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Juvenile Height Growth in the Subtropical Evergreen Broad-Leaved Forest at Chichijima in the Bonin (Ogasawara) Islands

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Abstract. Juvenile height growth of 19 species (277 individuals in total) was measured annually from 1977 to 1982 in a forest, 5–6 m high, dominated by *Distylium lepidotum*, at Chichijima. Juveniles of main canopy trees showed the rate of height growth, not more than 2 cm/year, which was lower than that of the shrub and the second-layer species. The death of terminal shoots and the occurrence of new leaders were frequently observed in almost all species. The sharp decrease in the annual height growth and the increase in the death rate occurred in 1980 or 1981 in many species in parallel, which was attributed to the unusual drought in the summer of 1980. An introduced pioneer species, *Pinus lutchuensis*, has been invading the forest which is thought to be in the stable climax stage of succession. The height growth rate of the pine juveniles, 19.9 cm/year, was much higher than any other native component species. This exceptional phenomenon is ascribed to the good light condition in the forest where the canopy is not fully closed in spite of the high stem density.

Introduction

The subtropical evergreen broad-leaved forest, 5–6 m high, located on the flat called Chuosan-higashi-daira at Chichijima has the highest species diversity of all forest types in the Bonin Islands (Shimizu 1983). This forest dominated by *Distylium lepidotum* was classified by the former researchers as one of the climax forests (Numata and Ohsawa 1970) or the natural forests (Okutomi et al. 1983) in contrast with the secondary forests.

But it consists of not only many shade-tolerant trees but also light-demanding species like *Schima mertensiana*. Juveniles of an introduced species, *Pinus lutchuensis*, are also found growing in the forest (Shimizu 1983). If the forest is in the climax stage, the invasion of the forest by such a pioneer species as the pine is not in accordance with the common sense of ecological succession.

On the other hand, it is difficult to determine the annual shoot growth by counting the number of annual rings or scars of winter bud scales because these marks are usually obscure in the subtropical region. Literature which deals with the field data of juvenile height growth in subtropical forests is scanty.

So this paper reports a study on the dynamics of the subtropical forest from the viewpoint of juvenile height growth of the component species.

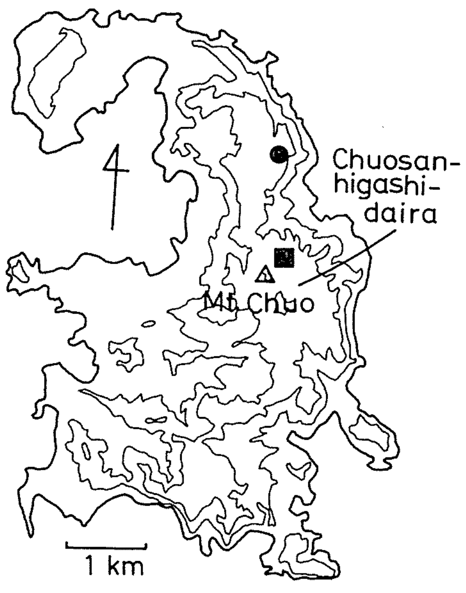

Fig. 1. Location of the quadrat in the forest (■) and the sunny open place (●) studied. Thin lines of the map show the 100 m contour.

Method

A quadrat (30 m × 30 m) was placed in the forest located on the flat called Chuosan-higashi-daira at Chichijima (Fig. 1). Five strata were determined in the forest according to the height from the ground (I: 4–6 m, II: 2–4 m, III: 0.7–2 m, IV: 0.2–0.7 m, V: <0.2 m). All woody species in the quadrat were recorded and the number of individuals was counted.

A total of 277 juveniles in 19 species was sellected to include as many species and as much variety of individuals in height as possible in the quadrat. (See Table 1 for the number of juveniles sampled in each species.) They were marked with color tapes and the stem height which was defined as the vertical distance between the ground surface and the highest living part of the plant was measured every December in 1977–1982.

The same measurement was made for some juveniles of *Pinus lutchuensis* and *Schima mertensiana* in a sunny open place (Fig. 1) in 1977–1981.

