Zusammenfassung

Bei fünfjährigen *Pinus radiata* ist die Bewurzelungsfähigkeit der Nadelbündel von derem Alter beeinflußt. Am besten bewurzelten **12—24** Monate alte Nadelbündel. Das hohe bzw. niedrige Bewurzelungsvermögen von Kurztriebsstecklingen einzelner Kiefern ist auch unter den identischen Ernährungsbedingungen einer Quarzkultur nachweisbar. Die Kurztriebsstecklinge eines Klons zeigten ebenfalls Schwankungen ihrer Bewurzelungsfähigkeit, doch ließen sich hier keine guten oder schlechten „Bewurzeler" nachweisen.

Resumen

La capacidad de arraigamiento de los braquiblastos de *Pinus radiata* de cinco años es influenciado por la edad de los fasciculos. El mejor arraigamiento se obtuvo con fasciculos de **12—24** meses de edad. La alta o escasa capacidad de arraigamiento de fasciculos de pinos individuales se mantiene también bajo el regimen controlado de nutricion mineral en cultivo de quarzo. Las estacas de fasciculos de los pinos de un clon muestran tambien variaciones en su capacidad de arraigamiento. Sin embargo, no se puede comprobar la existencia de buenos o malos „arraigantes" entre los pinos del clon.

Summary

The rooting capacity of short shoot cuttings of 5-year Monterey pine (P. *radiata)* is influenced by the age of the needle bundles. The highest rooting percentages were obtained from fascicles of **12—24** months. The high or low rooting capacity of the fascicles of individual pines was maintained even under the exactly controlled conditions of the mineral nutrition of a quartz culture. The short shoot cuttings of a clone show variations in their rooting capacity also. However, trees with a constant high or low rooting capacity could not be identified from this clone.

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Pollination of Teak (Tectona grandis L.)

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1. Introduction

The *Thai-Danish Teak Improvement Center* was started in January 1965 by agreement between the Thai and the Danish governments (KEIDING **1966).**

The characteristics of teak flowers and the mechanics of pollination were obviously considered of importance for the improvement work and studies of flowering and pollination were carried out during the flowering season of **1965** and continued the following year.

2. The Teak Flower

Teak in northern Thailand flowers from mid July and flowering continues throughout the rainy season until November.

The flowers are perfect, regular, and normally with **6** leaves in the ring. The corolla is white, it is undivided at the lower half, which forms a tube to which the **6** stamens are fixed. It contains a little nectar. The pistil is composed of an ovary with **4** ovules and a style with a forked stigma. Style and stamens are c. **6** mm long, the diameter of the corolla **6—8** mm.

The flowers appear scattered in large panicles *(fig. 1).* One inflorescence may contain several thousand buds, but not all of these develop during the period of flowering which lasts from **2** to **4** weeks. Generally only a few flowers occur at a time, on good days up to a hundred.

The flower opens a few hours after sunrise. At this time the anthers are flat and no pollen is visible. During the following hour they swell and then fully inflated pollen grains appear in small quantities. At midday thick belts of pollen have formed round the anthers.

In the evening of the same day or the next morning either the corolla alone together with the anthers or the complete flower falls off.

3. Control of Pollination

31. Isolation

The flower structure necessitates emasculation of every flower prior to isolation. The development of the antherc suggests that emasculation and isolation may be carried out for a short period after the flower is fully opened.

The appearance of flowers scattered on the inflorescence means that only one or a few flowers situated near each other can be isolated at a time. Taking advantage of the fact that flowers unfold only in the morning it is also possible to carry out isolation effectively by means of bags covering the whole inflorescence and of such construction that they can be taken off and put on frequently for emasculation, pollination and inspection. Both methods have been applied. *Fig. 1* shows a panicle with small bags isolating single flowers. In *fig.* 2 is seen how a complete inflorescence is covered by a large cotton bag stretched over a bomboo skeleton.

In several cases it has been possible to cover two inflorescences from neighbouring trees with one bag (see **413—414).**

32. Pollination period

In studies to determine the optimum period for controlled pollination pollen was applied at several stages of the

Figure 1. — Inflorescence with single flower isolation.

