SITE QUALITY AND THE COMPETITION BETWEEN WEEDS AND PLANTED SEEDLINGS IN RELATION TO WEEDING

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ABSTRACT

Planted *Cryptomeria japonica* D.Don and *Chamaecyparis obtusa* (Sieb. et Zucc.) Endl. seedlings were weeded to leave weeds around a seedling and growth was studied. The more weeds left around the seedling, the smaller was the exposure ratio of the seedling. Seedling growth decreased as the exposure ratio decreased. The higher the site quality, the greater was the advantage that weeding gave seedlings. These results implied that the value of mechanisation for labour-saving in weeding work depended on the site quality.

Keywords: weed competition; site quality; weeding; stand establishment; density effect; *Chamaecyparis obtusa*; *Cryptomeria japonica*; *Miscanthus sinensis*.

INTRODUCTION

There are about 10 million ha of plantations in Japan. About 80% of the plantations are less than 30 years old and need silvicultural treatments such as weeding, vine cutting, and thinning for successful stand establishment. A shortage of forestry workers makes careful tending of planted trees difficult, and so the benefit of mechanisation in silvicultural operations is often pointed out (Mimura 1994). Mechanisation requires development of machines and also suitable silvicultural practices. For example, in the course of weeding, all weeds around a seedling are usually cut and removed. Mechanisation to this extent risks cutting the seedlings. To develop suitable mechanised weeding methods, there is a need to determine the influence on crop growth of the number and proximity of weeds around individual planted seedlings.

In this paper, we discuss the influence of weeding method and site quality on early crop growth.

SITES AND METHODS

Study Site

Sites used for this study were Japanese cedar (*Cryptomeria japonica*) and Japanese cypress (*Chamaecyparis obtusa*) plantations, established in April 1989 in Tokyo University Forest in Chiba, located in the south-eastern part of the Boso Peninsula in central Japan (35°09'N, 140°09'E). Annual mean temperature and mean annual precipitation near the study sites were about 14°C and 2400 mm respectively from 1986 to 1989 (Tokyo University Forests 1992). In June 1990, three cypress plantations (Ch-1, Ch-2, and Ch-3) and three cedar plantations (Cr-1, Cr-2, and Cr-3) were selected as study sites. Planting spacing was 1.5 m (along contour line) × 1.8 m (along slope).

Plot and Weeding Treatment

At each site five plots were established, each containing about 15 seedlings and weeded to different extents. In Plot-0, all weeds were cut; in Plot-20, Plot-40, and Plot-80, weeds around a seedling were left in a square of 20 cm, 40 cm, and 80 cm, respectively. In Plot-N, all weeds were left. Weeding was done in June and September in 1990 and 1991, and in June 1992.

The dominant weed species at every study site was *Miscanthus sinensis* Anders. Mean weed height in Plot-N in October 1992, after four growth seasons, was 1.6 m at the cypress study sites and 2.0 m at the cedar study sites. As the height recovery of *M. sinensis* after cutting during the growth season was fast (Tange *et al.* 1993), the status of competition between planted seedlings and weeds during the growth season was represented more adequately by the status before weeding than that after weeding.

Seedling Growth

Basal diameter (D) and height (H) of every seedling were measured in June and November 1990, September 1991, October 1992, and October 1994.

Evaluation of Site Quality

Mean annual height growth rate of the seedlings free from weeds was taken as the index of site quality. Mean height increment of the tallest 15 seedlings in Plot-0 and Plot-20 from November 1990 to October 1992 was calculated. Five plots at each study site were considered to have the same site quality.

Evaluation of Competition between Seedlings and Weeds

The status of competition for light between a seedling and adjacent weeds was represented by the ratio of the crown length of the seedling not shaded by the weeds (Fig. 1). As the clear stem lengths of seedlings were negligible, the seedling height was regarded as the crown length. The exposure ratio of every seedling was measured in September 1991 and in October 1992 before weeding treatments.