Results

Species composition of the forest

Table 1 shows the species composition of the forest studied in this paper. The forest includes 38 woody species and it is mainly composed of *Distylium lepidotum*, *Pouteria obovata*, *Schima mertensiana*, *Syzygium buxifolium*, etc. The understory of the forest is occupied by not only many juveniles of the canopy species but also some shrub species such as *Boninia glabra*, *Callicarpa glabra*, *Pittosporum chichisimense*, *Symplocos pergracilis*, *Stachyurus praecox* var. *matsuzakii*, etc. most of which are endemic to Chichijima and the distribution of which is concentrated on this forest.

As the canopy of the forest is not fully closed in spite of rather high stem density of the canopy trees, it is fairly bright even in the forest. The relative light intensity was 11.2% on the forest

Table 1. Species composition of the forest and the number of juveniles sampled in this study

Species name	No. of individuals (/900 m²)					Juveniles sampled	
	I (4–6 m)	II (2–4 m)	III (0.7–2 m)	IV (0.2–0.7 m)	V (<0.2 m)	Sapling (≥0.2 m)	Seedling (<0.2 m)
Bischofia javanica					1		
*Boninia glabra**		31	69	5	51	4	4
Boninia grisea		6	1	1			
*Callicarpa glabra**		2	9	60	102	6	6
Cinnamomum insularimontanum				1	1		
Clinostigma savoryana		3	2	3		2	1
Distylium lepidotum	108	83	42	396	936	16	10
Elaeocarpus photiniaefolius	5	10	9	20	50	3	3
Evodia nishimurae	13	3			12		1
Fagara boninensis					5		1
Ficus boninsimense		1	3	9	6	3	
Gardenia boninensis	2	19	9	1	2	1	
Geniostoma glabra	6	1	1	6	32	1	2
Hibiscus glaber	7	16	10	3	9	1	2
Ilex matanoana	33	9	13	32	225	2	9
*Juniperus taxifolia**	1						
Ligustrum micrantum	10	91	198	1626	1727	9	12
Machilus boninensis	3	36	163	137	78	10	2
Machilus kobu	1		1			1	
Myrsine maximowiczii	41	2	4	4	18	1	1
Neolitsea sericea		5	28	3		2	1
Osmanthus insularis				1	7		
*Osteomeles boninensis**		1			8	1	1
Pandanus boninensis	37	15	51	70	3	4	1
*Photinia wrightiana**			1		6	1	
Pinus lutchuensis	2	5	7	16	81	16	9
*Pittosporum chichisimense**		5	15	37		4	6
Pouteria obovata	82	39	54	114	13416	7	35
Psychotria homalosperma	12		2		3		
Rhaphiolepis indica var. *integerrima*	14	32	37	319	716	14	7
Schima mertensiana	79	18	21	17	430	6	17
Stachyurus praecox var. *matsuzakii**		1	3	4	4	1	
*Symplocos pergracilis**		8	58	11		1	
Syzygium buxifolium	57	68	76	319	579	6	5
*Tarenna subsessilis**		1	4	62	229	4	5
*Vaccinium boninense**	1	2	3		1		
Viburnum japonicum var. *boninsimense**				1			
Wikstroemia pseudoretusa	6	5	39	86	325	6	3
Total	520	518	933	3364	18766	133	144

* Undergrowth shrub species.

floor (the mean value of 50 sampling spots). Juveniles of the canopy trees, especially of *Distylium lepidotum* and *Pouteria obovata*, are abundant in the forest. Furthermore, it is characteristic of the forest that a pioneer species, *Pinus lutchuensis*, has been invading the forest, though no individuals of the pine have become matured yet (field observation).

Height growth rate of the species

Fig. 2 gives the height growth rate (mean annual growth in height, cm/year) of the juveniles which were classified into seedlings (<0.2 m) and saplings (≥0.2 m). The height growth rate of the main canopy species (*Distylium lepidotum*, *Pouteria obovata*, *Schima mertensiana*, *Syzygium buxifolium*, *Pandanus boninensis*, *Ilex matanoana*) was not more than 2 cm/year, which was generally lower than that of the undergrowth shrubs (*Boninia glabra*, *Callicarpa glabra*, *Tarenna subsessilis*) and the second-layer species (*Ligustrum micrantum*, *Wikstroemia pseudoretusa*). Saplings grew in height faster than seedlings in all species studied. In contrast with the native component species, the saplings of *Pinus lutchuensis* showed the exceptionally high rate of height growth, 19.9 cm/year.

