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FRUITING AND SEEDLING SURVIVAL OF DIPTEROCARPS IN A LOGGED FOREST

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APPANAH, S. & MOHD. RASOL ABD. MANAF. 1994. Fruiting and seedling survival of dipterocarps in a logged forest. The hill dipterocarp forests form the bulk of the production forest in Peninsular Malaysia. These forests are mainly harvested by selective felling. The minimum diameter limit for felling dipterocarps, the predominant timber group, is about 50 - 60 *cm*. Smaller trees and poles are left to form the residuals for the second cut. No attention, however, is paid to seedling regeneration, which will form the third and subsequent cuts. It is assumed that the seedling crop would have survived the logging. Nothing is known about the capacity of the small residuals to fruit and regenerate the forests with new seedling crops. Some observations of a 'localized' fruiting by some residual dipterocarps in a logged-over hill forest are reported here. The fruiting was relatively very poor compared to that observed during mast fruiting in lowland forests. However, the fruit loss due to predation and other causes was lower than expected. The seedlings from such a sporadic fruiting survived well, and 14% of them persisted into the third year following fruit fall. This has positive implications for management of hill dipterocarp forests. Logged forests can potentially regenerate if an adequate number of well distributed mature residual dipterocarps are retained, and the seedling crops are given silvicultural tendings.

Key words: Malaysian forests - logging - dipterocarps - fruiting - insect predation - seedling regeneration - management

APPANAH, S. & MOHD. RASOL ABD. MANAF. 1994. Pembuahan dan kemandirian biji benih dipterokarpa di hutan yang sudah di balak. Hutan bukit dipterokarpa membentuk sejumlah besar dari hutan pengeluaran di Semenanjung Malaysia. Kebanyakan dari hutan ini dituai secara tebang pilih. Had diameter minima untuk tebangan dipterokarpa, iaitu kumpulan balak yang utama, ialah antara 50 - 60 *cm*. Pokok-pokok yang kecil dan kayu jaras yang di tinggalkan untuk membentuk dirian baki bagi tebangan kedua. Bagaimanapun, perhatian tidak diberikan kepada pemulihan anak benih yang bakal membentuk dirian baki bagi penebangan ketiga dan seterusnya. Adalah diandaikan bahawa anak benih dapat bertahan semasa pembalakan. Tiada apa yang diketahui tentang keupayaan pokok baki untuk membuah atau memulihkan hutan dengan anak benih yang baru. Beberapa perhatian tentang pembuahan setempat oleh saki-baki pokok dipterokarpa di hutan bukit sudah dibalak dilaporkan disini. Tahap pembuahan adalah jauh lebih rendah berbanding dengan pembuahan di hutan pamah dipterokarpa. Namun demikian, kehilangan buah yang disebabkan oleh pemangsaan dan atas sebab-sebab lain adalah lebih rendah dari yang dijangkakan. Anak benih daripada pembuahan spora dapat hidup dengan baik dan 14% daripadanya kekal hingga tahun ketiga setelah kejatuhan buah tersebut. Ini memberikan implikasi positif tentang pengurusan hutan bukit dipterokarpa. Hutan yang sudah dibalak mempunyai potensi untuk memulih sekiranya dirian baki dipterokarpa secukupnya di tinggalkan dan anak benih diberikan penjagaan silvikultur.

Introduction

The majority of the studies on the fruiting and seedling regeneration of dipterocarps, the major timber species in Malaysia, are confined to lowland forests (Barnard 1956, Nicholson 1958, Fox 1973, Liew & Wong 1973, and others). But at present most of the productive timber lands are in the hills. Burgess (1975) started observations on the regeneration patterns in the hill forests, but they were mostly in undisturbed areas.