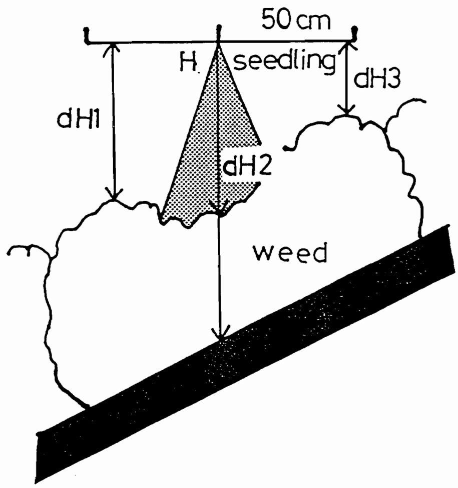

FIG. 1–Method for measuring the exposure ratio of the crown (ERC). The equation used was:

$$ERC = (dH1+dH2+dH3+dH4)/4/H$$

where H was seedling height and dH1, dH2, dH3, and dH4 were the differences between the seedling height and the maximum height of the weeds within a radius of 50 cm from the seedling in four directions.

RESULTS AND DISCUSSION

Weeding Method and Growth of Planted Seedlings in Relation to Site Quality

Mean height increments of the seedlings free from weeds at each site are shown in Table 1. At the cypress sites, the site qualities represented by the mean height growth of the top 15 seedlings (about half the seedlings in Plot-0 and Plot-20) free from weeds were significantly different each other for two out of the three sites. At the cedar sites, the site quality of Cr-3 was significantly lower than Cr-1 and Cr-2. From this stand point, Ch-1, Ch-3, and Cr-3 were classified as low quality sites and Ch-2, Cr-1, and Cr-2 were classified as high quality sites.

The influence of weeding treatment on the exposure ratio of cypress seedlings and cedar seedlings for 2 years is also shown in Table 1. Where more weeds were left around a planted seedling, as in Plot-N and Plot-80, the exposure ratio was significantly smaller than for the seedlings free from weeds in Plot-0 and Plot-20 (Table 1). The decrease in the exposure ratio in the plots left with many weeds was more apparent at the low quality sites than the plots at the high quality sites (Table 2). The decrease in the D^2H increment compared with the seedlings free from weeds in Plot-0 and Plot-20 was apparent in the plots where the mean exposure ratio of the seedlings was generally less than 0.5 (Table 1).

The D^2H increments, the increment of biomass, of both tree species decreased as the exposure ratio decreased (Fig. 2 and 3). Although the biomass increment ($d(D^2H)$) decreased as the exposure ratio decreased, the ratio of height increment to diameter increment (dH/dD) increased (Fig. 2 and 3). Increase in this ratio indicated that more biomass was allocated to height growth than to diameter growth. Diameter growth was more sensitive than height

TABLE 1–Height growth ratio of seedlings free from weeds and treatment effect on seedling growth at each study site (mean ± standard deviation; means followed by the same letter within a column are not significantly different—t-test, p<0.05).

Species	Study site	H-growth(1)* (cm/year)	H-growth(2)* (cm/year)	Plot	Exposure ratio of crown	$d(D^2H)$† (cm^3/2 years)
Ch. obtusa	Ch-1	34.7±8.6a	41.3±2.9c	Plot-N	–0.03 ±0.47b	3.7 ±2.2b
				Plot-80	0.17 ±0.36b	5.9 ±7.3ab
				Plot-40	0.40 ±0.68ab	2.4 ±8.6a
				Plot-20	0.75 ±0.09a	11.4 ±7.7a
				Plot-0	0.70 ±0.11a	10.0 ±5.1a
	Ch-2	44.9±7.9a	50.6±4.2a	Plot-N	0.22 ±0.24d	9.2 ±9.8b
				Plot-80	0.65 ±0.26c	14.2 ±10.8ab
				Plot-40	0.84 ±0.14b	14.2 ±6.7ab
				Plot-20	0.92 ±0.14ab	11.0 ±7.2b
				Plot-0	0.97 ±0.04a	20.8 ±11.3a
	Ch-3	38.5±8.8a	45.9±4.6b	Plot-N	–0.56 ±1.20d	3.4 ±4.5c
				Plot-80	0.27 ±0.41c	5.2 ±4.7bc
				Plot-40	0.58 ±0.34b	8.8 ±7.9ab
				Plot-20	0.67 ±0.29b	9.5 ±5.4a
				Plot-0	0.89 ±0.09a	10.2 ±5.3a
Cr. japonica	Cr-1	88.5±18.8a	102.3±9.7a	Plot-N	0.58 ±0.19c	106.2 ±59.1a
				Plot-80‡	–	–
				Plot-40	0.80 ±0.14b	118.5 ±70.8a
				Plot-20	0.90 ±0.04a	141.3 ±42.0a
				Plot-0	0.93 ±0.02a	128.3 ±63.1a
	Cr-2	79.5±24.7a	97.6±12.3a	Plot-N	0.58 ±0.17c	45.2 ±36.5a
				Plot-80	0.78 ±0.17b	67.9 ±42.9a
				Plot-40	0.92 ±0.07a	51.1 ±26.0a
				Plot-20	0.95 ±0.06a	74.3 ±40.2a
				Plot-0	0.96 ±0.07a	72.5 ±38.3a
	Cr-3	66.0±12.7a	75.6±8.2b	Plot-N	0.25 ±0.19c	13.8 ±5.2c
				Plot-80	0.41 ±0.29c	16.5 ±11.0c
				Plot-40	0.79 ±0.09b	36.6 ±13.8b
				Plot-20	0.86 ±0.07ab	46.5 ±25.8ab
				Plot-0	0.92 ±0.09a	58.1 ±30.1a

