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Fruit Dispersal of Dipterocarps

By

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Summary : The fruit dispersal of *Shorea contorta* VID. was demonstrated in the Makiling forests, College of Forestry, the University of the Philippines at Los Baños in 1979 as the basic study of biological characteristics of dipterocarps for the design of a silvicultural system for the regeneration of dipterocarp forests. And, with the results in the past related reports, the fruit dispersal of dipterocarps was discussed.

Most dipterocarp fruits are winged and so the matured fruits have been supposed to be distributed far from the mother tree by wind. However, the results for *Shorea contorta* indicated that the fruit-fall of individual mother trees continued for about one month and over 90% of viable fruits were dispersed within 30 m from the mother tree in the forest. Though there are some exceptional cases of the far-dispersal of dipterocarp fruits by storms, rainshowers, and other agents, an analysis of all available data seems to indicate that the dispersal of viable dipterocarp fruits and the succeeding seedling settlement for natural regeneration will not be reliable far over around 30m from the mothertree under normal wind condition in the closed forest despite of much variation in the fruit and fruit-wing properties of different species.

Introduction

The fruit-wings of dipterocarps are recognized as the 5 sepals in the fruit-initiating stage and thereafter the sepals develop largely and lignify in so many-nurved 2 to 5 wings[5]. With some exceptions, generally, there are 5 wings in genus *Dryobalanops*, 3 fully developed longer than the other 2 rudimentary shorter wings in genera *Parashorea*, *Pentacme*, and *Shorea*, and 2 wings only develop in genera *Anisoptera*, *Dipterocarpus*, and *Hopea* as shown in Photos 1~7. Accordingly, the number of fruit-wings with the degree of union on the bases of calyx-lobes with one another and with fruit (nut) and the relative lengths of 5 calyx-lobes are considered as one factor for identification of each dipterocarp species[19].

In the early stage of fruit maturation, the sepals are observed in different colors, light-green, scarlet, purple, or red depending on species with similar green color of pericarps, and these colors turn in light-brown with the progress of fruit maturation and then in golden brown finally[20]. As the color-change of sepals usually occurs before the change of pericarps from green to brown, the pericarps of freshly fallen fruits are sometimes seen still with a green color[7]. And, for dipterocarps with short-survival fruits, the browning of sepals is the important external indicator to know the best time for collection of full and sound fruits.

In the practice of the fruit handling and nursery works, the fruit-wings of dipterocarps are rather troublesome for transportation, sowing, and the preparation of wider nursery beds than usual. And if the fruits are treated after plucking the wings off, it is inevitable that the notorious short-survival of dipterocarp fruits of 2 to 3 weeks under normal condition will

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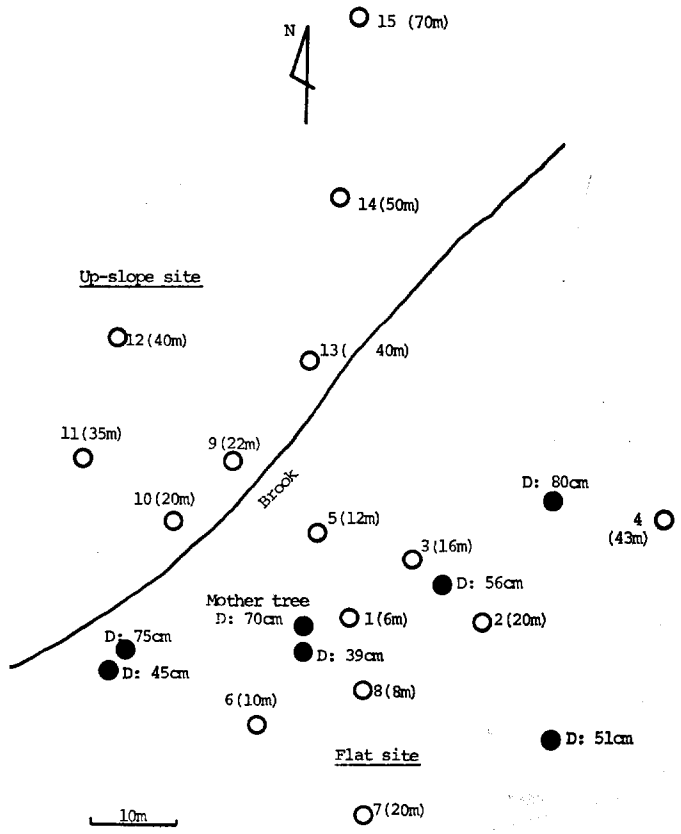
result in the decrease of the seedling production. The matured calyx-lobes are leathery and, in some species, especially in most *Anisoptera*, *Dipterocarpus*, and *Dryobalanops* species, they are usually united with one another and with fruit. After germination, the calyx rapidly integrates but the dead or damaged (mostly by weevils) fruits may retain their form for a considerable period[19]. And, accordingly, the plucking work of wings from nut itself is extremely laborious and time-consuming even with a knife or a pruning hook for dipterocarps.

Under windy condition, the large fruit-wings have the effective role of the fruit dispersal of dipterocarps[5].

