possible to undertake successful cross pollination even if it must be stressed again that it is difficult to obtain large progenies.

Summary

During the years 1948-52 flower observations and controlled pollinations in *Fagus* were carried out in connection with the tree breeding work at the Hørsholm Arboretum under the guidance of dr. C. SYRACH LARSEN.

The most thorough flower investigations which were connected with leafing observations were carried out in Kew Gardens in England 1950. The main result is that the females begin to flower shortly after leafing-out and the males when the leafing-out has finished. It is stressed that many trees differ from the mean, and even if beech normally is metandric, protandric individuals are found (table 2 and 3). The degree of metandry varies with the weather conditions, so that a warm and dry spring results in a shorter period of metandry than a cool and humid spring. It is also shown that the north side of a tree flowers later than the south side.

From a series of experiments it appears that unpollinated female flowers of *Fagus sylvatica* are receptive to pollen for a period of 10—14 days. They are therefore receptive all the time the male flowers are releasing pollen and even later (table 4).

A considerable number of experiments have been carried out to investigate to what degree selfpollination takes place. The results vary from tree to tree and also from year to year. The main conclusion is that *Fagus sylvatica* shows a rather high degree of selfsterility, although individual trees may be selffertile to a fairly high degree (table 5). A low fertilization percent is also found in the mast from well isolated trees.

The technique of controlled pollination is described. Control-bags — i. e. emasculated, unpollinated bags — show that the technique can be considered quite safe (table 6). The normal development of involucre and nuts in the control-bags proves that *Fagus sylvatica* is parthenocarpous.

The success of the species cross between *Fagus sylvatica* and *orientalis* has been good (table 7). Through counts of lateral veins of leaves it is shown that the plants raised from these crossings are hybrids (table 9). The attention is drawn to the difficulty of obtaining large progenies by controlled pollinations, owing to the small number of nuts per bag, losses during storage and in the nursery.

The mean heights of unfortunately rather small progenies of *Fagus sylvatica* × *Fagus orientalis* and pure *Fagus sylvatica* are compared (table 8). No clear heterosis can be discerned in the hybrids, and attention is called to the influence on the progenies of the combining ability of the individual parent trees and of the faster juvenile growth of *Fagus orientalis*.

Attempts have been made to cross *Fagus grandifolia* and *Fagus sylvatica*. Although a few good nuts were obtained, it has not yet been possible to raise any plants.

Within *Fagus sylvatica* controlled pollinations were carried out mostly in order to solve technical pollination problems (table 5).

Zusammenfassung

Titel der Arbeit: *Blütenbeobachtungen und kontrollierte Kreuzungen bei Fagus.* —

Während der Jahre 1948 bis 1952 wurden im Zusammenhang mit dem Züchtungsprogramm des Arboretums Hørsholm unter der Leitung von Dr. C. SYRACH LARSEN Blütenbeobachtungen und kontrollierte Kreuzungen an *Fagus* ausgeführt.

Die umfassendsten Untersuchungen über Blüte und Belaubung wurden im Kew Garden, England, 1950, vorgenommen. Daraus ergibt sich, daß sich die ♀ Blüte kurz nach dem Blattaustrieb und die ♂ Blüte nach Abschluß des Blattaustriebs entfaltet.

Es muß aber betont werden, daß viele Bäume von dieser Regel abweichen und, obwohl die Buche normalerweise metandrisch ist, protandrische Individuen gefunden werden (Tab. 2 und 3). Der Grad der Metandrie ist abhängig vom Wetter, so daß in einem warmen und trockenen Frühjahr die metandrische Periode kürzer ist, als in einem kühlen und nassen Frühjahr. Außerdem wurde festgestellt, daß an der Nordseite der Bäume die Blüte später einsetzt als an der Südseite.

Aus einer Versuchsserie ging hervor, daß unbestäubte ♀ Blüten von *Fagus sylvatica* 10 bis 14 Tage für den Pollen fängisch bleiben. Sie sind also während der ganzen Zeit der ♂ Blüte und sogar noch länger für Pollen aufnahmefähig (Tab. 4).

