

## Restoration of Natural Environment by Creation of Environmental Protection Forests in Urban Areas\*

### — Growth and development of environmental protection forests on the Yokohama National University campus — Second Report\*

#### 都市における環境保全林形成による自然性の回復 — 横浜国大キャンパスの環境保全林の生長・発達 — 第2報\*

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#### Synopsis

The growth and development of environmental protection forests on the Yokohama National University campus was reported in this Bulletin (Miyawaki & Fujiwara 1988). In February 1992 a follow-up survey of the growth and development of environmental forests on the Yokohama National University campus was done at the permanent quadrat sites. The site condition, especially drainage, was the most important factor during the first six years (Miyawaki & Fujiwara 1988). After six years, planted individuals prepare the environment well and smaller trees grow two times bigger on the area with bad drainage. Planted trees on the slope still grow well, but they grow 1.5 times more than before. In the forest, after ten years, the individual growth rates of the diameter at breast height were greater than growth rates of tree height. Also species growth rates are different from before.

### 1. Introduction

Natural forests are the most stable natural ecosystem. Our experimental research on creation of environmental protection forests, which began in 1970, has produced 20 year-old forests (Miyawaki, Fujiwara, Ozawa 1993). In 1988 growth was surveyed on the Yokohama National University campus. The first report "ecological greenery planting: tree planting" shows that seedlings of 0.5m height grew to 9m and developed into true environmental protection forests over a period of 11 years. Maintenance was not required after the first two or three years. These forests developed gradually into multi-stratal communities by means of an ecological equivalent of "natural selection". There were three types of permanent quadrats on the Yokohama National University campus, which were first planted on flat terrain in 1976 and on slopes and flat terrain in 1980. The first report showed that the areas with bad drainage had slow growth and areas with good drainage had better growth. How did they grow after these results? The growth and

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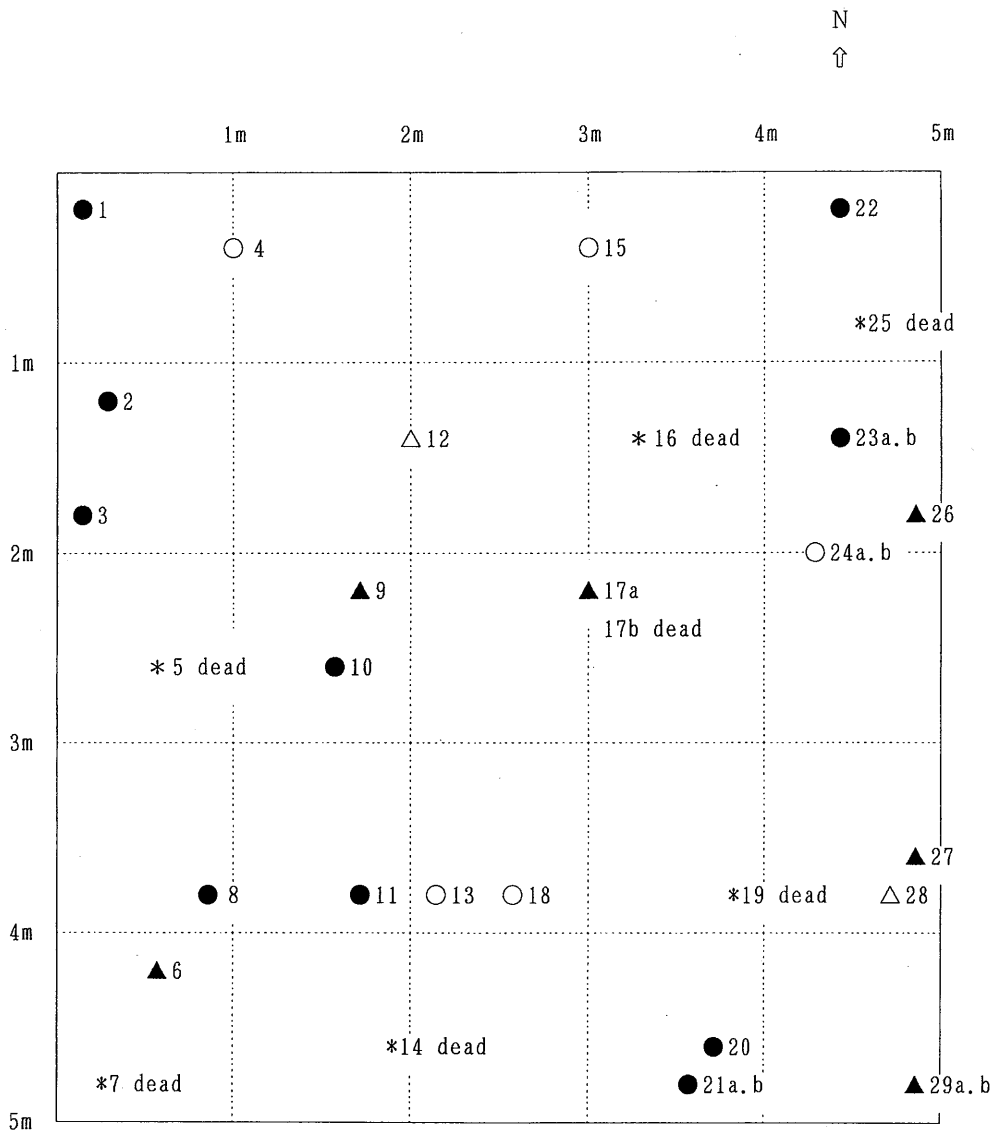
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development of environmental protection forests were surveyed and reported over 12 years (Miyawaki 1982, Fujiwara 1983, Miyawaki & Fujiwara 1983 a,b; Miyawaki, Fujiwara, Nakamura, Kimura 1983). No research has been done after these 12 years.