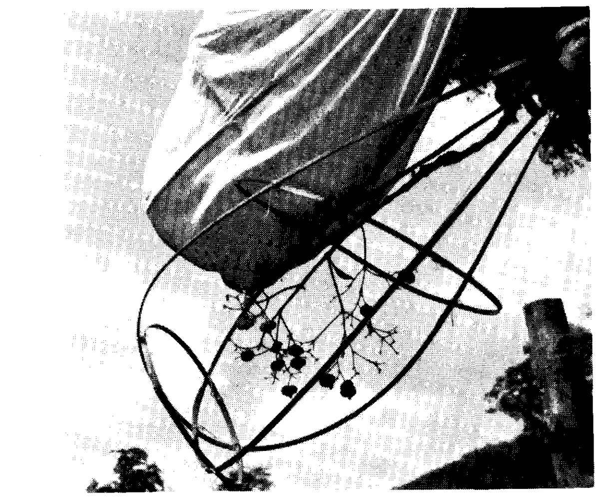

Figure 2. — Isolation by big cotton bags protecting complete inflorescences. The bags are stretched over bamboo skeletons.

flowering cycle. The pollinations include crossings and selfings of 14 trees aged 7—30 years.

For technical reasons it was not possible to study the receptivity of the stigma and the fertility of pollen separately. Nothing was known about the retention of pollen viability during storing and therefore fresh material was applied at every pollination. Consequently one cannot distinguish whether fruit formation is a result of a favourable condition of pollen, of the stigma, or both. Judging by appearance it is the authors' impression that the stigma is receptive during most of the flowering hours and that the variation of successful pollinations is mainly due to different stages of pollen maturity.

The definition of the stages and the results of the pollinations are seen from *table 1.* No fruits have developed in the control bags suggesting that the period employed for isolation is safe and that the bags offer adequate protection against undesired pollination.

The highest percentage of fruits is obtained from pollinations carried out at stage 2—3 and 3, and thus the early afternoon seems the proper time to carry out controlled pollination.

Table 1. — Controlled pollination. Pollen was applied at different stages of the flowers' one-day cycle. — Emasculation and isolation was carried out at stage 1 or 1—2. Every flower was isolated by a small bag, which was cut open for pollination and afterwards sealed with adhesive tape. "Control" indicates flowers which were not pollinated.

Stage	Description	Crosspollination		Selfpollination		Control	
		No. of bags	No. of fruits	No. of bags	No. of fruits	No. of bags	No. of fruits
1	Within one hour after opening, (8.00—9.00 am).	28	1 (4%)	13	0	145	0
1-2		40	9 (23%)	20	0		
2	Pollen grains seen clearly on anthers, (10.00—11.00 am).	37	5 (14%)	32	0		
2-3		86	36 (42%)	113	1 (1%)		
3	Plenty of pollen on the anthers, (12.00—3.00 pm).	105	42 (40%)	114	3 (3%)		
3-4		17	0	8	0		
4	Pollen brownish, (4.00—6.00 pm).	63	10 (16%)	54	1 (2%)		
Total		376	103 (27%)	354	5 (1%)	145	0

33. Application of pollen

The short life and the scattered situation of the flowers, the small amount of pollen available from each and the stickiness of the grains render collection of pollen in large quantities impracticable. For the pollinations described in this report pollen was obtained from newly cut flowers and administered by means of a small brush or it was applied by removing an anther with a pair of tweezers and rubbing it gently against the stigma.

34. Check of fruit development

The small cotton bags which were used to isolate single flowers were furnished with date, time of pollination, and registration number of the male parent. In this way it was possible to keep check on every flower and several pollinators could be used per inflorescence.

When a complete inflorescence was isolated by a single big bag more emasculations could be overcome during the short time at disposal (flowers, which were not emasculated had to be cut off every day). Because of the difficulty in attaching markings to every flower in such a way that they would remain intact until harvest only pollen from one clone was used in each bag.

35. Harvest of fruits

The fruits were harvested c. 4 months after pollination. To reduce loss from breakage (see *table 3)* and to bring down the cost of inspection and maintenance of scaffoldings it would have been convenient to collect the fruits earlier. Early harvest however, may diminish the germination capacity (Eidman 1934).

Germination studies have confirmed that teak fruits need to mature on the tree for some months after they have developed to full size *(table 2).*

Table 2. — Germination percent of fruits harvested after open pollination from 6 trees. 40—90 fruits were collected per tree on each date. They were airdried and stored in tight containers until pretreatment and sowing.