* H-growth(1) and H-growth(2) mean annual height increments from November 1990 to October 1992 of all seedlings and the top 15 seedlings selected in terms of height growth in Plot-0 and Plot-20, respectively, where the seedlings were little influenced by weeds.

† The $d(D^2H)$ means increment of D^2H for 2 years from November 1990 to October 1992.

‡ Data from Plot-80 at Cr-1 were not available.

TABLE 2–Effect of each weeding treatment on the exposure ratio of crown in relation to the site quality* (mean±standard deviation. Means followed by the same letter within a column are not significantly different—t-test, p<0.05).

Species	Study site	Plot-N	Plot-80	Plot-40	Plot-20	Plot-0	H-growth(2)* (cm/year)
Ch. obtusa	Ch-1	–0.03±0.47a	0.17±0.36b	0.40±0.68b	0.75±0.09b	0.70±0.11c	41.3
	Ch-2	0.22±0.24a	0.65±0.26a	0.84±0.14a	0.92±0.14a	0.97±0.04a	50.6
	Ch-3	–0.56±1.20b	0.27±0.41b	0.58±0.34b	0.67±0.29b	0.89±0.09b	45.9
Cr. japonica	Cr-1	0.58±0.19a	†	0.80±0.14b	0.90±0.04b	0.93±0.02a	102.3
	Cr-2	0.58±0.17a	0.78±0.17a	0.92±0.07a	0.95±0.06a	0.96±0.07a	97.6
	Cr-3	0.25±0.19b	0.41±0.29b	0.79±0.09b	0.86±0.07b	0.92±0.09a	75.6

* Index of site qualities as shown in Table 1.

† Data from this plot were not available.

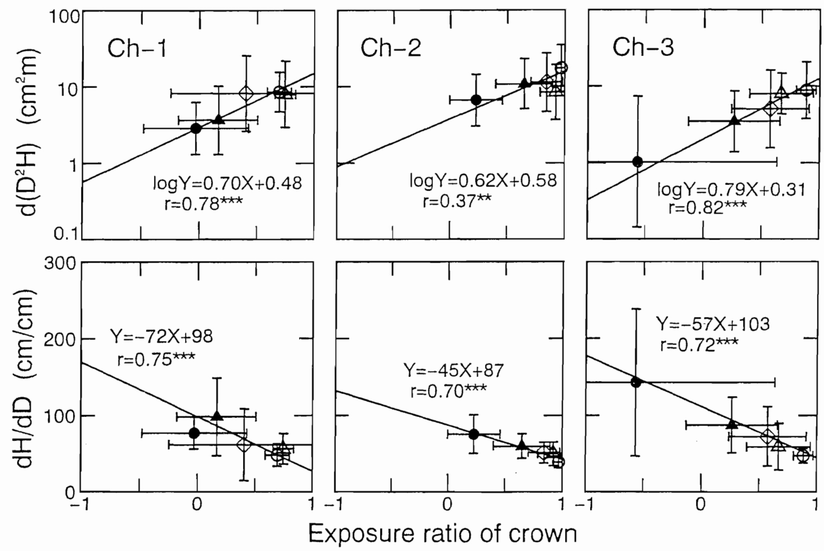

FIG. 2–Relationship between exposure ratio in October 1992 and the growth of *Chamaecyparis obtusa* seedlings: dD, dH, and $d(D^2H)$ were increments of basal diameter (D), seedling height (H), and D^2H for the 2 years from November 1990 to October 1992; ○ = Plot-0, Δ = Plot-20, □ = Plot-40, ▲ = Plot-80, ● = Plot-N. Symbols and bars indicate mean values and standard deviations, respectively.