## 2. Survey method and location

The height and DBH growth of planted trees in the permanent quadrat plots at Yokohama National University (UB-1, UB-2, UB-3) were measured by Hayashi and Mr. Sirin Kawla-Ierd

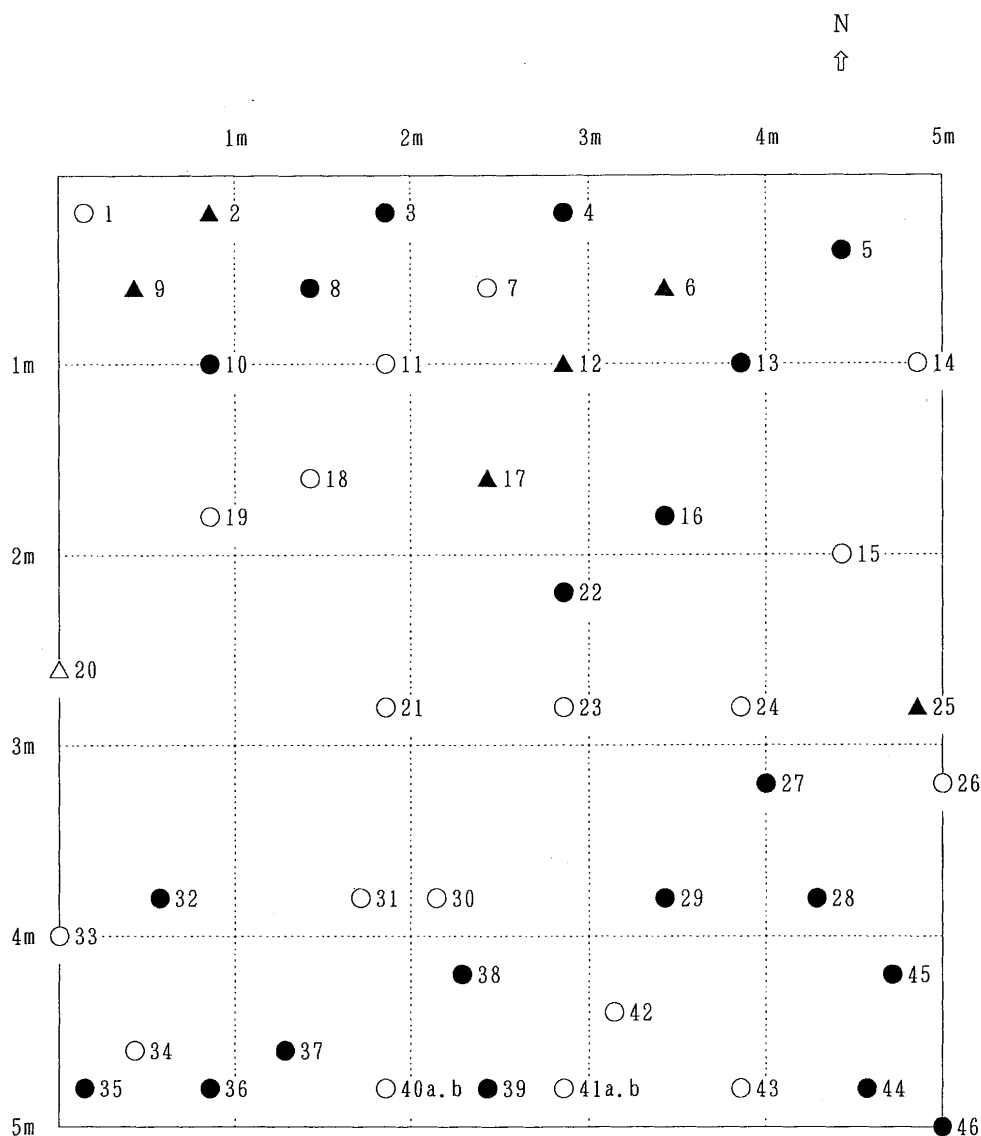


**Figure 1.** Sketch map shows location and species of individual trees which have been studied in the 5x5m<sup>2</sup> plot UB-1.

- *Quercus myrsinaefolia*
- *Quercus glauca*
- ▲ *Persea thunbergii*
- △ *Cinnamomum camphora*
- \* Dead

(Royal Development Division, Chitralada Palace, Thailand) on January 29, 1992. The vegetation in the permanent quadrats was surveyed by the Braun-Blanquet Method (1964, cf. Fujiwara 1987).

The environmental protection forest on the north side of the Institute of Environmental Science and Technology, which is 12 years old, was planted from pot seedlings 0.5-1.2m tall, with well developed root systems, two individuals per  $m^2$  in May 1976 (UB-1). The UB-2 forest is located west of the main gate of YNU on a slope, and UB-3 is located on a flat area next to the parking space of the Economics Faculty. The site of UB-3 has especially bad drainage. The



**Figure 2.** Sketch map shows location and species of individual trees which have been studied in the 5x5m<sup>2</sup> plot UB-2.