Fig. 3 indicates the annual height growth of the saplings of *Pinus lutchuensis* and *Schima merten-*

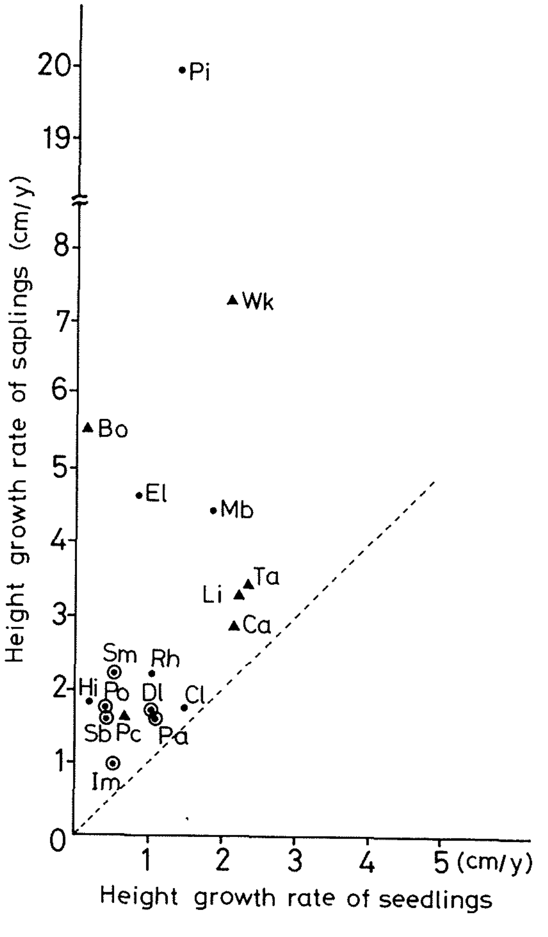

Fig. 2. Height growth rate of the seedlings (<0.2 m) and saplings (≥0.2 m) of the main component species. ●, Canopy tree species (⊙, dominant species); ▲, undergrowth shrub or second-layer tree species.
Abbreviations of the species names are as follows: Bo, *Boninia glabra*; Ca, *Callicarpa glabra*; Cl, *Clinostigma savoryana*; Dl, *Distylium lepidotum*; El, *Elaeocarpus photiniaefolius*; Hi, *Hibiscus glaber*; Im, *Ilex matanoana*; Li, *Ligustrum micrantum*; Mb, *Machilus boninensis*; Pa, *Pandanus boninensis*; Pc, *Pittosporum chichisimense*; Pi, *Pinus lutchuensis*; Po, *Pouteria obovata*; Rh, *Rhaphiolepis indica* var. *integerrima*; Sb, *Syzygium buxifolium*; Sm, *Schima mertenisana*; Ta, *Tarenna subsessilis*; Wk, *Wikstroemia pseudoretusa*.