On the other hand, the production and dispersal of dipterocarp fruits have the advantage of making feasible the establishment of practical silvlculture management system in virgin and secondary dipterocarp forests. Regretfully, the biological information on dipterocarps is still obscure and so the biological analyses of dipterocarps and their forests will be urgently needed for future successful management of them prior to more severe exploitation of the remaining dipterocarp forests.

Family dipterocarpaceae has 16 genera and about 600 species throughout the world, and they are mostly distributed in the Southeast Asia, particularly in the tropical rainforests



Remarks : ● ; *Shorea contorta*, D ; Diameter
○ ; Location of traps, ( ) ; Distance from mother tree, 1～15 ; Trap No.

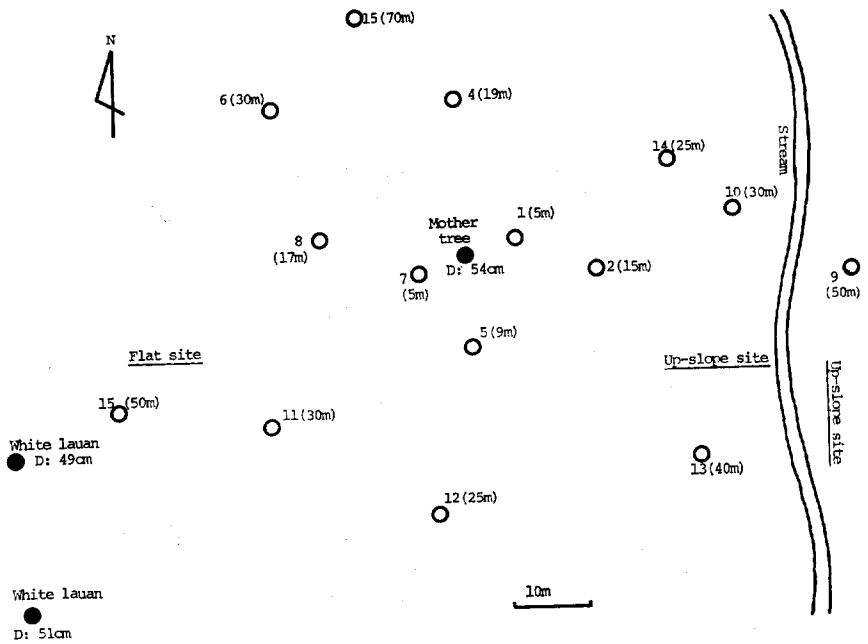
Fig. 1　Location of Fruit-traps for Mother Ttee No. 1.

with constant high temperature and humidity in Indonesia, Malaysia, Philippines, Thailand, and other countries. Among them, the detailed data and the observational descriptions about fruit dispersals have been limited to just the following species : *Anisoptera* and *Dipterocarpus* spp.[22], *D. caudiferus* MERR. and *Dryobalanops lanceolata* BURCK.[11], *Hopea* sp.[22], *Parashorea plicata* BRANDIS[3], *P. tomentelle* (SYM.) W. MEIJER[11)15], *Shorea bracteolata* DYER[22], *S. curtisii* DYER *ex* KING[2], *S. gibbosa* BRANDIS[11], *S. leprosula* MIQ.[2)4)9)22], *S. macroptera* DYER[4)22], *S. parvifolia* DYER[2)22], *S. platyclados* V. SL. *ex* FOXW.[3], *S. ovalis* (KORTH.) BLUME[4)11], and *S. superba* SYM.[11] until now.

Study method and results

In the Makiling forests, the most typical dipterocarp species in the Philippines are growing naturally or in the plantation areas, and some of them had been observed regularly for phenological study since September, 1976. In 1979, *Anisoptera thurifera* (BLCO.) BLUME, *Dipterocarpus grandiflorus* BLCO., and *Shorea contorta* were bearing flowers sporadically and their fruits were collected in the period from April to August, 1979. Among the fruiting dipterocarp trees, the 2 *Shorea contorta* individuals, one in the Mahogany plantation areas along Makiling Mountain Pass and the other in the Makiling Botanical Garden's Nursery Compound, were selected for the study of fruit dispersal.

Shorea contorta is one of the species producing the wood known as white lauan. It is a large tree reaching a height 40～50 m and a diameter of 150 cm, and the most commonly distributed species in the Philippines. The fruit is tomentose and accuminate and has 5 wings of fruiting calyx with unequal length, 3 longer and the other shorter[6].



Remarks : ○ ; Location of traps, D ; Diameter
( ) ; Distance from mother tree, 1～15 ; Trap No.

Fig. 2 Locations of Fruit-traps for Mother Tree No. 2.

Table 1. Number of *Shorea contorta* Fruits Collected in the Traps.