- *Quercus myrsinaefolia*
- *Quercus glauca*
- ▲ *Persea thunbergii*
- △ *Cinnamomum camphora*
- \* Dead

UB-2 and UB-3 forests were planted in March 1980. The planting density of UB-2 was two individuals per  $\text{m}^2$ , and that of UB-3 one individual per  $\text{m}^2$ . The numbers and locations of individuals are shown in Figure 1-3. The growth data are shown in Table 1-3. The relationship of tree height and diameter of breast height (DBH) is shown in Figure 4-6.

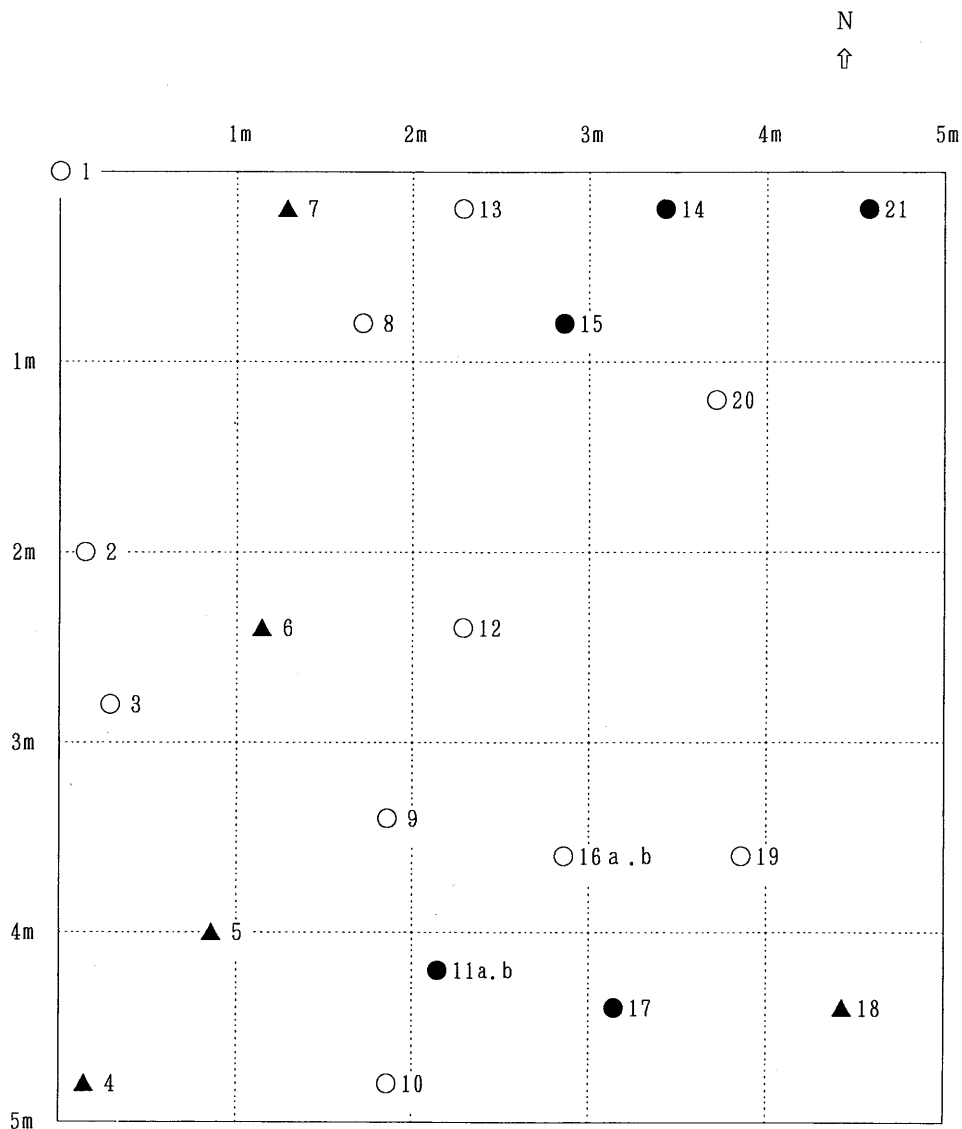


Figure 3. Sketch map shows location and species of individual trees which have been studied in the  $5 \times 5 \text{m}^2$  plot UB-3.

- *Quercus myrsinaefolia*
- *Quercus glauca*
- ▲ *Persea thunbergii*
- △ *Cinnamomum camphora*
- \* Dead

### 3. Results

Three sites changed as follows: 1) in UB-1 seven of 34 individuals had died by 1988, by "natural selection." *Quercus glauca* species had not grown so much, only 0.15–1.61m. The growth of *Quercus myrsinaefolia* was 0.36–1.63m, mean height higher than that of *Q. glauca*.