All these studies conclude that following a mast fruiting of dipterocarps, the forest floor is densely covered with seedlings. Each mature tree may produce up to about 250,000 fruits, but the average is about 130,000 (Chan 1980). Fruit predation is very heavy, but still about 45% of the fruits develop into seedlings. The seedling populations decline rapidly under the closed canopy of the natural forest (Barnard 1956, Wyatt-Smith 1958). But whenever a gap opens up, these bank of seedlings take off rapidly. Following logging, successful regeneration depends on seedlings already present on the forest floor and heavier openings do induce faster growth (Nicholson 1958, Liew & Wong 1973).

The above studies were done with a view towards managing forests under a tropical shelterwood system, the Malayan Uniform System. Currently most hill forests are selectively logged. Commercial trees above 50-60 *cm* DBH are harvested, and the second crop is dependent on the smaller residuals. This is where the problem lies. Selective felling pays no attention to seedling regeneration. Therefore, the third and subsequent cuts would depend on the seedling regeneration already existent and future seed crops produced by the residuals left behind.

The resulting question is, will these smaller residuals in logged forests start flowering and fruiting early enough to establish new seedling crops? Towards answering them, we initiated studies on the natural regeneration of logged-over hill forests. During one 'localized' flowering in a logged-over hill dipterocarp forest, many of the dipterocarp residuals, most of which were small trees between 30 to 50 *cm* DBH, did flower (Appanah & Rasol 1990). This is unusual because such small trees rarely flower in undisturbed forests. The next issue is, will this 'localized' flowering lead to adequate fruit crops that can ward off predator pressure? This arises from the observation that isolated fruitings have been wiped out completely by predators (Ashton 1969, Chan 1980). The present study reports the fate of the 'localized' flowering by following up the fruit set and early seedling establishment in a logged hill dipterocarp forest.

Materials and methods

Site

The site is located in Sungai Tekam Forest Reserve, Pahang, Peninsular Malaysia (Lat. 4° 15' N; Longtd. 102° 27' E). The terrain in the area is generally rough, and the altitude about 100 - 500 *m* a.s.l. The vegetation in the area approximated that of the lowland dipterocarp forests, and *Shorea* and *Dipterocarpus* species predominated the emergent layer before the forest was logged. The fruiting trees were located in a clump within a gently sloping valley of the Sungai Tekam River. The site was selectively logged four years before this study.

Fruiting trees and seedlings

A total of 12 fruiting trees were located in the valley. Some trees set very few fruits, less than about 50, and were excluded from the sample. A 90° segment was laid under each tree, originating from the base in one of the cardinal directions. The direction was fitted so as to avoid overlap with neighbouring trees of similar species. The segments were extended up to 25 *m* long; few fruits fell beyond that distance in most cases. For estimation of total fruit set, the number was multiplied by four.

All the fruits of the tree that fell in the segment were scored for the following characteristics: immature, mature and sound, damaged by insects (includes damage from vertebrates), and fungal rot. Fruits of other species could be recognized, and were not collected.

In a neighboring 90° segment of the fruiting tree, the germinating seedlings were followed for survival and establishment. The seedlings were marked with wooden pegs to locate them, and they were followed for 30 months. Only six trees were thus examined for seedling development. Like with the fruits, the seedlings of the different species could be differentiated after some practice.

Results

Fruiting

The fruiting began in June 1987, and fruits were shed mainly in September 1987. Of the 12 fruiting trees in the sample, one was a *Hopea pubescens*, and all the rest belonged to six species of *Shorea* (Table 1). The mean DBH (diameter at breast height) of the 12 trees was 49.8 *cm* (Table 1). While the majority of the trees in the sample were between about 32 to 58 *cm* DBH, one exceptional relic was about 84 *cm* DBH. It was not logged.

The number of fruits (crop) set by the trees varied considerably. *H. pubescens* set the highest number of fruits, with just above 14,000 (Table 1; note that the figure represents that counted from one segment only). The rest of the dipterocarps, five *Shorea* species, produced about 2,300 or fewer fruits. One particular tree produced only 88 fruits. The mean number of fruits collected under each segment was about 2,300. The estimate for the four segments will be 9,200, the average number of fruits produced by each tree in the clump.