Um den Grad der Selbstbestäubung festzustellen, wurde eine große Anzahl Untersuchungen durchgeführt, aus denen sich ergab, daß Unterschiede zwischen den einzelnen Bäumen und in den verschiedenen Jahren bestehen. Es zeigte sich aber, daß *Fagus sylvatica* im allgemeinen zu einem hohen Grade selbststeril ist, wenn auch einzelne Individuen eine verhältnismäßig hohe Selbstfertilität haben (Tab. 5). Eine geringere Fruchtbarkeit findet sich außerdem bei einzeln stehenden Bäumen.

Die Technik der kontrollierten Kreuzungen wird beschrieben. Kontrolltüten — d. h. solche mit kastrierten und unbestäubten Blüten — zeigten, daß die Technik als sicher angesehen werden kann (Tab. 6). Die normale Entwicklung des Involucrums und der Bucheckern in den Kontrolltüten ergaben, daß *Fagus sylvatica* parthenocarp ist.

Der Erfolg der Artkreuzung zwischen *Fagus sylvatica* und *Fagus orientalis* war gut (Tab. 7). Durch Auszählung der Blattnerven wurde nachgewiesen, daß die aus den Kreuzungen hervorgegangenen Pflanzen Bastarde sind (Tab. 9). Besondere Schwierigkeiten bestehen darin, genügend große Nachkommenschaften von den kontrollierten Kreuzungen zu erhalten, was durch die geringe Anzahl Samen pro Tüte, sowie durch Verlust bei der Lagerung und in der Baumschule bedingt ist.

Die Mittelwerte der Höhe der leider kleinen Nachkommenschaften von *Fagus sylvatica* × *Fagus orientalis* und der der reinen *Fagus sylvatica*-Kreuzungen wurden miteinander verglichen (Tab. 8). Eine sichere Heterosis der Bastarde konnte dabei nicht festgestellt werden. Beachtung verdient daher möglicherweise mehr die Kombination der individuellen Fähigkeiten und das Jugendwachstum der *Fagus orientalis.*

Bei Kreuzungsversuchen zwischen *Fagus sylvatica* × *grandifolia* wurden zwar einige Samen erhalten, aus denen aber keine Pflanzen angezogen werden konnten.

Die Kreuzungen innerhalb von *Fagus sylvatica* wurden hauptsächlich zur Klärung der technischen Kreuzungsbedingungen durchgeführt (Tab. 5).

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Referate

Arnborg, T., and Hadders, G.: **The Society for Practical Forest Improvement.** (Die Gesellschaft für praktische Waldverbesserung.) Svenska Skogsvårdsför. Tidskrift 51, 172—182 (1953).