Table 1. Growth data of trees in PQ UB-1 (planted in May 1976)

No	Scientific Name	Total Height (m)			Diameter of Breast Height (cm)			Vitality (1992)
		15 Feb. 1988	29 Jan. 1992	4 year increment	15 Feb. 1988	29 Jan. 1992	4 year increment	
1	<i>Quercus myrsinaefolia</i>	3.26	3.21	-0.05	1.4	1.4	0	1
2 a	<i>Quercus myrsinaefolia</i>	5.58	6.73	+1.15	4.3	4.7	+0.4	3
2 b	<i>Quercus myrsinaefolia</i>	5.44	6.25	+0.81	2.1	3.1	+1.0	5
3	<i>Quercus myrsinaefolia</i>	7.14	8.58	+1.44	6.4	8.2	+1.8	4
4 a	<i>Quercus glauca</i>	4.60	4.80	+0.20	2.9	3.4	+0.5	2
4 b	<i>Quercus glauca</i>	2.44	2.25	-0.19	1.0	1.0	0	1
4 c	<i>Quercus glauca</i>	3.62	3.37	-0.25	2.1	2.1	0	1
5	<i>Persea thunbergii</i>	2.67	dead	—	2.3	dead	—	—
6	<i>Persea thunbergii</i>	7.15	9.91	+2.76	7.4	8.6	+1.2	3
7	<i>Quercus myrsinaefolia</i>	3.44	dead	—	2.0	dead	—	—
8	<i>Quercus myrsinaefolia</i>	5.10	5.01	-0.09	3.6	3.9	+0.3	1
9	<i>Persea thunbergii</i>	4.57	4.66	+0.09	3.1	3.6	+0.5	3
10	<i>Quercus myrsinaefolia</i>	7.32	7.15	-0.17	4.7	5.1	+0.4	2
11	<i>Quercus myrsinaefolia</i>	6.18	7.39	+1.21	3.4	4.3	+0.9	4
12	<i>Cinnamomum camphora</i>	9.04	9.22	+0.18	6.0	9.4	+3.4	5
13	<i>Quercus glauca</i>	7.58	8.43	+0.85	4.6	6.3	+1.7	5
14	<i>Persea thunbergii</i>	4.23	dead	—	2.6	dead	—	—
15	<i>Quercus glauca</i>	6.86	6.32	-0.54	3.8	3.9	+0.1	2
16	<i>Cinnamomum camphora</i>	3.60	dead	—	2.8	dead	—	—
17	<i>Persea thunbergii</i>	2.21	2.78	+0.57	1.4	1.4	0	1
18	<i>Quercus glauca</i>	3.58	4.28	+0.70	1.7	1.8	+0.1	2
19		—	—	—	—	—	—	dead
20	<i>Quercus myrsinaefolia</i>	4.59	6.22	+1.63	2.7	3.3	+0.6	5
21	<i>Quercus glauca</i>	6.91	8.52	+1.61	4.5	5.3	+0.8	5
22	<i>Quercus myrsinaefolia</i>	4.16	4.52	+0.36	2.0	3.1	+1.1	1
23 a	<i>Quercus myrsinaefolia</i>	5.55	5.13	-0.42	2.8	3.4	+0.6	3
23 b	<i>Quercus myrsinaefolia</i>	5.45	5.13	-0.32	2.6	3.2	+0.6	3
24 a	<i>Quercus glauca</i>	3.02	3.18	+0.16	1.2	1.3	+0.1	1
24 b	<i>Quercus glauca</i>	1.74	dead	—	1.5	dead	—	—
25	<i>Persea thunbergii</i>	5.04	dead	—	2.2	dead	—	—
26	<i>Persea thunbergii</i>	4.87	4.74	-0.13	2.5	3.0	+1.0	3
27	<i>Persea thunbergii</i>	1.72	1.66	-0.06	2.5	3.0	+0.5	1
28	<i>Cinnamomum camphora</i>	8.32	9.47	+1.15	9.4	11.7	+2.3	5
29 a	<i>Cinnamomum camphora</i>	8.80	10.06	+1.26	11.8	14.7	+2.9	5
29 b	<i>Cinnamomum camphora</i>	8.05	8.47	+0.42	10.3	10.3	0	5

	Total height average (m)		D. B. H average (cm)	
	1988	1992	1988	1992
<i>Quercus myrsinaefolia</i>	5.43	5.94	3.2	3.9
<i>Quercus glauca</i>	4.83	5.14	2.7	3.1
<i>Persea thunbergii</i>	4.10	4.75	3.0	3.5
<i>Cinnamomum camphora</i>	8.55	9.31	8.1	11.5

Table 2. Growth data of trees in PQ UB-1 (planted in March 1980)