Trap No.	Direction & Distance	July						August						Total
		13	16	19	23	26	30	2	6	9	13	17	20	
〔Tree No. 1〕														
	m													
1	E 6	—	2	4	3	2	2	6	—	1	15	6	—	41
6	S SW 10	—	2	2	—	—	—	—	—	—	—	—	—	4
8	S E 8	—	—	2	—	1	—	—	1	—	2	—	—	6
														(28.2%)51
2	E 20	—	—	1	—	—	—	—	—	—	1	2	—	4
3	N E 16	—	2	2	1	2	4	7	2	1	9	3	—	33
5	N 12	—	3	4	2	3	4	18	5	2	12	6	—	59
7	S S E 20	—	5	—	—	—	—	—	—	—	—	—	—	5
10	N W 20	3	—	2	1	—	2	1	—	—	—	—	—	9
														(89.0%)110
9	N W 22	—	—	—	—	—	—	2	—	—	—	2	—	4
														(91.1%) 4
4	N E E 43	—	2	—	—	—	—	—	—	—	—	9	—	11
11	N W 35	—	—	—	—	—	1	—	—	—	—	—	—	1
12	N W 40	—	—	—	—	—	—	—	—	—	—	—	—	—
13	N 40	—	—	—	—	—	—	1	—	—	1	1	—	3
14	N 50	—	—	—	—	—	—	—	—	—	—	—	—	—
15	N 70	—	—	—	—	—	—	—	—	—	1	—	—	1
														(100.0%)16
Total														181
〔Tree No. 2〕														
1	E 5	2	—	3	—	3	3	3	2	—	6	3	—	29
5	S 9	4	—	1	—	2	2	2	—	—	3	—	—	14
7	S W W 5	3	—	—	2	1	3	1	—	—	2	—	—	13
														(30.9%)56
2	E 15	—	—	—	2	1	2	2	1	—	5	2	—	15
4	N 19	1	—	—	2	2	1	—	—	—	6	—	—	12
8	W 17	—	—	—	2	—	—	—	—	—	—	—	—	2
														(92.4%)29
6	N W 30	—	—	—	—	—	—	—	—	—	—	—	—	—
10	E 30	—	—	—	—	1	2	—	—	—	—	—	—	3
11	S W 30	—	—	—	—	—	—	—	—	—	—	—	—	—
12	S 25	—	—	—	—	—	—	—	—	—	—	—	—	—
14	N E E 25	—	—	—	—	—	—	—	—	—	—	—	—	—
														(95.7%) 3
3	N N W 40	—	—	—	—	—	—	—	1	—	—	3	—	4
9	E 50	—	—	—	—	—	—	—	—	—	—	—	—	—
13	S E 40	—	—	—	—	—	—	—	—	—	—	—	—	—
15	S W W 50	—	—	—	—	—	—	—	—	—	—	—	—	—
														(100.0%) 4
Total														92

Remark : (%) is total % in the circle of 10m, 20m, and 30m from the mother tree.

The 15 fruit-traps [a polyethylene net spread on the bottom of 1 m² wooden frame (10 cm height)] were prepared for each of sample mother trees and they were distributed at random around trees as shown in Figures 1 and 2. Since July 13th, when the fruit started to fall on the site floor from the mother tree, collection and counting the number of collected viable fruits had been continued every 3 and later 4 days until the last fall of the fruits on August 17th. Around the sample trees, there were some other fruiting trees as seen in Figures 1 and 2, but their fruits were distinguished easily from the other by their forms and sizes of fruits and fruit-wings.

The results in Table 1 showed that about 30% of totally collected viable fruits fell within 10 m, almost 90% were gathered within 20 m from the mother tree and there were only 16 fruits (9%) which were collected outside 30 m from the mother tree No. 1. In the mother tree No. 2, the same fruit dispersal trend occured and there were only 5% of totally collected viable fruits outside a 30 m radius from the mother tree.

Approximately 185,000 viable fruits in the sample tree No. 1 and 48,000 in the sample tree No. 2 were produced and their fruit-fall continued for about one month from mid-July to mid-August, 1979.

Discussions

Under constant and continuous observation, the fruit-trap method will be the best way to know the tree fruit or seed dispersal distance directly, but in this method, the distance by secondary dispersal which will be brought by rain water or animals mostly after reaching on the site floor is almost omitted. The estimation by the settled seedlings for the same purpose is applicable anytime and even in the place where the tree phenology is usually unable to be observed and the obtained value includes the secondary dispersal distance to a certain degree. By any method, the exceptionally far-dispersal of the fruits by the gusts of wind, storms, rain-showers, and other agents is impossible to be determined correctly, and, at the same time, it may be negligible for consideration of general design of silviculture management system.

Fortunately, the authors had been continuing the phenological observations of some dipterocarp species individuals in the compound of Makiling forests. The 2 *Shorea contorta* individuals among them were sampled to make sure how far the fruits were dispersed from the mother tree by the periodical and direct counting of the number of viable fruits caught in the fruit-traps. According to our measurements of fruit properties for *Shorea contorta*[21], in any item of fruit and fruit-wing properties, considerable variation was indicated with every individual tree in Table 2 the same as those for *Dryobalanops aromatica* GAERTN. f.[20]. Namely, the mean weight of individual fruit was calculated at the range from 2.4 g at minimum to 6.7 g at maximum among individual trees and, averaged about 5 g. However, the majority of sample tree's fruit with such a considerable variation fell down equally within 30 m from the mother trees under normal wind condition in the forests.

In Table 3, all the data in the past reports in regard to the fruit dispersal distances and the fruit properties of dipterocarps were summarized comparatively. Excepting *Shorea curtisii*, all the other data in Table 3 were surveyed in the forests. The fruit dispersal distance for *Shorea curtisii* which was standing on the mountain ridge at 365 m above sea level was surveyed in the open site by fruit-trap method. Moreover, the viable fruits in this study were only 8% of totally collected fruits including the dead or decayed ones and the author[2] mentioned that the viable fruits fell close to the mother tree. Namely, the value for *Shorea curtisii*

Table 2. Fruit Properties of White Lauan (*Shorea contorta* VIDAL).