Not all the fruits set were sound. At the beginning, many immature fruits were aborted for no apparent and visible causes. Of the mature fruits that fell, some harboured insects (weevils) at various stages of development, from larvae, pupae, or adults. In some instances the adult insects had already left, leaving behind an empty fruit case. In addition to the insects, some of the fallen fruits appeared to have been attacked by vertebrates. Teeth marks were visible on the fruits. These were few and were lumped into the category of losses due to insect predation. Next, there were fruits that appeared fully developed, but did not germinate at all. They appeared to be infected by a fungus, and the cotyledons turned bluish. The fruit rotted rapidly on the forest floor following fruit shedding.

Table 1. The number of fruits set during a 'localized" fruiting by a small population of dipterocarps in a logged hill dipterocarp forest (Sungai Tekam F.R.). Fruit loss due to insects, fungi, and those that fell immaturely are given

Species	DBH (*cm*)	No. of fruits				
		Sound	Insect	Fungi	Immature	Total
Hopea pubescens	42.7	12222	508	316	990	14036
Shorea dasyphylla	44.8	616	39	24	279	958
S. lepidota	54.3	2132	51	17	183	2383
S. lepidota	32.3	62	4	0	22	88
S. leprosula	51.5	177	11	8	63	259
S. leprosula	43.7	848	45	41	218	1152
S. leprosula	38.2	153	16	6	77	252
S. macroptera	54.4	1488	101	87	683	2359
S. macroptera	57.8	1384	275	12	260	1931
S. macroptera	38.5	915	125	19	388	1447
S. parvifolia	54.9	487	38	14	268	807
S. resina	84.4	1480	27	29	536	2072
Total	597.5	21964	1240	573	3967	27744
Mean	49.8	1830.3	103.3	47.8	330.6	2312.0
%		79.1	4.5	2.1	14.3	100
Total per tree (x 4)		7321.3				9248.0

Note: The fruits falling within a segment, with 25 *m* radius from the base of the tree, and 90° spread, were examined. The number of fruits should be multiplied by four to represent the full production of each tree.

For the whole population, 14.3% of the fruit crop was aborted prematurely, 4.5% was predated by insects (and vertebrates), and about 2.1% was lost to fungal infection. The number of sound fruits and crop size appear strongly related, and it can be expressed in a simple linear regression with $r^2 = 0.9972$, a slope of 0.88, the intercept at -205.4, and a standard error of 185.8 (Figure 1). No other such straightforward relations could be detected.

Seedling

For the six trees whose seedling populations were followed, an average of about 1,890 seedlings were found in the 25 *m* radius segment (Table 2). For the whole tree, the estimate is about 7,564 seedlings. The seedling populations declined rapidly, and before the end of the third year (30 months), seedling populations declined rapidly, and only 14.3% of the original population survived. The average number of seedlings left under each tree was estimated at 1,084.