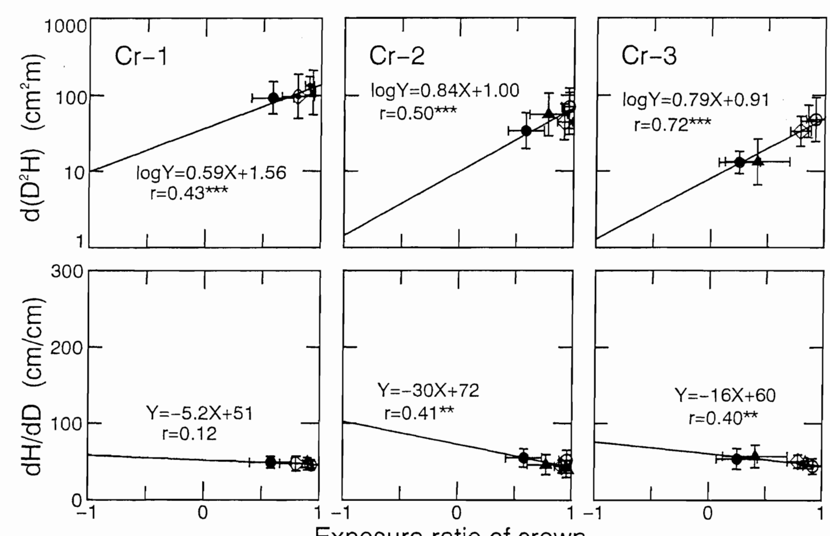

FIG. 3–Relationship between exposure ratio in October 1992 and height growth of *Cryptomeria japonica* seedlings. Symbols as for Fig. 2.

growth to a decrease in the exposure ratio, more so in cypress than in cedar seedlings. This effect has also been demonstrated with trees growing under a canopy (Axelsson *et al.* 1979; Tange *et al.* 1991), under high density conditions (Lanner 1985), and where the lower part of crown was pruned (Slabaugh 1957). These growth characteristics were related to translocation of photosynthetic products as controlled by light quality (Asakawa *et al.* 1974). At our study sites, the height growth rates of the seedlings whose exposure ratios were more than 0.6 were less influenced by the competition with neighbouring weeds (Tange *et al.* 1993).

Relative frequency of the seedlings with exposure ratios of more than 0.6 in September 1992 was higher in plots with small amounts of weeds, such as Plot-0 and Plot-20, than in plots with large amounts of weeds, such as Plot-80 and Plot-N. Within any one weeding treatment, the relative frequency was higher in plots at high quality sites than in plots at low quality sites (Table 3). These results indicate that weeding gave a greater advantage to seedlings at the high quality sites than to those at the low quality sites.

TABLE 3–Influence of the site quality* on the relationship between the weeding treatments and the ratios of the seedlings whose exposure ratios of the crowns were larger than 0.6.

Species	Study site	Plot-N	Plot-80	Plot-40	Plot-20	Plot-0	H-growth(2)*
		Relative frequency (%)					(cm/year)
Ch. obtusa	Ch-1	0	18	50	92	92	41.3
	Ch-2	0	58	79	100	100	50.6
	Ch-3	8	27	56	84	92	45.9
Cr. japonica	Cr-1	31	85†	80	100	100	102.3
	Cr-2	31	80	100	100	100	97.6
	Cr-3	0	25	93	100	100	75.6

* Index of site qualities as shown in Table 1.

† Results from this plot were obtained in September 1991. Others were obtained in October 1992.