Tree No.	Locality	Date of collection	No. of fruits per kg (est.)	Fruit			Fruit-wing				At the time collected	
							Long		Short			
				Weight (g)	Length (cm)	Width (cm)	Length (cm)	Width (cm)	Length (cm)	Width (cm)	M. C. (%)	G. R. (%)
1	Tungao, Agusan del Norte	6-12-'77	254	3.9	3.3	1.4	11.4	2.1	—	—	43.6	100
2	〃 , 〃	〃	227	4.4	2.9	1.6	11.3	2.5	4.0	0.8	42.5	92
3	〃 , 〃	〃	410	2.4	2.7	1.1	9.7	1.7	4.3	0.9	42.1	98
4	Makiling, Laguna	23- 4-'79	207	4.8	3.2	1.6	12.9	2.5	5.5	1.1	53.3	74.7
5	〃 , 〃	17- 7-'79	149	6.7	3.1	2.1	9.2	2.1	3.8	1.2	47.1	78.3
6	〃 , 〃	〃	189	5.3	2.9	1.8	11.4	2.7	4.4	1.2	44.9	84
7	〃 , 〃	20- 7-'79	271	3.7	3.0	1.6	—	—	—	—	41.8	95.3
8	Quezon National Park	10- 8-'79	189	5.3	3.5	1.6	13.4	2.6	5.7	1.0	44.1	96.7
9	〃	〃	220	4.6	3.4	1.5	12.2	2.5	4.4	1.0	46.5	100
10	〃	14- 8-'79	204	4.9	3.1	1.7	14.0	2.9	5.5	0.9	40.2	100
11	〃	〃	156	6.4	3.8	1.7	13.7	2.8	4.6	1.0	50.2	100
Average			225	4.8	3.2	1.6	11.9	2.4	4.7	1.0	45.1	92.6

Remarks : Property values were shown as the mean of 100 fruits or fruit-wings.
M. C.=Moisture Content on the fresh weight basis, the mean of 3 lots (5 fruits each).
G. R.=Germination Ratio by laboratory test, the mean of 3 lots (25 fruits each).

Table 3. Dispersal Distances and Properties of Dipterocarp Fruits.

Scientific name	Dispersal distance			Property*		
	Majority (m)	Maximum (m)	Source	Length (cm)	Width (cm)	Weight (g)
Dipterocarpus caudiferus	30	40	LIEW & WONG 1967	—	—	—
Dryobalanops lanceolata	30	40	〃 〃	1.3～	1.0～	—
Parashorea plicata	—	60	CAGUIOA 1936	1.5～2.8	2.0～	—
P. tomentelle	35	—	NICHOLSON 1965	—	—	—
〃	40	50	LIEW & WONG 1967	—	—	—
〃	40	50	〃 〃	—	—	—
〃	—	60	〃 〃	—	—	—
Shorea contorta	30	45	TAMARI & JACALNE 1979	2.7～3.8	1.1～2.1	2.4～6.7
S. curtisii	40**	80**	BURGESS 1968	1.9	1.0	—
S. gibbosa	30	40	LIEW & WONG 1967	2.0	—	—
S. leprosula	20	50	CHAN 1976	1.5～1.8	0.9	0.5～0.6
S. macroptera	20	50	〃 〃	2.0～2.4	0.8～0.9	1.0
S. ovalis	30	50	LIEW & WONG 1967	2.0～2.1	1.1～1.2	1.0～1.1
〃	20	50	CHAN 1976	2.0～2.1	1.1～1.2	1.0～1.1
S. parvifolia	20	20	LIEW & WONG 1967	1.4～1.8	0.7～0.8	0.3～0.5
S. superba	30	60	〃 〃	1.3	0.8	—

Remarks : * Source ; FOXWORTHY (1938)[6], MEIJER & WOOD (1964)[13], SYMINGTON (1974)[19], TAMARI (1976)[20] and TAMARI & others (1980)[21].

** Including 92% dead and damaged (by weevils) fruits, and germinated fruits only within 30m from the mother tree.

is rather higher compared with other data. Fruit dispersal distance may, more or less, depend on many factors such as species, location, direction and speed of wind, forest site condition, crop size, height of the mother tree, fruit weight, winged or wingless, and others. Among these factors, generally, light or winged fruits are assumed to be dispersed further away from the mother tree than heavy or wingless fruits. Concerning dipterocarps, there are many kinds of fruit in weight, size, and others in Table 4[20)21)]. For example, the average fruit weight is 0.08 g for *Hopea dyeri* HEIM, lightest, over 20 g for *Dipterocarpus dyeri* PIERRE, *D. grandiflorus*, and *D. warburgii* BRANDIS, and 87 g for one *Vatica* sp., heaviest. Despite of so much variations of the fruit properties with species, the fruit dispersal distances of the majority in Table 3 were ranged within 20 to 40 m from the mother tree similarly. The casual observations on *Shorea leprosula*, *S. parvifolia*, and *S. platyclados* suggest that these species produce much more viable fruits in comparison with *Shorea curtisii* but that their distribution range is little, if any, better than that of *Shorea curtisii*[2)], too. Thus, in the absence of wind and even under normal wind condition, the dipterocarp winged fruits fall down almost vertically[11)].