Tree no.	Date of harvest		
	1. 11. 66	5. 12. 66	19. 1. 67
V. 53	5.6	25.0	22.8
V. 59	20.4	22.1	20.4
V. 65	15.9	47.6	62.9
V. 67	0.0	38.8	60.0
V. 68	20.9	37.4	27.0
V. mf	43.7	55.7	67.9
Average	19.4	37.7	48.5

Table 3. — Effect of insects on fertilization. Single bags contained whole inflorescences, double bags two or parts of two inflorescences. In each of the bags for handpollination c. 35 flowers were pollinated.

Type of pollination	Bags put up	Bags intact at harvest	Total fruits	Fruits per inflorescence
Single bags				
(Selfing)				
Supplied with insects	7	6	33	5.5
Without insects	9	6	8	1 3
	16	12	41	3.4
Double bags				
(Crossing and selfing)				
Supplied with insects	6	3	160	26.6
Without insects	5	5	24	2.4
	11	8	184	11.5
Handpollination				
Selfing	15	13	17	1.3
Crossing	15	11	57	5.2
	30	24	74	3.4
Open pollination	10	10	414	41.4

4. Natural Pollination

41. *Investigation procedure*

67 isolation bags of the types described below were put up on 15 trees aged 8—20 years. 1—3 different types were represented on every tree. The bags covered one or two inflorescences. "Single" bags were all put up before flowering had started, in the "double" bags parts of at least one inflorescence had to be removed at the time of isolation. The removed parts could amount to c. 75%.

Insects were enclosed in some of the bags, some were not interfered with at all (wind pollination) and in some bags pollination was carried out by hand.

411. *Single bags supplied with insects.* — The bags isolated one inflorescence. Throughout the period of flowering they were supplied with 5—10 bees every 3—5 days, this being the period the insects could stay alive in the bags. The bees were captured in swarms and kept isolated from teak flowers 1—5 days before they were transferred to the bags.

412. *Single bags not supplied with insects.* — Apart from inspection the bags were left to themselves until fruit harvest.

413. *Double bags supplied with insects.* — The bags contained two inflorescences from neighbouring trees. As long as there were flowers on both inflorescences they were supplied with insects as under (411).

414. *Double bags not supplied with insects.* — Isolation was carried out like (413). Apart from inspection the bags were left to themselves until fruit harvest.

415. *Handpollination.* — The pollination was carried out as described under (33). C. 35 flowers were pollinated in each bag.

416. *Open pollination.* — A number of fruits were collected from bags put up immediately after the inflorescences had finished their flowering.

42. *Results*

Table 3 shows the number of fruits harvested. The distribution to diameter classes is illustrated by the histograms *fig. 3.* The germination results appear in *table 4* (fruits under 6 mm were not tested, a few more fruits were lost during pretreatment).

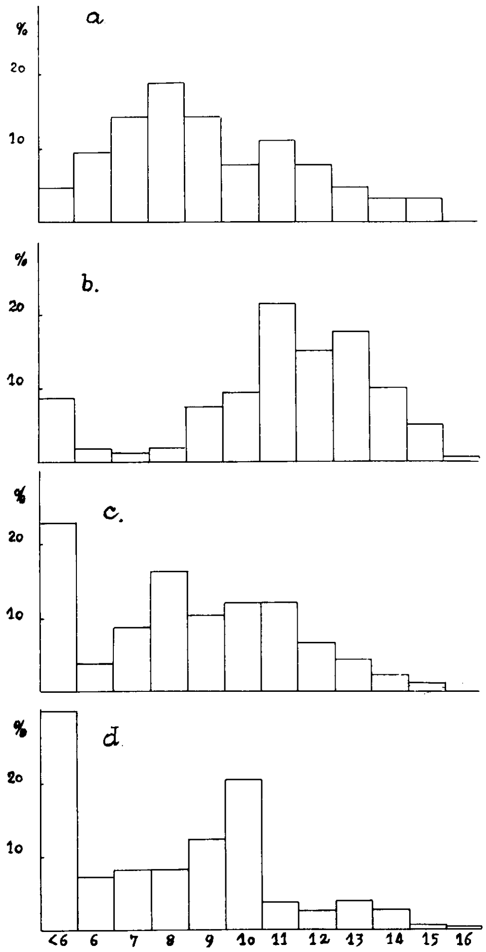

Figure 3. — Distribution of fruits to diameter classes (< 6, 6—16 mm). All fruits included in *tables 1 and 3* were measured. Fruits under 6 mm were excluded when calculating the mean diameter. — a. — *Selfpollination:* 63 fruits, mean diameter 9.3 mm. — b. — *Crosspollination by hand:* 160 fruits, mean diameter 11.6 mm. — c. — *Cross- and selfpollination, double bags:* 184 fruits, mean diameter 9.6 mm. — d. — *Open pollination:* 414 fruit, mean diameter 9.3 mm.