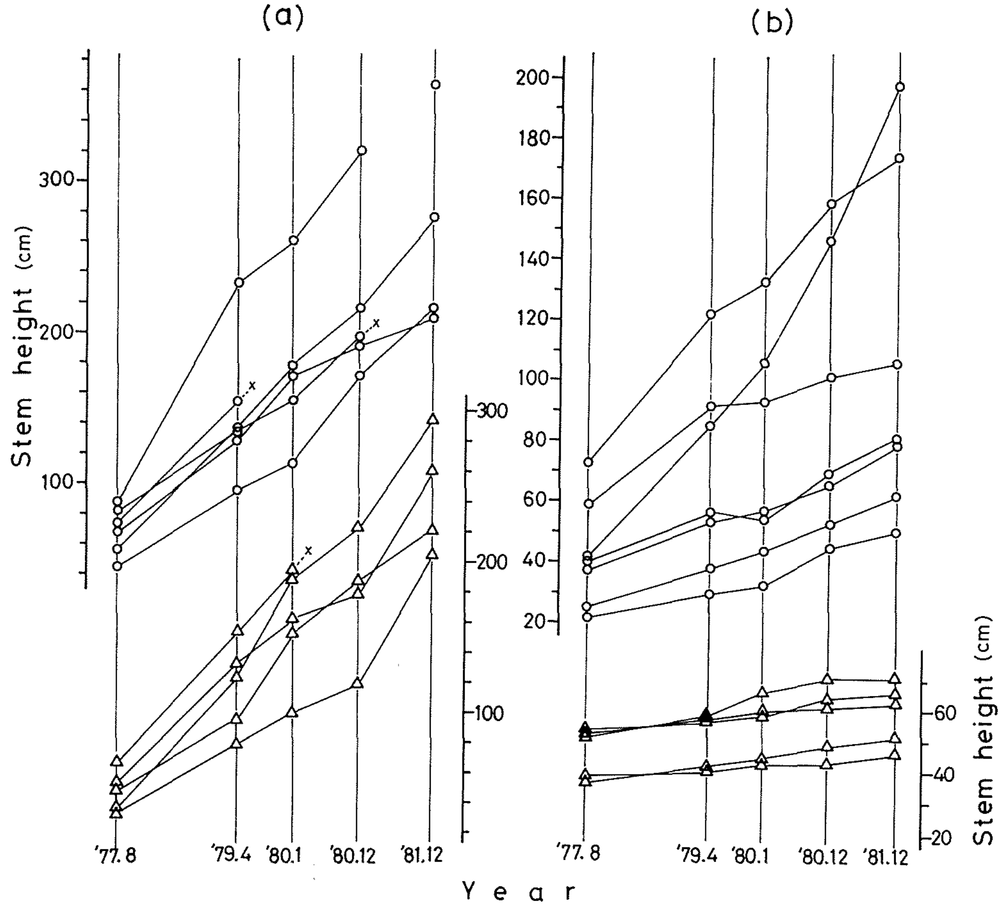

Fig. 3. Annual height growth of the saplings of *Pinus lutchuensis* (circle) and *Schima mertensiana* (triangle). (a) In the sunny open place; (b) In the forest.

siana which was measured in the forest and in the sunny open place. The height growth rate of the pine, 45.8 cm/year, was nearly the same as that of *Schima mertensiana*, 49.7 cm/year, in the open place, but the former was much higher than the latter in the forest.

Height growth rate of the individuals

Fig. 4 shows the height growth rate of all individuals studied in this work. The growth of saplings was faster than that of seedlings, as mentioned before, but there seems to be no positive correlation between the height growth rate and the stem height of saplings (0.2–2 m in height) at the beginning of the measurement.

The death of terminal shoots and the occurrence of new leaders at lower positions as indicated in Fig. 5 were observed in many individuals of almost all species. Especially *Pouteria obovata*, *Callicarpa glabra* and *Tarenna subsessilis* showed the frequent shoot exchange of this type (Fig. 4). But recognized were no such special trend as the higher rate of height growth after the shoot exchange than before, or vice versa.

The high death rate was recorded in *Distylium lepidotum*, *Ligustrum micrantum*, *Pittosporum chichisimense*, *Syzygium buxifolium*, etc. On the other hand, only a few individuals died during the study period in *Pouteria obovata*, *Rhaphiolepis indica* var. *integerrima*, *Ilex matanoana*, etc. Dead individuals were concentrated on the seedlings and the saplings less than 0.5 m in stem height (Fig. 4).