Referring to other species, the wingless fruits of *Fagus crenata* BLUME (standard average weight : 0.15 g) fell mostly under the mother tree's crown or around the crown edge[8)] and the effective fruit dispersal distance for natural regeneration was estimated at up to 5 m outside the crown of the mother tree[18)]. Similarly, the wingless *Quercus crispula* BLUME fruits (standard average weight : 2.4 g) were settled within 2 to 3 m from the crown of the mother tree[10)]. Accordingly, in comparison with such wingless fruits (nuts), the dipterocarp winged fruits (nuts) are dispersed a little more effectively by fruit-wings, which retard the speed of fall by rapid

Table 4. Fruit Properties of Dipterocarps in Different Species.

Scientific name	Fruit			Fruit-wing				Number of Fruit-lots	Locality and Date collected
				Long		Short			
	Weight (g)	Length (cm)	Width (cm)	Length (cm)	Width (cm)	Length (cm)	Width (cm)		
Anisoptera aurea	4.1	2.5	1.9	13.0	2.7	—	—	3	Quezon N. P., Phil.; Aug., 1979
A. scaphula	1.6	1.8	1.5	12.8	2.0	—	—	3	Bentong, Mal.; Aug., 1974
A. thurifera	2.2	1.7	1.5	8.2	1.5	—	—	4	Makiling, Phil.; Nov., 1978 & March, 1980
Balanocarpus heimii	4.2	2.9	1.1	—	—	—	—	2	Ampang & Kepong, Mar.; Feb. & March, 1972
Dipterocarpus baudii	3.4	2.9	1.9	11.3	2.3	—	—	1	Kepong, Mal.; March, 1972
D. crinitus	1.7	2.7	1.1	8.6	1.8	—	—	3	Ampang & Sungai Durian, Mal.; Oct., 1972 & Jan., 1973
D. dyeri	25.8	6.5	3.1	14.5	3.1	—	—	1	Kepong, Mal.; Apr., 1974
D. gracilis	4.6	2.3	2.0	10.2	2.3	—	—	2	Makiling, Phil.; Aug., 1977 & 1978
D. grandifiorus	22.9	5.6	3.9	17.0	4.3	—	—	7	Makiling & Quezon N. P., Phil.; Aug., 1977 & 1979, Sept., 1978
D. hasseltii	—	5.3	3.4	15.8	3.2	—	—	1	Tungao, Phil.; Dec., 1977
D. oblongifolius	0.8	2.9	1.0	9.4	1.5	—	—	1	Kepong, Mal.; July, 1972
D. warburgii	23.8	4.6	3.2	16.8	3.7	—	—	3	Makiling, Phil.; Sept., 1978
Dryobalanops aromatica	5.6	3.2	1.7	6.1	1.8	—	—	8	Kanching, Kepong, & Kuala Lumpur, Mal.; June, 1972, Feb., July, & Aug., 1973
D. oblongifolia	8.7	3.3	2.4	—	—	—	—	2	Kepong, Mal.; July & Aug., 1972
Hopea dyeri	0.1	0.8	0.4	3.4	0.7	—	—	2	Ulu Gombak, Mal.; Sept., 1973
H. foxworthyi	0.2	1.1	0.5	3.4	0.8	—	—	4	Makiling & Quezon N. P., Phil.; Aug., 1977 & 1978
H. helferi	0.1	0.8	0.5	4.2	1.1	—	—	1	Kepong, Mal.; Oct., 1972
H. mengarawan	0.2	1.1	0.4	4.1	1.0	—	—	1	Merlimau, Mal.; Feb., 1972