Table 4. — Germination results. The figures indicate number of seed germinated, in percent of number of fruits sown.

	Number sown	Germinated	
		Number	%
Selfpollination	56	7	13
Crosspollination	140	126	90
Double bags	132	42	32
Open pollination	180	120	67

43. Discussion

431. *Pollination method.* — Making allowance for conditions in the isolation bags being not quite natural the results as presented in *table 3* suggest that insects are the main agents of pollination. Wind plays only a minor role.

432. *Regeneration method.* — The figures in respect of fruit formation *(tables 1 and 3)*, fruit diameter *(fig. 3)*, and germination *(table 4)* all point to teak being mainly a cross-pollinating species.

The fact that insects succeeded in producing a relatively great number of fruits in bags where only selfpollination was possible suggests that a normal batch of fruits will contain many selfings. Calculating by the germination percentages *(table 4)* the element of selfpollination in the fruit lot deriving from open pollination amounts to c. 30%. The fruits from double bags are likely to contain a high number of selfings because the flowering periods of the two inflorescences did not completely coincide.

Judging from *table 1 ("control")* fruits will not develop without preceding pollination.

Acknowledgement

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Summary

Studies at the Thai-Danish Teak Improvement Center in Thailand were intended to give information about the flowering habit of teak *(Tectona grandis* L.), to find a technic of controlled pollination, and to establish the natural ways of pollination and generative reproduction.

It appears that the flowering period of the individual flower is one day. Emasculation and isolation may be carried out for approx. one hour after the flower has fully opened. The early afternoon is the best time for pollination.

Insects were found the principal agents of natural pollination although some windpollination may take place.

Teak is mainly a crosspollinating species, but fruits after selfpollination occur. The germination of these fruits is poor compared to that of fruits resulting from crosspollination. Apomixis has not been observed.

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Heritability of Height Growth in Western White Pine Seedlings

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The use of heritability estimates to predict genetic gain in tree breeding programs may be seriously restricted by the fact that combined environmental and nonadditive genetic effects may exert a stronger, less predictable influence than additive gene action on quantitatively inherited traits of tree species. Such an influence almost certainly operates on the trait of growth rate of western white pine *(Pinus monticola* DOUGL.). Genotypic reaction to the environment is of course maximized under varying natural conditions, but for some species it is probably also substantial under the relatively controlled conditions of a nursery, greenhouse, or growth chamber, even if simulation of natural conditions, and not stress, is the imposed environment.

Naturally outcrossing tree species are highly heterozygous and commonly show patterns of natural variation that include varying degrees of genotype-environment interaction and phenotypic plasticity. These phenomena certainly have a genetic basis (BRADSHAW 1965), but they nevertheless represent nonadditivity in the derivation of narrow-sense heritability estimates. Hence, breeders are cautioned that a heritability value applies only to the population, trait, and environment for which the value was determined.

Under such restrictions, heritability values having much general usefulness are difficult to obtain. Published values are useful simply as gross indicators of the feasibility of selection for one or more traits (HANSON 1963; CAMPBELL 1964; NAMKOONG *et al.* 1966).

Information about the relative amounts of additive and nonadditive genetic variances and environmental variance for tree characteristics is rather meager (NAMKOONG *et al.* 1966). Nevertheless, even this is potentially useful and is interesting from the theoretical standpoint. Such information can be made more meaningful by analysis of the heritability concept itself, using actual data. Answers are needed to such questions as these: How do the components of variance for a given population vary over typical site or age gradients? What changes in variance components can be expected from use of realistically different populations for their derivation? — from use of male and female parents from different populations? — from use of different males and females from the same population? — from variation in the number of male or female parents within practical limitations for forest trees? Some answers may be available from investigations of growth rate of progenies of western white pine.

Breeding for blister rust resistance in western white pine in the Intermountain region requires investigations of growth and quality traits to assure that rust resistant progenies are not inferior from these standpoints. Because of the wide variety of macro- and micro-environments to which this species is apparently adapted, we are continually seeking knowledge about genetic control over white pine traits other than resistance.

This study presents the components of variation in juvenile height growth of 1- and 2-year-old progenies from a new experiment and compares the results with those from

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