No	Scientific Name	Total Height (m)			Diameter of Breast Height (cm)			Vitality (1992)
		15 Feb. 1988	29 Jan. 1992	4 year increment	15 Feb. 1988	29 Jan. 1992	4 year increment	
1	<i>Quercus glauca</i>	6.62	8.75	+2.13	6.7	8.9	+2.2	5
2	<i>Persea thunbergii</i>	6.38	7.61	+1.23	6.8	8.5	+1.7	5
3	<i>Quercus myrsinaefolia</i>	5.68	5.14	-0.54	4.9	4.9	0	4
4	<i>Quercus glauca</i>	5.82	7.46	+1.64	5.4	7.0	+1.6	4
5	<i>Quercus myrsinaefolia</i>	3.29	3.11	-0.18	2.5	3.0	+0.5	3
6	<i>Persea thunbergii</i>	5.64	7.71	+2.07	6.7	10.7	+4.0	5
7	<i>Quercus glauca</i>	5.59	7.63	+2.04	5.8	7.1	+1.3	5
8	<i>Quercus myrsinaefolia</i>	5.84	6.21	+0.37	4.1	4.8	+0.7	4
9	<i>Persea thunbergii</i>	6.12	7.79	+1.58	7.0	10.2	+3.2	5
10	<i>Quercus myrsinaefolia</i>	4.63	4.69	+0.06	3.2	3.8	+0.6	3
11	<i>Quercus glauca</i>	5.20	6.57	+1.37	5.0	5.2	+0.2	3
12	<i>Persea thunbergii</i>	5.71	8.60	+2.89	7.0	11.7	+4.7	5
13	<i>Quercus myrsinaefolia</i>	5.84	7.01	+1.17	5.0	6.1	+1.1	5
14	<i>Quercus glauca</i>	5.04	7.29	+2.25	5.6	8.8	+3.2	5
15	<i>Quercus glauca</i>	4.59	5.35	+0.77	4.3	5.3	+1.0	4
16	<i>Quercus myrsinaefolia</i>	4.64	5.34	+0.70	3.6	4.4	+0.8	4
17	<i>Persea thunbergii</i>	5.35	6.32	+0.97	5.4	7.1	+1.7	5
18	<i>Quercus glauca</i>	5.76	6.93	+1.17	4.8	5.8	+1.0	5
19	<i>Quercus glauca</i>	5.27	7.01	+1.74	4.9	7.2	+2.3	5
20	<i>Cinnamomum camphora</i>	5.50	6.47	+0.97	5.7	6.1	+0.4	2
21	<i>Quercus glauca</i>	4.72	4.72	0	3.6	4.2	+0.6	3
22	<i>Quercus myrsinaefolia</i>	3.60	5.25	+1.65	5.0	5.0	0	3
23	<i>Quercus glauca</i>	5.34	7.00	+1.66	4.8	6.6	+1.8	5
24	<i>Quercus glauca</i>	3.71	4.62	+0.91	1.9	2.6	+0.7	1
25	<i>Persea thunbergii</i>	6.23	7.79	+1.56	6.7	12.1	+5.4	5
26	<i>Quercus glauca</i>	5.05	6.42	+1.37	5.5	11.0	+5.5	5
27	<i>Quercus myrsinaefolia</i>	5.11	6.22	+1.11	5.1	5.8	+0.7	4
28	<i>Quercus myrsinaefolia</i>	5.19	6.32	+1.13	4.5	6.1	+1.6	4
29	<i>Quercus myrsinaefolia</i>	4.46	4.37	-0.09	2.7	3.0	+0.3	2
30	<i>Quercus glauca</i>	4.92	6.90	+1.98	6.2	9.3	+3.1	5
31	<i>Quercus glauca</i>	4.80	5.04	+0.24	3.8	6.9	+3.1	4
32	<i>Quercus myrsinaefolia</i>	5.63	6.32	+0.69	5.5	6.0	+0.5	5
33	<i>Quercus glauca</i>	5.30	6.63	+1.33	4.8	6.6	+1.8	5
34	<i>Quercus glauca</i>	5.54	7.29	+1.57	5.2	8.0	+2.8	5
35	<i>Quercus myrsinaefolia</i>	4.45	dead	—	6.6	dead	—	—
36	<i>Quercus glauca</i>	4.34	5.03	+0.69	3.6	4.8	+1.2	2
37	<i>Quercus myrsinaefolia</i>	4.94	5.64	+0.70	3.6	4.7	+1.1	5
38	<i>Quercus myrsinaefolia</i>	4.83	5.02	+0.19	3.5	4.4	+0.9	3
39	<i>Quercus myrsinaefolia</i>	5.04	4.90	-0.14	3.9	4.4	+0.5	4
40 a	<i>Quercus glauca</i>	3.96	dead	—	4.1	dead	—	—
40 b	<i>Quercus glauca</i>	4.37	5.92	+1.55	3.5	5.0	+1.5	5
41 a	<i>Quercus myrsinaefolia</i>	5.43	7.84	+2.41	5.6	7.6	+2.0	5
42	<i>Quercus glauca</i>	4.73	6.04	+1.31	3.2	4.0	+0.8	4
43	<i>Quercus glauca</i>	5.81	6.32	+0.51	4.5	5.5	+1.0	5
44	<i>Quercus myrsinaefolia</i>	5.56	6.64	+1.08	4.4	6.1	+1.7	5
45	<i>Quercus myrsinaefolia</i>	4.98	7.12	+2.14	5.2	6.8	+1.6	5
46	<i>Quercus myrsinaefolia</i>	4.82	5.77	+0.95	3.5	4.2	+0.7	4

	Total height average (m)		D. B. H average (cm)	
	1988	1992	1988	1992
<i>Quercus myrsinaefolia</i>	4.95	5.72	4.3	5.0
<i>Quercus glauca</i>	5.07	6.45	4.6	6.4
<i>Persea thunbergii</i>	5.91	7.64	6.6	10.0
<i>Cinnamomum camphora</i>	5.50	6.47	5.7	6.1

Table 3. Growth data of trees in PQ UB-3 (planted in March 1980)