H. nervosa	1.4	1.9	1.3	12.4	2.5	—	—	1	Kepong, Mal.; July, 1973
H. odorata	0.2	1.0	0.7	4.7	1.0	—	—	6	Kepong, Mal.; Nov., 1972, May & June, 1974
H. sangal	0.3	1.2	0.8	5.9	1.4	—	—	1	Kepong, Mal.; Sept., 1973
H. subalata	1.1	1.8	1.3	—	—	—	—	1	Kepong, Mal.; Oct., 1974
H. wighteana	0.4	1.0	0.8	5.2	1.1	—	—	1	Kepong, Mal.; June, 1972
Parashorea densiflora	7.8	2.3	2.3	—	—	—	—	3	Ulu Gombak, Mal.; Jan., 1973
P. malaanonan	—	2.6	1.8	13.9	1.9	8.0	0.5	1	Sandakan, Mal.; Sept., 1974
Shorea acuminata	0.2	1.6	0.5	5.2	1.0	3.0	0.4	1	Kepong, Mal.; July, 1972
S. assamica	1.1	1.9	1.2	8.8	1.5	5.4	0.5	2	Bukit Tapah & Tersang, Mal.; Jan., 1973
S. bracteolata	0.6	2.1	1.1	8.1	1.4	4.4	0.4	1	Kanching, Mal.; Aug., 1972
S. contorta	4.8	3.2	1.6	11.9	2.4	4.7	1.0	11	Makiling, Quezon N. P., & Tungao, Phil.; Dec., 1977, Apr., July, & Aug., 1979
S. dasyphylla	0.6	1.5	0.9	8.1	1.4	—	—	1	Bentong, Mal.; Jan., 1973
S. gysbertsiana	24.8	5.6	2.9	10.6	3.9	6.6	1.4	2	Kepong, Mal.; June & Aug., 1972
S. leprosula	0.6	1.6	0.9	7.5	1.4	3.2	0.2	2	Bentong, Chikus & Tersang, Mal.; Jan., 1972, Feb., 1973
S. macroptera	1.0	2.2	0.9	9.8	1.5	4.1	0.5	2	Bentong & Tersang, Mal.; Jan., 1973
S. maxima	11.4	4.2	2.0	—	—	—	—	2	Kepong, Mal.; Sept., 1972
S. ovalis	1.1	2.0	1.2	10.2	1.7	7.9	0.6	3	Ulu Gombak, Mal.; Sept., 1974
S. parvifolia	0.4	1.6	0.7	6.4	1.2	2.2	0.2	6	Bentong, Chikus & Tersang, Mal.; Jan., 1972, Jan. & Feb., 1973
S. pauciflora	0.7	1.6	1.1	8.9	1.4	5.3	0.7	1	Bentong Mal.; Feb., 1973
S. platyclados	1.0	2.0	1.0	8.4	1.2	5.4	0.5	4	Bukit Tapah & Kepong. Mal.; Sept. & Nov., 1973, Feb., 1974
S. singkawang	12.1	4.6	2.2	4.0	0.8	—	—	2	Kepong. Mal.; Sept., 1972 & 1974
S. sumatrana	1.4	1.7	1.4	1.2	1.2	1.0	0.8	1	Kepong, Mal.; July, 1972
S. talula	2.3	2.6	1.5	6.9	1.3	—	—	1	Kepong, Mal.; Sept., 1972
Vatica sp.?	87.0	6.7	5.4	—	—	—	—	1	Kepong, Mal.; Sept., 1973

Remarks : N. P. ; National Park, Phil. ; Philippines, Mal. ; Malaysia

gyration during the process of fruit fall and consequently bring fruit far from the mother tree. In the case of *Abies sachalinensis* MAST. (standard average weight : 0.01 g) and *Acer mono* MAXIM. var. *marmoratum* HARA f. *heterophyllum* NAKAI, their winged seeds or fruits dispersed similarly within 20～40 m from the mother trees[16]. Namely, in closed forest, even the winged fruits will be distributed within approximately 30 m from the mother tree similarly despite of much differences in the properties of fruits and fruit-wings for every species and every individual. As CHAN[4] mentioned previously, the inefficient dispersals of winged fruits under normal stand conditions may be due to the checking effects of dense canopies.

Concerning the far-dispersal of winged seeds in the open stand, the typical and detailed prccess can be seen in Table 5 for *Betula Ermanii* CHAM.[14]. *Betula Ermanii*, the important pioneer species in the sub-frigid forests in Japan, produces small seeds which are counted for about 2,500,000 per kg. Field investigations were carried out at the logged-over sites down wind from the mother tree zones. Based on the actual seed dispersal and the subsequent settled seedlings, the effective dispersal distance of *Betula Ermanii* seeds for natural regeneration was estimated at 75 to 100 m from the mother tree zone. In dipterocarps, whose fruits are heavier with larger wings by far compared with *Betula Ermanii* seeds, there are a few observational descriptions of the exceptionally far-dispersal of the fruits, and the lighter fruits among them have been observed to be distributed further occasionally by the gustwinds preceding thunderstorms[18]. According to WEBBER's observation[22], dipterocarp fruits, *Shorea leprosula* and others', which covered the surface of the dam were brought by a little wind storm after once swirling upwards over 400 to 500 feet in the clouds over the mother trees and they were scattered all along the pass out to the boundary (about half a mile away) of Bubu Forest Reserve, West Malaysia. Then, KOCHUMMEN and NG[9] found that *Shorea leprosula* seedlings in

Table 5. Seed Dispersal of *Betula Ermanii* (NAKANO & Others, 1970).

Distance from the Belt of Mother Trees (m)	Fruits per m^2 in			
	Iwanai (Wais)		Kucchan (Niseko)	
	Number	(%)	Number	(%)
10	4, 131	40. 4	1, 273	45. 7
20	2, 368	23. 1	693	24. 9
30	750	7. 3	254	9. 2
40	621	6. 1	271	9. 8
50	224	2. 2	82	2. 9
60	128	1. 3	79	2. 8
70	571	5. 6	46	1. 7
80	442	4. 3	32	1. 2
90	579	5. 6	25	0. 9
100	390	3. 8	20	0. 7
110	9	0. 1	3	0. 1
120	19	0. 2	4	0. 1
Total	10, 232	100. 0	2, 782	100. 0

Remarks : I ; Belt of the mother trees ; 30～35 m × 80～90 m in Iwanai and 30～35 m × 100～120 m in Kucchan.
II : Survey down the current wind.
III ; Survey period ; Sept. 2～Nov. 2 in Iwanai and Aug. 28～Oct. 25 in Kucchan.