Zur besseren Durchführung eines gemeinsamen Aufforstungsprogrammes und zur Vereinheitlichung der Bestandespflege bei einem Teil des ausgedehnten privaten Waldbesitzes in Schweden ist 1941 die „Gesellschaft für praktische Waldverbesserung“ gegründet worden. Der Gesellschaft gehören heute 14 Waldbesitzerfirmen an, die zusammen etwa 3 Millionen ha Wald bewirtschaften. — Der vorliegende Beitrag enthält im wesentlichen einen Bericht dieser Institution über dort laufende Arbeiten auf dem Gebiete der Forstpflanzenzüchtung. Die Verfasser schildern zunächst die bisher durchgeführte umfangreiche „Plusbaumauslese“ in den Beständen der Gesellschafter. Sie hat die Registrierung von etwa 1800 Bäumen (vorwiegend Kiefern, aber auch Fichten und Birken) in einem Gebiet zwischen 58° und 67° nördl. Breite ergeben. Davon sind für die Kiefer 350 Individuen als „wirkliche Plusbäume“ in eine besondere Kartei aufgenommen worden. Einige Beispiele für sie werden im Original abgebildet. 2 Diagramme veranschaulichen die überragende Höhe solcher Bäume (meist zwischen 20 und 30 m) gegenüber Durchschnittsnachbarn des gleichen Bestandes. Schlanke Kronenformen wurden bevorzugt, da angenommen werden muß, daß sie gegen Schäden am besten geschützt sind. Der Standraum solcher Formen soll jedoch nicht verkleinert werden. — Von den bereits verkarteten Kiefern stellte man 1952 etwa 7000 Freiland- und 3000 Gewächshaus-Pfropfungen her, die zur Anlage von Samenplantagen Verwendung finden. Eine ältere derartige Plantage in Marksund (etwa 66° nördl. Breite) fruktifiziert bereits. Wegen größerer Ertragssicherheit legt man alle Samenplantagen der Gesellschaft (stets etwa 25 Plusbäume enthaltend) unter den jeweils günstigsten Klimabedingungen des Bezirkes in Küstennähe an. Bei ihrer Begründung werden zunächst von 25 Plusbäumen jeweils 1 Pfropfling, zufallsmäßig durchmischt, im Abstand 7×7 m gepflanzt. Nach Durchführung wird dann die gleiche Serie von 25 Pfropflingen noch ein zweites Mal dazwischen gestellt, und zwar derart, daß niemals Pfropflinge des gleichen Plusbaumes Nachbarschaftsberührung bekommen. Dadurch entsteht als Ergebnis eine Plantage in einem Verband von 5×5 m. Beim Älterwerden der Pflanzung (nach etwa 20 Jahren) kann dann je 1 Pfropfling eines jeden Plusbaumes wieder entfernt werden, ohne daß sich die Qualität ihrer Zusammensetzung ändert. Zur räumlichen Isolierung gegenüber anderen Plantagen oder gleichartigen Waldbeständen sind Abstände von 500 bis 1000 m vorgesehen. Erwartet wird (etwa 10 bis 15 Jahre nach der Begründung) je ha Samenplantage 15 bis 25 kg Saatgut, aus dem sich 1 500 000 Pflanzen erziehen lassen (ausreichend für die Neuanlage von 400 ha). — Kleinere Gesellschafter erhalten 1 bis 2 ha, größere bis zu 20 ha Samenplantagen. Die erste Fertigstellung des Programmes ist bis zum Jahre 1958 vorgesehen. — Neben diesen Arbeiten laufen Nachkommenschaftsprüfungen von 400 Plusbäumen. Ihre Ergebnisse sollen für die spätere Neuanlage von Samenplantagen maßgebend sein (in etwa 25 Jahren auswertbar). Die jetzt im Aufbau befindlichen Plantagen aus guten Phänotypen sollen aber den einstweiligen Saatgutbedarf decken. Außerdem sind zur Samengewinnung auch einige „Plus-Bestände“ festgelegt worden, die, soweit möglich, beerntet werden sollen. — Zur Prüfung alles gewonnenen Saatgutes stehen der Gesellschaft zur Zeit 45 eigene Pflanzgärten mit einem Gesamtareal von 55 ha zur Verfügung. Dort können 60 Millionen Jungpflanzen angezogen werden, die zur Bestellung von 15 000 ha ausreichen. — Versuche mit fremden Holzarten sind geplant. — Zur Unterrichtung ihrer Mitglieder wird von der Gesellschaft ein Informationsdienst mit einem Mitteilungsblatt unterhalten. Seitz

Rünger, H. G., und Klauditz, W.: **Über Beziehungen zwischen der chemischen Zusammensetzung und den Festigkeitseigenschaften des Stammholzes von Pappeln.** Holzforschung 7, 43—58 (1953).