No	Scientific Name	Total Height (m)			Diameter of Breast Height (cm)			Vitality (1992)
		15 Feb. 1988	29 Jan. 1992	4 year increment	15 Feb. 1988	29 Jan. 1992	4 year increment	
1 a	<i>Quercus glauca</i>	2.76	5.82	+3.06	4.5	6.2	+1.7	5
1 b	<i>Quercus</i>	3.56	dead	—	4.1	dead	—	—
2	<i>Quercus glauca</i>	2.56	4.58	+2.02	2.3	4.4	+2.1	5
3	<i>Quercus glauca</i>	1.11	4.13	+3.02	2.3	4.2	+1.9	5
4	<i>Persea thunbergii</i>	10.75	4.98	+3.23	3.7	6.0	+2.3	4
5	<i>Persea thunbergii</i>	2.03	5.57	+3.54	4.8	8.3	+3.5	5
6	<i>Persea thunbergii</i>	1.37	4.62	+3.25	2.3	4.6	+2.3	4
7	<i>Persea thunbergii</i>	3.82	5.75	+1.93	4.9	10.3	+5.4	5
8	<i>Quercus glauca</i>	3.38	5.01	+1.63	3.5	5.2	+1.7	5
9	<i>Quercus myrsinaefolia</i>	2.92	5.19	+2.27	4.3	6.3	+2.0	5
10	<i>Quercus glauca</i>	3.04	5.35	+2.31	3.0	5.5	+2.5	4
11 a	<i>Quercus glauca</i>	4.24	5.62	+1.38	4.4	6.9	+2.5	5
11 b	<i>Quercus glauca</i>	3.98	5.57	+1.59	4.1	7.5	+3.4	5
12	<i>Quercus myrsinaefolia</i>	3.51	5.35	+1.84	3.7	5.6	+1.9	4
13	<i>Quercus glauca</i>	4.07	5.97	+1.90	7.1	13.4	+6.3	5
14	<i>Quercus myrsinaefolia</i>	3.66	5.46	+1.80	4.5	7.4	+2.9	5
15	<i>Quercus myrsinaefolia</i>	4.23	6.32	+2.09	5.0	10.2	+5.2	5
*16 a	<i>Quercus glauca</i>	3.59	5.86	+2.27	3.2	5.4	+2.2	4
16 b	<i>Quercus glauca</i>	3.36	5.21	+1.85	2.7	4.1	+1.4	4
17	<i>Quercus myrsinaefolia</i>	3.47	5.58	+2.11	3.1	5.1	+2.0	4
18	<i>Persea thunbergii</i>	3.27	5.22	+1.95	3.3	6.8	+3.5	4
19	<i>Quercus glauca</i>	3.75	5.51	+1.76	3.0	8.7	+5.7	5
20	<i>Quercus glauca</i>	4.24	5.61	+1.37	4.6	6.8	+2.2	5
21	<i>Quercus myrsinaefolia</i>	3.81	4.77	+0.96	3.2	5.5	+2.3	5

	Total height average (m)		D. B. H average (cm)	
	1988	1992	1988	1992
<i>Quercus myrsinaefolia</i>	3.60	5.45	3.9	6.6
<i>Quercus glauca</i>	3.36	5.35	3.7	6.5
<i>Persea thunbergii</i>	2.45	5.23	3.8	7.2
<i>Cinnamomum camphora</i>	—	—	—	—

*Persea thunbergii* grew very well (2.76m within 4 years). The individuals of *Cinnamomum camphora* were higher trees in this PQ plot in 1988. In 1992 they are still tall, but *Persea thunbergii*, *Q. myrsinaefolia* and *Q. glauca* co-mixed in the canopy layer. The DBH of *Cinnamomum camphora* is bigger than for the other species (9.4–14.7cm). The DBH of the other species is variable. The negative values of height show damage by snow accumulation in end of January, 1991 and 1992 (Table 1–3). 2) The height and DBH of the individual trees of UB-2 on the slope become almost the same height as in UB-1, except four individuals of the UB-1 canopy layer. The height of individual trees of UB-2 is 1.5 times bigger than before, and the DBH is 1.7 times bigger. Even *Quercus glauca* grew well on the slope (0.77–2.25m higher than before). 3) The height of individual trees of UB-3 is half that of UB-1, but the DBH is about the same. The individual trees of UB-3 grew twice as high, and their DBH was twice as large as in 1988. The four-year height increment is almost 1–3.5m. The first six years of growth was very slow, but, four years later they grow very well.

#### 4. Conclusion

From the results and comparison with data in 1983 (Fujiwara 1983) and 1988 (Miyawaki and Fujiwara 1988), the following points are concluded:

- 1) The growth over 12 years after plantation of potted seedlings becomes slow. The growth of DBH is greater than tree height growth after 10 to 12 years.
- 2) Planting on a slope (better drainage) shows better growth than on a flat area (poor drainage). The growth of tree height on the slope is still better than that on the flat area after six years old. DBH growth on the slope, however, is smaller than on the flat area.
- 3) On the slope, *Persea thunbergii* (Lauraceae species) grows better than the evergreen *Quercus*