the study plot for natural plant succession which was established after farming in Kepong 30 years ago were originated from the nearest mother tree, locating on the hill at the distance of half a mile away from the plot. Thus, dipterocarp fruit-wings are so effective for fruit dispersal under strong wind and, in the mountain ridges or slopes, fruits are also brought down by rainshowers. There are some cases in which the fruits are carried far away by animals. Baur[1] grouped the seedlings of rainforest trees in 3 main classes on the basis of their subsequent behaviors and gave the terms "*secondary species*", "*truely tolerant species*", and "*gap opportunists*". He categorized the slow-growing dipterocarps to belonging to the "*truely tolerant species*" and other dipterocarps to "*gap opportunists*". Of course, these classes are not entirely clear-cut, but, at least, there will be none of dipterocarps in the rainforests belonging to the "*secondary species*" which require almost complete light for survival and growth (and, in most cases, for germination also). Dipterocarps is notorious for the short survival of fruits, intolerant to desiccation, and so it is impossible for dipterocarp fruits to survive and germinate under tropical full sun light condition. On the other hand, the tropical rainforests are characterized by the multiplicity of tree species with several layers of vegetations and, accordingly, there will be severe competition for survival and growth of seedlings among species and individuals if the fruits are produced and dispersed sufficiently. In such natural rainforests, besides the carpetted seedlings in the favorable site condition under the mother tree in lowland and hillfoot forests, the seedlings settled by exceptional far-dispersal of winged fruits of "*truely tolerant species*" or "*gap opportunists*" dipterocarps may be significant for dipterocarps, succession if they will be given the favorable gap in the forest. Paa and Gerald[17] mentioned that the far-dissemination of winged *Shorea almon* Foxw. fruits by rain water is partly explains about their common distribution throughout the Philippines.

After all, the successor's settlements of dipterocarps in the forests are marked surely within around 30 m from mother tree. Though, by clearing site floor including logging the neighbouring trees and shrubs which disturb the normal flight of winged fruits, the furtuer dispersal of fruits up to 40～50 m over 30 m from the mother tree may be expected, the wider gap over 30 m from the mother tree may be unfavorable for short-survival dipterocarp fruits and their seedlings which belong to the "*truely tolerant species*" or "*gap opportunists*". Based on these results of fruit dispersal of dipterocarp species and Chan's result[4] as regards the spatial distribution of adult trees in the dipterocarp virgin forest in Pasoh (dipterocarps' density was 7.2 trees per ha : 0.3 for *Shorea dasyphylla*, 0.9 for *S. acuminata*, 1.4 for *S. macroptera*, 0.9 for *S. lepidota*, 1.0 for *S. parvifolia*, and 2.7 for *S. leprosula*), in order for regeneration to work under shelterwood in practical application at least the 4 mother trees in an unit species per ha are required. As shown in Figures 1 and 2, it will be easy to find the necessary mother trees in the natural and secondary dipterocarp forest at lowland and hillfoot, and if the mother trees of the same species are scarce or maldistributed the loss may be made up by other dipterocarp species with similar timber quality. The mother trees of *Shorea contorta* in Table 1 produced approximately 185,000 and 48,000 fruits despite of the scanty fruiting year, and then the settled seedlings by these fruits are estimated at over 100,000 per ha in the rate of the settled seedlings/total viable fruits for about 50% (usually, *Shorea contorta* fruits have very good germination abilities as seen in Table 2). Accordingly, with the present situation for the regeneration operation of dipterocarp forests, the biggest stumbling block comes in forecasting when the mother trees will bear the necessary fruits, although, the most important hill forest dipterocarps, *Shorea curtisii* and *S. platyclados* are presumed to produce fruits at least every

5 years and most lowland dipterocarps with *Shorea leprosula* and *S. parvifolia* in the hill forests about 2 to 3 years[2]. In any case, in the hill forests and the mountain ridges with scarce- or maldistribution of dipterocarps it will be more efficient to improve them with enrichment planting to a certain degree.

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フタバガキ科樹木果実の飛散*

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摘　　要

フタバガキ科樹木の果実の多くは2～5枚の大型果翼をもっている。もともと5枚の花の萼片のうち，よく発達して木化するものと，途中で退化するものとがあるために，例外もあるが，一般的には *Dipterocarpus* と *Hopea* 属は2枚，*Parashorea*, *Pentacme* と *Shorea* 属は長い3枚と短い2枚，*Dryobalanops* 属は5枚の果翼をもっている。これらの果翼は果実の飛散にきわめて効果的と考えられてきたが，*Shorea contorta* の母樹2本についてトラップ法で果実飛散距離を調べたところ，閉鎖した林内では大多数の果実は母樹から30mの範囲に落下することがわかった。同時に，フタバガキ科果実の飛散に関するこれまでの記録を検討したところ，強風で約1kmとばされたり，傾斜面とか山頂近くの母樹の果実が熱帯驟雨で遠くに流されたり，あるいは鳥，リスなどの動物によって遠くに運ばれたりすることもあるけれども，閉鎖した林内で普通に風が吹いている条件では，いずれも母樹から20～40m内に大多数の果実は落下するという事実が裏付けられた。フタバガキ科樹木果実と同じように堅果ではあるが果翼をもたない日本産のブナやナラの果実は，ほとんど母樹の樹冠下か樹冠の1.5～2.0倍の距離までしか飛散しないが，有翼のトドマツ種子とイタヤカエデの果実の大多数は母樹から20～30mの範囲内に落下する。すなわち，有翼種子または果実は無翼のものにくらべると風によって効果的に運ばれるとしても，閉鎖した林分で通常風の条件下では有翼の効果はそれほど大きくない。