Seedling Growth after Weeding Treatment and Stand Establishment

The relationship between exposure ratio in October 1992 and the height increment for 2 years from October 1992 to October 1994, when weeding treatment was not carried out, is shown in Fig. 4. The larger the seedling exposure ratio in October 1992, the greater the growth rate of seedlings after weeding. This result implies that early weed competition continued to influence seedling growth for 2 years after the weeding treatments.

The relationship between site quality and the relative frequency of the seedlings released from weed competition is shown in Fig. 5. Site quality is expressed as the mean annual height growth rate of seedlings free from weeds (Table 1). The standard of release from weed competition was seedling height of more than 2 m on cypress, or more than 3 m on cedar, after six growth seasons. At high quality sites such as Ch-2, Cr-1, and Cr-2, planted seedlings in Plot-N (no weeding) out-competed weeds, and weeding was not necessary for stand establishment. But at low quality sites such as Ch-1, Ch-3, and Cr-3, weeding was necessary for stand establishment, and weeding treatments that left large amounts of weeds around a seedling (Plot-80) did not give enough advantage to the seedlings over the weeds. At low quality sites, all weeds around a seedling have to be removed.

CONCLUSIONS

Effect of weeding treatments on seedling growth depended on site quality. The higher the site quality, the greater the advantage given to the seedlings in competition with the weeds,

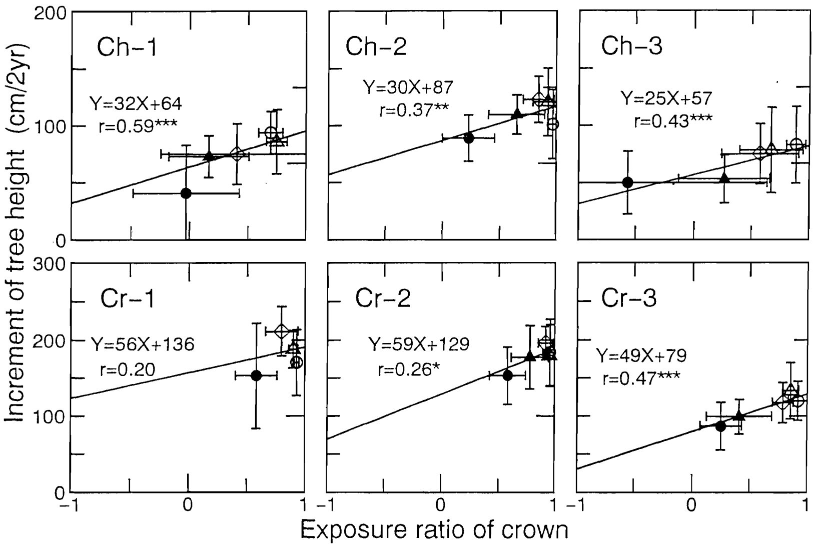

FIG. 4–Relationship between the exposure ratio of the crown in October 1992 and height growth for 2 years from October 1992 to October 1994 where weeding had not been carried out. Symbols as for Fig. 2.

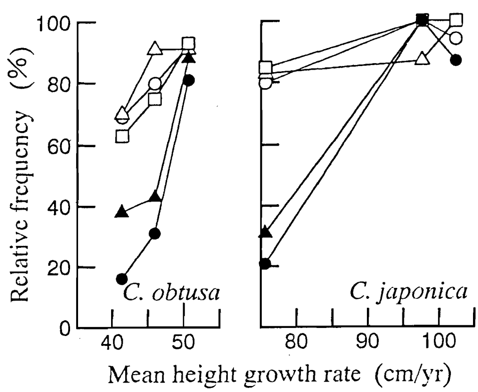

FIG. 5–Influence of site quality on the relationship between the amounts of weeds left around the seedling and the ratios of the seedlings released from competition with weeds after six growth seasons. Site quality represented by the mean height growth of the tallest 15 seedlings in Plot-0 and Plot-20, as shown in Table 1. *Chamaecyparis obtusa* seedlings released from competition with weeds were 2 m taller and *Cryptomeria japonica* seedlings were 3 m taller. Symbols as for Fig. 2.

even where many weeds were left around a seedling. At the lower quality sites, in order to establish trees successfully it was necessary to help seedlings to compete with weeds. These results imply that the effectiveness of mechanisation for reducing labour in weeding work depends on the site quality.

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