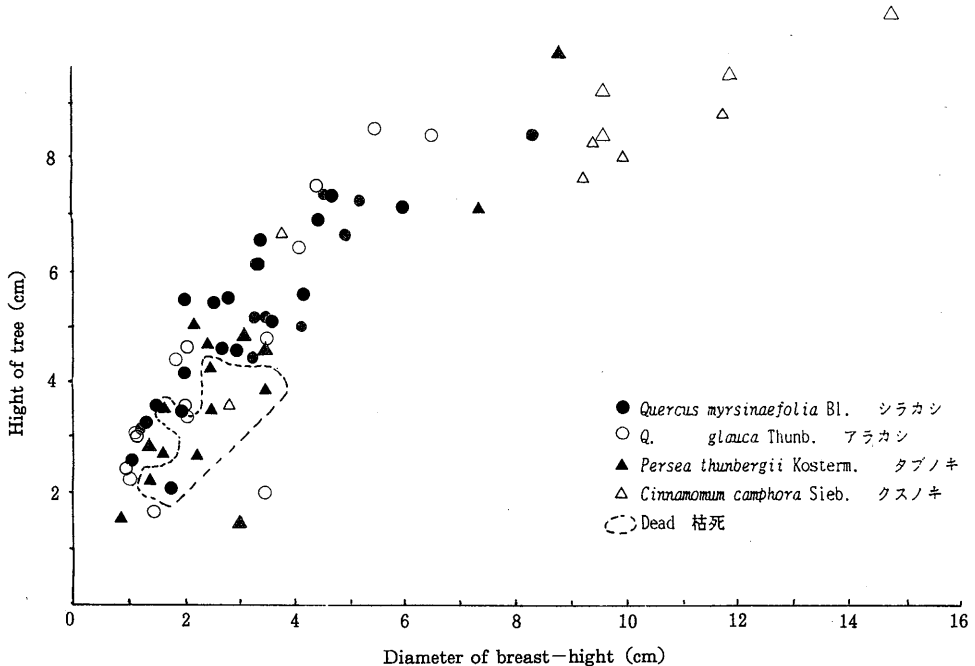


Figure 4. Relationships of the tree height and diameter at breast height in forest UB-1. Black color: data in 1988; green color: data in 1992.

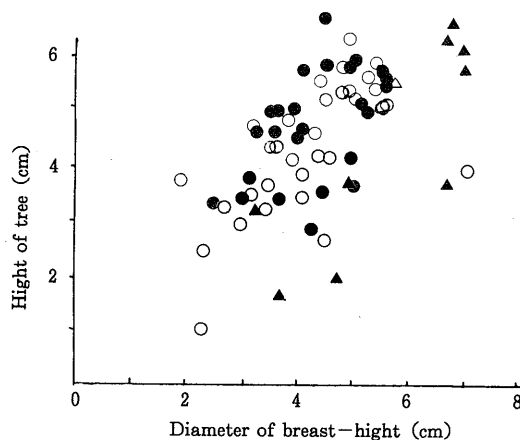


Figure 5. Relationships of the tree height and diameter at breast height in forest UB-2. Black color: data in 1988; green color: data in 1992.



species (Fagaceae). On the flat area, evergreen *Quercus*, especially *Quercus glauca*, shows better DBH growth than *Persea thunbergii*.

4) It was clear that we cannot guess the age of trees from the height and/or DBH from sixteen-year records of an even-age plantation. Their growth records are full of variety. They are about the same age, but their growth of tree height and DBH has no rule.

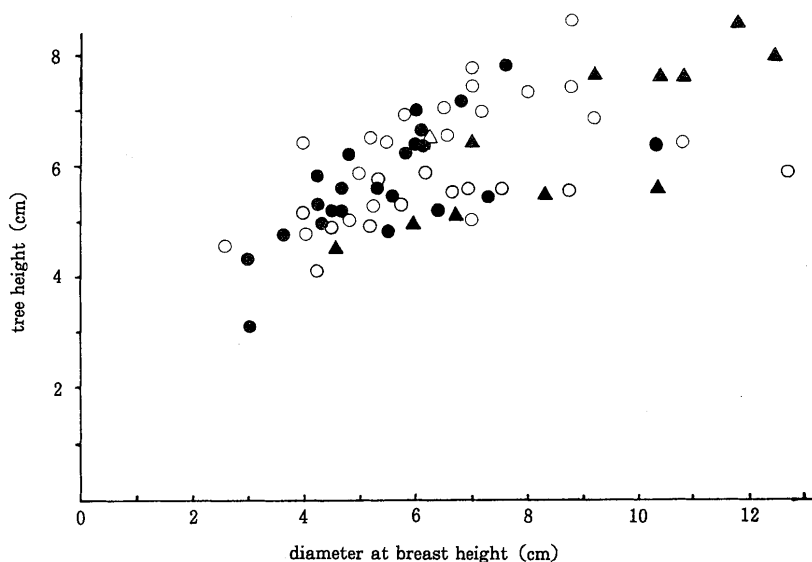


Figure 6. Relationships of the tree height and diameter at breast height in forest UB-3. Black color: data in 1988; green color: data in 1992.