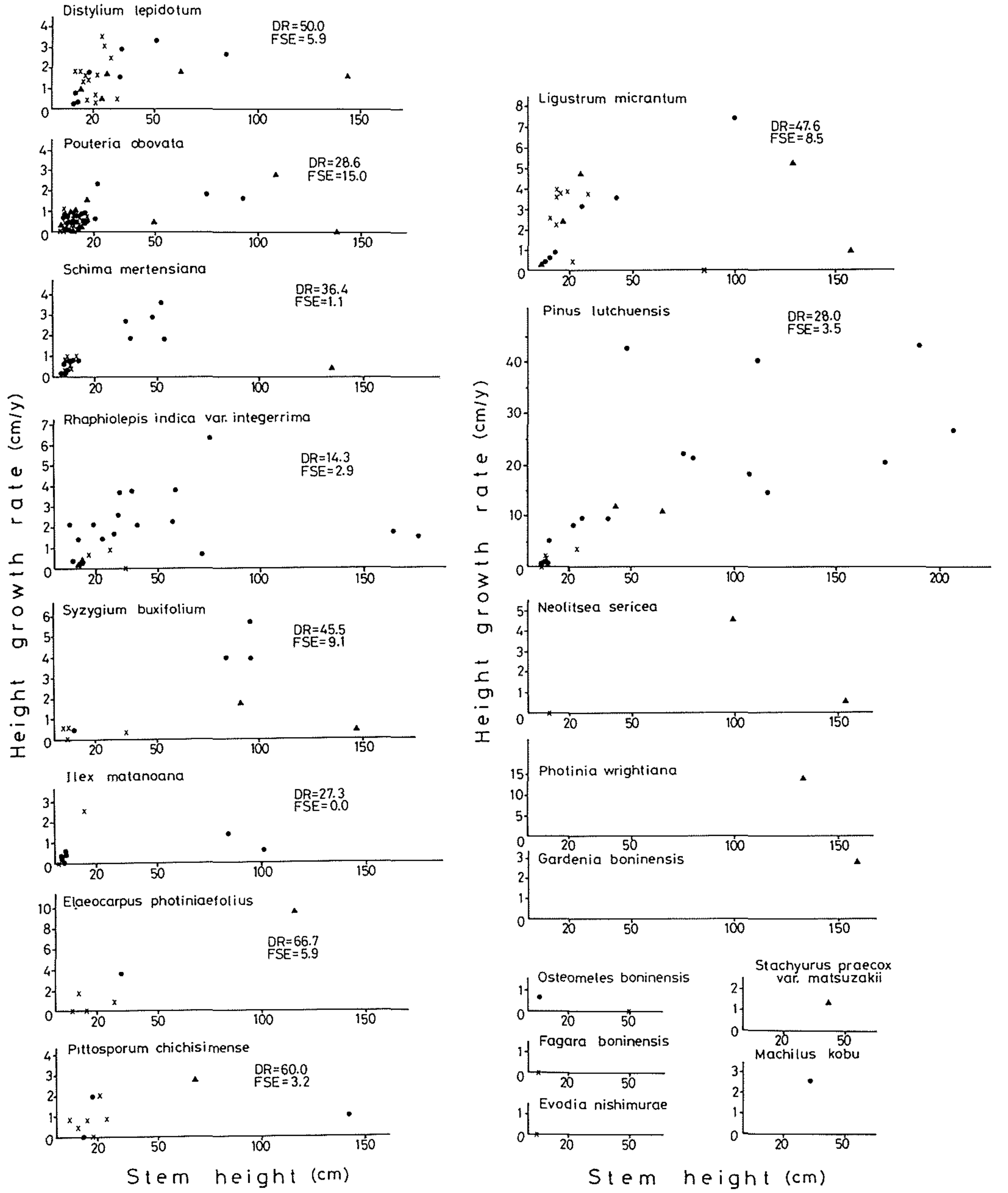

Fig. 4

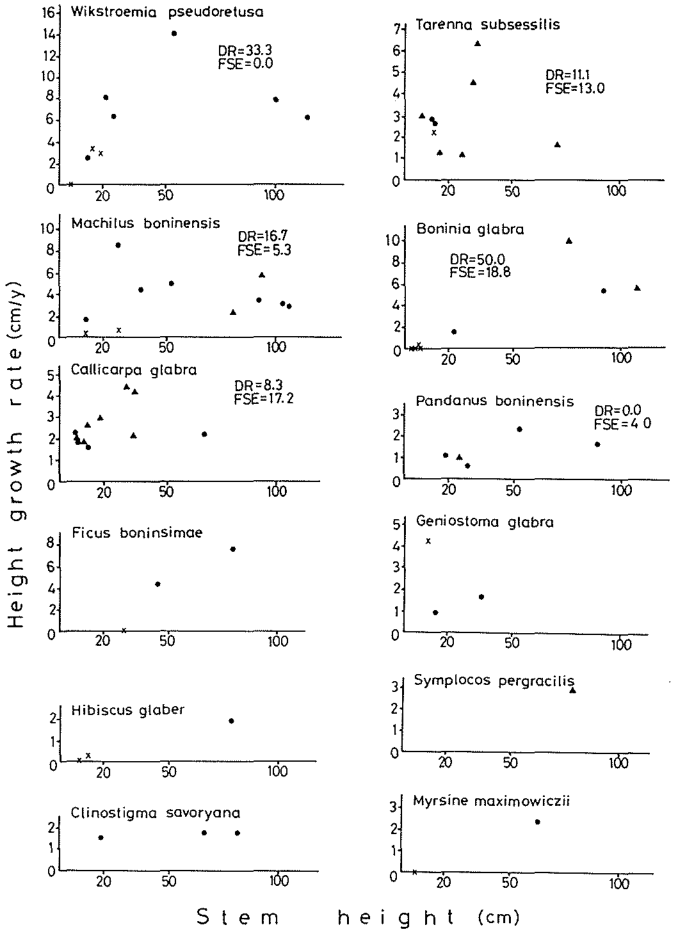

Fig. 4. Relation between the stem height at the beginning of the measurement and the height growth rate of all juveniles studied. Those that died (×) or exchanged the leading shoot (▲) during the study period are indicated differently. The death rate (DR, %) and the frequency of shoot exchange (FSE, %) are also presented.

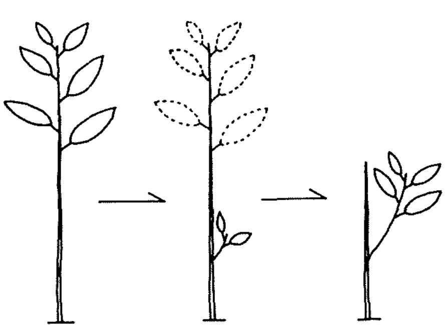

Fig. 5. Schematic presentation of the exchange of a leading shoot.

Annual height growth and death rate

Fig. 6 presents the annual change of the height growth and the death rate of some main component species. The sharp decrease in the annual height growth was found in 1981 in *Callicarpa glabra, Distylium lepidotum, Ligustrum micrantum, Machilus boninensis, Rhaphiolepis indica* var. *integerrima* and *Wikstroemia pseudoretusa*. On the other hand, the high death rate was observed in 1980 or 1981 in almost all species presented in Fig. 6. These phenomena occurring in many species in parallel seem to have some relation with the unusual drought which attacked Chichijima in the summer of 1980.