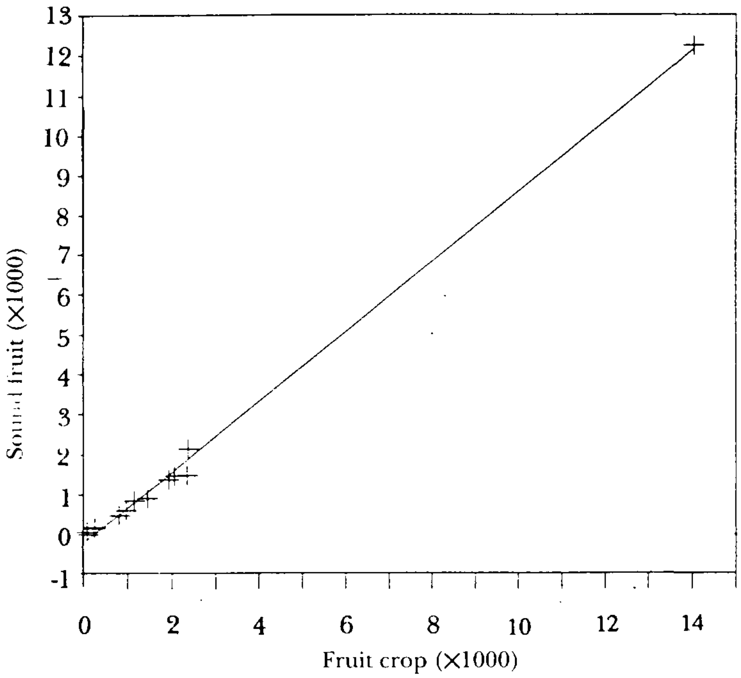

Figure 1. The linear relationship between the number of sound fruits and the fruit crop of dipterocarps fruiting in a logged-over hill dipterocarp forest. The regression is Y = -205.4 + 0.880X; (df = 11, r^2 = 0.9972, s_{sx} = 185.8)

Table 2. The number of seedlings surviving following a 'localised' fruiting in a logged hill dipterocarp forest (Sungai Tekam F.R.)

Species	10/1987	2/1988	6/1988	6/1990
Hopea pubescens	5204	2048	1435	129
Shorea macroptera	1007	781	672	624
S. macroptera	1488	396	236	181
S. macroptera	2598	984	775	536
S. parvifolia	970	308	246	154
S. resina-nigra	76	14	6	0
Total	11343	4531	3370	1624
Mean	1891	755	562	271
%		39.9	29.7	14.3
Total per tree (x 4)	7564	3020	2248	1084

Note: The seedlings were from the neighbouring segment from the one where a destructive sampling of the fruits was done (see Table 1). The segment size is the same as that for fruit fall count. The seedlings were followed for 2.75 years starting in October 1987.

The decline in the seedling populations differed between the species (Table 2). Only a few seedlings of *S. resina-nigra* germinated and none survived at the end of the observation period. *H. pubescens* produced the largest number of seedlings, over 5,200, but only a tiny fraction, about 2.5% remained alive in the third year. With *S. macroptera* and *S. parvifolia*, the trees had about 1,000 - 2,000 seedlings, and about 10-60% were still alive in the third year. The factors causing seedling mortality were not observed, but they did include pig and elephant damage.

Discussion

Dipterocarp fruiting in the aseasonal Malaysian forests can be categorized into three classes (see Appanah 1993). First is the unprecedented mast fruiting, when almost half or more mature dipterocarps in a forest fruit heavily. This fruiting can be region wide. Next is the 'localized' or sporadic fruiting event which is not widespread, and may be limited only to a small area of a forest, example a single river valley. While many trees in the area will fruit, it is not as general a phenomenon as the mast fruiting. Finally, there is the isolated fruiting event. This usually involves only a few trees. The Sungai Tekam Forest Reserve has been under observation since 1981 to 1987 (unpublished records). During this period, isolated fruitings occurred almost annually, and 'localized' fruitings were observed twice. No mast fruiting was witnessed though.

The 'localized' fruitings of dipterocarps in regenerating forests do not bear any resemblance to the heavy mast fruiting events in undisturbed forests (Appanah 1985). During the heavy 1976 mast fruiting in Pasoh, an undisturbed lowland forest, the fruit crop set by mature dipterocarp trees was as high as 249,000, with an average of about 128,000 (range 19,000 - 249,000; n=10) (Chan 1980). The 'localized' fruiting in Sungai Tekam Reserve represents a less than 10% effort of that observed in Pasoh. A variety of factors may influence the crop size. Among them include duration between two mast fruitings (Ashton *et al.* 1988), and the tree's crown position (Fox 1972). The tree's size may also have such an influence. The trees left in the logged compartments of Sungai Tekam Reserve are mainly small individuals compared to the ones examined in Pasoh. This might provide a partial explanation for the small crop size in Sungai Tekam. Desultory observations do suggest that 'localized' fruitings usually result in small crops as well.