Shorea contorta で得られた結果を基に試算すると，フタバガキ科を主要構成樹種とする熱帯降雨林の天然更新に必要な単一種母樹は最低haあたり4本となる。低地または山麓のフタバガキ原生林または2次林では，これら必要な母樹は容易にみつかる。万一，同一樹種の母樹が不足または偏在するときでも，同じような材質をもつフタバガキ科の他の樹種が活用できる利点もある。これらのことから，当面の問題点は“何時必要充分な果実が得られるかを予測する”ことにある。また，フタバガキ林業が低地林から山岳丘陵地に追いあげられている現状では，必要な母樹が不足または偏在しがちになるので，ある程度植え込みを併用した施業体系を推進してゆくことになろう。

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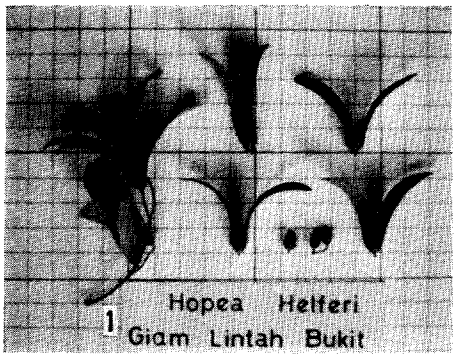

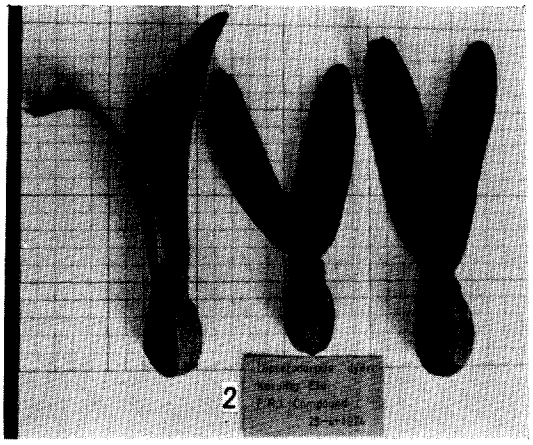

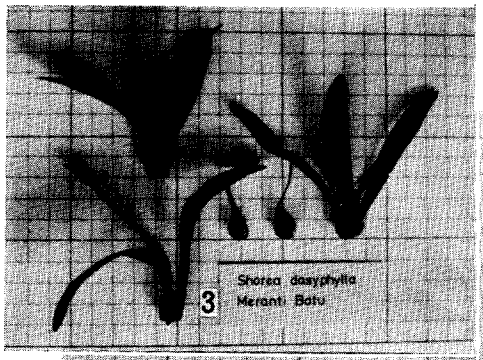

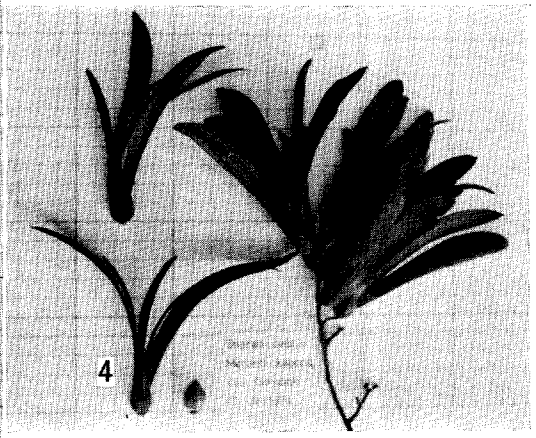

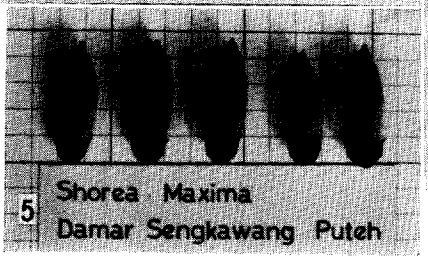

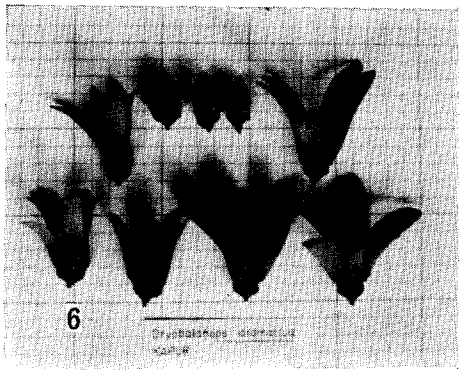

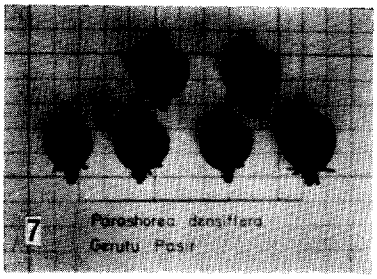

Photos 1～7. Sample Fruits of Dipterocarps
(The least measure : 1×1 cm²)