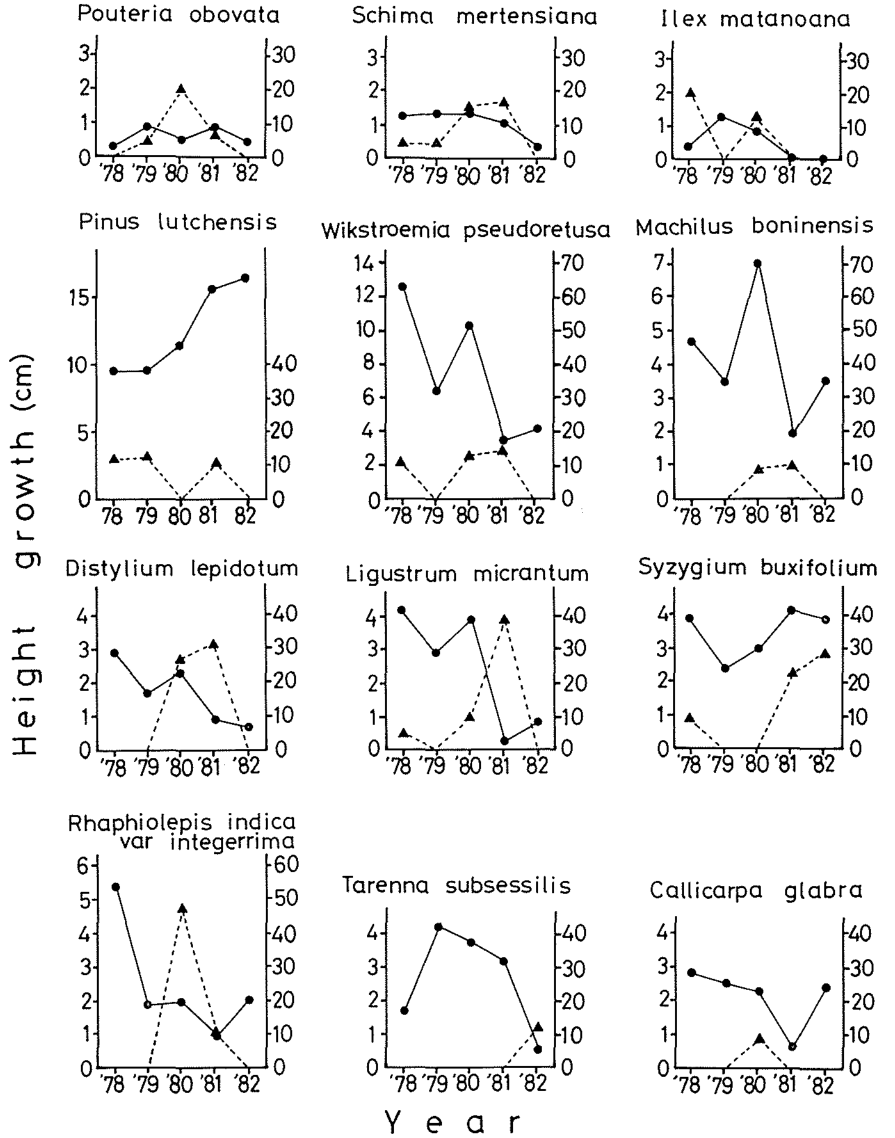

Fig. 6. Annual change of the height growth (circle and solid line) and the death rate (triangle and broken line).

Discussion

Seedlings and saplings of the main canopy species grew slowly in the forest, i.e. not more than 2 cm/year (Fig. 2). The exchange of the leading shoot was frequently observed in many species (Fig. 4). Moreover, many sample individuals died during the 5-year study period (Fig. 6), though juveniles of the main canopy species are abundant in the forest (Table 1). So the turnover of the canopy trees would be rather slow, unless the role of canopy gaps in regeneration of the forest is taken into account.

On the other hand, there is no record that the trees of this forest were cut before World War II. The forest has not received any human activity since the end of World War II. The forest is characterized by the several undergrowth shrub species whose distribution is centered on this forest at Chichijima (Shimizu 1983). The regeneration mechanism of the forest of this type is thought to be a series of tree-by-tree replacement in conjunction with small gap formation by a single dead tree (Shimizu 1984). So the structure and the species composition of the forest are rather stable. The successional stage of the forest can be defined as the climax in the sense that the forest is in the terminal stable stage on the site (Lincoln et al. 1982).

But a light-demanding species, *Pinus lutchuensis*, which was first introduced to the Bonin Islands in 1899 (Toyoshima 1938), has been invading the forest (Table 1). Its shoot growth is exceptionally much faster than any other native component species in the forest (Fig. 2). The invasion of a climax forest by a pioneer species is an unusual phenomenon from a commonsense standpoint of ecological succession. This occurs in the forest perhaps because the light condition is good enough for the pine juveniles to grow in the forest although the forest is in the climax stage. But the reason why the canopy of the forest is not fully closed has not been investigated. In addition, the phenomenon may be related to the island situation that the pine as a new comer to the Bonin Islands has not been adjusted to the stable ecosystem in the islands which had been accomplished through the longtime history of the islands.

Crowns of some pine saplings which had been under the canopy at the beginning of this study in 1977 were located above the canopy in 1984 (field observation). It is speculated that they will become emergent trees in the forest in a near future.

A severe drought attacked Chichijima in the summer of 1980. The damage to plants was concentrated on the dwarf scrubs, 0.3–1.5 m high, located on mountain ridges and edges of sea cliffs, whereas no clear damage of the canopy trees was observed in the forest studied in this paper at that time (Shimizu 1982).

But the drought seems to have had some influences on the juveniles in the forest because the sharp decrease in the annual height growth in 1981 and the increase in the death rate in 1980 or 1981 were found in many species in parallel (Fig. 6). The delay of the drought influence on the height growth may be attributed to the fact that the height growth in 1980 had almost finished before the summer, and the influence of the drought appeared in the height growth of the following year.

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