In the fruiting in Sungai Tekam, crop size was very variable between individuals. No clear trends, intraspecific or interspecific, could be discerned; the small sample size obviates any such examinations. Nevertheless, crop size (*i.e.*, number of fruits) seems to be influenced by the size of the fruit. In this study, *Hopea pubescens* had the biggest crop. Its fruit is very small, perhaps the smallest among all Malaysian dipterocarps. All the other *Shorea* species in the study sample had bigger fruits, and smaller crops. Species like *Dipterocarpus* and *Dryobalanops*, which were not part of the study, have large fruits and usually produce relatively smaller crops compared to the *Shorea* species (personal observation).

Not all the fruits initiated reach maturity and germinate into seedlings. Many fruits perish, caused by several factors. While still on the tree, the fruits are predated by curculionid weevil (*Nanophyes shoreae*) (Browne 1961 and others), and parakeets, squirrels and monkeys (Appanah 1985). Upon dispersal, the fruits are further attacked by scolytid beetles (*Poecilips advena, P. gedeanus* and *P. medius*) (Kalshoven 1956, Daljeet Singh 1974, Chan 1980, Toy 1991) and pigs (Anonymous 1953). Fruits also fall prematurely before ripening, caused perhaps by bad weather, lack of pollination, injury from ovipositing weevils, *et cetera.* Fruits are also lost as a result of fungal infestation (Hong 1981). The fungi are species of *Botryodiplodia, Cylindrocladium, Fusarium* and *Schizophyllum.*

In this 'localized' fruiting, the crop losses were due to: a) abortion - 14%; b) insects and other animals - about 4.5%; and c) fungal infection - about 2%. Hong (1981) observed much higher losses, up to 25% due to insect predation, and 4.3% from fungal infection during a mast fruiting. Hong did not record losses in the field and that due to abortion. The total losses during the 'localized' fruiting from all agencies were about 21% of the fruit crop. By comparison, Chan (1980) reported fruit predation and losses of 61.0 and 93.7% during sporadic or isolated fruiting, and an average of 56% (estimated from Chan's original figures) during a mast year. He, however, did not give a breakdown of the losses caused by individual agencies.

The low fruit loss of only about 21% in the present study appears to contradict the predator-satiation hypothesis of Janzen (1974). The hypothesis predicts that mast fruiting evolved to satiate predator pressure, and isolated or 'localized' fruitings will be mostly destroyed by predators. Therefore, the strong regression suggesting increase in sound fruit production being dependent on increase in crop size is rather puzzling. Nonetheless, alternative explanations may exist to explain the low predation of fruits observed during a 'localized' fruiting in a logged forest. In such a forest, the environment is altered drastically, and this may be unfavourable for major predators like the beetles. Logging may have resulted in loss of host trees supporting the beetles between fruiting years. This could have reduced the beetle populations such that they are less effective during a fruiting.

While the estimated average production of sound fruits was about 7,300, the number of seedlings estimated from the neighbouring segments was about 7,500. (The seedling sample was estimated from only six out of the 12 trees observed for fruiting though). The seedling populations declined rapidly, and only about an estimated 1,000 or about 14% of the original seedling crop survived into the third year following fruiting. This does not depart much from an estimate made by Liew and Wong (1973). They found about 17% of the original seedling crop remained alive four years later in a Sabah forest. But obviously initial crop size matters, and theirs was a much bigger mast crop; their figures are estimated on an acreage basis, unlike in the present study which gives estimates for individual trees.

In terms of forest management implications, although 'localized' fruitings in logged forests are not sizable crops like that produced during mast years, the fruit crop is not wiped out as expected from observations of isolated fruiting individuals. This spells positive tidings for logged forests: selectively logged forests with adequate number of mature residuals should be able to generate the seedling crops needed for future crops following the second cut. However, their densities may not be as high as in the case with mast fruiting events in undisturbed forests. This deficiency can be offset by treating the seedling populations following mast or localized fruiting events in logged forests. Seedlings should be freed from competition from weed species and climbers. In addition, mature residuals should be left, as far as possible, well distributed in the forest so stocking of seedlings can be more evenly spread.

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