Von der These ausgehend, daß ein bestimmter mechanischer Zustand des Holzes durch die chemische Zusammensetzung des Holzes bedingt wird, ergibt sich die Möglichkeit, die „Wertholzgüte“ einer Holzart durch chemische Analyse mittelbar zu beschreiben. Dieser Weg müßte dann gleichzeitig brauchbar sein, um eine Selektion bei der Züchtung auf erwünschte Holzeigenschaften durchzuführen. Dabei ist nicht nur der Cellulosegehalt allein wichtig, sondern auch das Festigkeitsgefüge auf Grund von morphologisch-mechanischen Faktoren. In Verfolg dieser Vorstellungen wurde untersucht, ob und inwieweit bei dem Holz der verwendeten drei Pappelhybriden (*Populus grandis*, *P. marilandica*, Grafhorster Pappel) eine Abhängigkeit der Zugfestigkeit vom Cellulosegehalt, der Druckfestigkeit vom Ligningehalt und dieser Festigkeitseigenschaften vom Zusammenwirken von Cellulose, Lignin und Hemicellulosen festgestellt werden kann. Für die Untersuchungen wurden eigene Verfahren entwickelt, die chemisch-analytische und mechanisch-analytische Reihenuntersuchungen in einfachen Laboruntersuchungen ermöglichen. Die Genauigkeit dieser Methoden wurde an Hand gesicherter Resultate getestet und als ausreichend brauchbar erwiesen.

Es ergab sich, daß an den drei Pappelsorten grundsätzlich eine übereinstimmende Tendenz in der Ausbildung der Zug- und Druckfestigkeitsverhältnisse in Abhängigkeit vom Cellulose- und Ligningehalt festzustellen war. Im einzelnen treten dagegen geringe Unterschiede auf, deren Ursache in der Reaktion der Pflanze auf die mechanische Beanspruchung liegen dürfte, wobei zunächst unentschieden bleiben muß, ob dieser Reaktionsprozeß durch genetische oder Umweltsfaktoren allein oder zur Hauptsache ausgelöst wird. Vermutlich liegt eine noch näher zu analysierende Komplexbeziehung zwischen erblicher Konstitution des mechanischen Gesamtsystems und einer starken Variabilität der mechanisch-chemischen Reaktionsfähigkeit vor. Die Ausbildung von Zugholz nach mechanischer Dauerbeanspruchung von Jungpflanzen weist darauf hin. Im Zusammenhang mit weiteren, notwendigen Untersuchungen über andere, die Holzqualität bestimmenden Erbfaktoren sehen die Verf. in fortschreitender Analysierung der chemischen Zusammensetzung des Holzes eine Möglichkeit, der Züchtung die Handhabe zu einer Auslese auf Grund chemischer und mechanischer Holzanalyse zu geben. Grehn

Lantz, A.: **Knoppympning av tall.** (Knospenpfropfung bei Kiefer.) Skogen 39, 136 (1952).

Bei der Kiefernpfropfung, besonders im schwedischen Norrland, ist man oft gezwungen, mit einer weniger guten Reisqualität zu arbeiten. Da diese Pfropfreiser in der Regel von Plusbäumen stammen, die gute Eigenschaften besitzen, ist es wünschenswert, das einmal eingesammelte Material auch pfropfen zu können. Die bisher üblichen Pfropfmethoden (Seiten-, Seitensteckpfropfung und T-Schnitt) mit ihrem etwas längeren Reis leiden neben anderem nicht selten unter von Pilzen hervorgerufenem Nadelbefall, was ein Gelingen der Pfropfung erschwert oder unmöglich macht. Die in Sundmo, der Norrlandstation des Vereins für Forstpflanzenzüchtung in Schweden, durchgeführten Versuche mit einer Knospenpfropfung an der Kiefer erbrachten gegenüber den bisher üblichen Methoden ein weit besseres Pfropfergebnis. Bei 100 Pfropfungen dieser Art mit ausgesprochen schlechtem Reismaterial wurde ein Anwachsprozent von ca. 70 erzielt, was sonst mit den bisherigen Methoden nicht erreicht worden wäre. Während man bisher von einer Pluskiefer im günstigsten Falle nur etwa