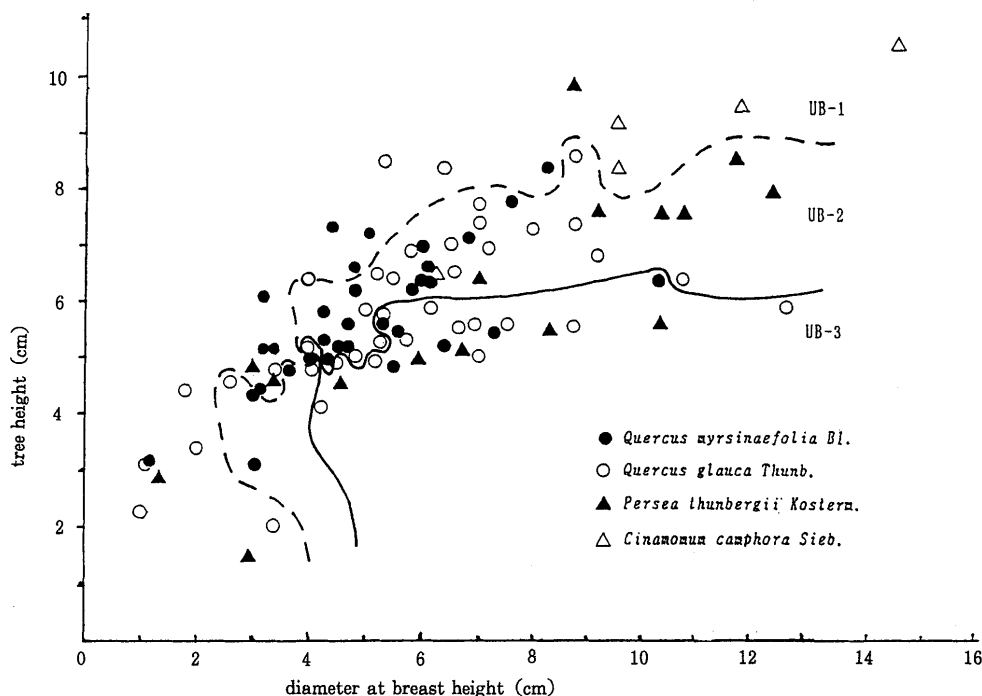


Figure 7. Relationships of the tree height and diameter at breast height in all three environmental forests based on data in 1992.

The location of Yokohama National University is at the edge of the potential evergreen *Quercus* forest region (Miyawaki et al. 1972). This permits the following as plantation species: evergreen *Quercus* species and *Castanopsis*, *Persea*, and *Cinnamomum* (Miyawaki ed. 1986). These conclusions were gotten from the 16 years of plantation results based on the Miyawaki theory (p. 73–107 in this Bulletin).

### References

- Braun-Blanquet, J. 1964. Pflanzensoziologie. Gröndzüge der Vegetationskunde. 3rd edition. 865pp. Springer-Verlag, Vienna/New York.
- Fujiwara, K. 1983. Investigation of the Growth Process of Environmental Forest in the Industrial Area in *Camellietea japonicae*. In: Abstracts, 20–22. Yokohama National University.
- Fujiwara, K. 1987. Aims and Methods of Phytosociology or "Vegetation Science". Plant Ecology and taxonomy to the memory of Dr. Satosi Nakanishi. pp. 607–628. The Kobe Geobotanical Society.
- Miyawaki, A. 1982. Umweltschutz in Japan auf vegetationsökologischer Grundlage. Bull. Inst. Environm. Technol. Yokohama Nat. Univ., 11: 107–120.
- Miyawaki, A. (ed.) 1986. Vegetation of Japan. Vol.7 Kanto. 605pp. (with 4 color maps and veg. tables). Tokyo: Shibundo (in Japanese, with English and German summaries).
- Miyawaki, A. and K. Fujiwara 1988a. Restoration of Natural Environment by Creation of Environmental Protection Forests in Urban Areas. (Japanese). Sato K. ed.: Research Report of Special Expenditure on Educational Research, 1987, Yokohama National University. "Studies on Analysis and Application of Macro and Microbiological Systems". pp. 29–32. Yokohama National University.
- Miyawaki, A. and K. Fujiwara 1988b. Restoration of natural environment by creation of environmental protection forests in urban areas. Growth and development of environmental protection forests on the Yokohama National University campus. Bull. Inst. Environ. Sci. Technol., Yokohama Nat. Univ. 15: 95–102.
- Miyawaki, A., K. Fujiwara and E. O. Box. 1978. Toward harmonious green urban environments in Japan and other countries. Bull. Inst. Environm. Technol. Yokohama Nat. Univ., 14: 67–82.
- Miyawaki, A., K. Fujiwara, Y. Nakamura and M. Kimura. 1983. Ecological and vegetation-scientific studies on creation of environmental protection forest in the industrial areas of Japan. Yokohama Phytosoc., Vol.22, part 1 (84 pp.) and part 2 (151 pp.), with color maps (in Japanese, with German and English summaries). Yokohama.
- Miyawaki, A., K. Fujiwara, and M. Ozawa. 1993. Native forest by native trees. – Restoration of indigenous forest ecosystems –. (Restoration of environmental protection forest by Miyawaki's method). Bull. Inst. Environm. Technol. Yokohama Nat. Univ., 17: 73–107.
- Miyawaki, A., H. Tohma, K. Fujiwara, M. Inoue, M. Furuya, Y. Sasaki, H. Harada, K. Ohno and K. Suzuki. 1972. Vegetation of Yokohama City. 141pp. with color maps (Japanese, with German summary). Yokohama City.