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Clonal Variation in Sugi on the Resistance to Cryptomeria Bark Borer (*Senamotus Japonicus* LACORDAIRE) and the Population Dynamics by Setting the Bark Borer Free in a Cage

By

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Summary : 'The releasing test to select a candidate clone with resistance to the bark borer, was conducted in a nesting cage planted with 47 clones at Kansai Breeding Office, Forest Breeding Institute and we investigated the clonal variations on resistance of *Sugi* (*Cryptomeria japonica*) and population dynamics of the bark borer during the period from April 1991 to April 1992. There were clonal variations concerning the number of larvae boring in the bark, the boring ratio in the sapwood, ratio forming pupal chamber and so on. Furthermore, significant differences were also observed concerning the fresh weight of newly-emerged adults and bored length of the sapwood. In July 1991, as *Dasychira argentata* infested heavily all sample trees, there were only two clones in which pupal chambers were not formed by the bark borer, and general resistivity was also at a low level.

The relative growth rate for each sample tree was negatively correlative to both the number of larvae boring in the bark and forming pupal chamber, and negative correlation was also obtained between the number of larvae boring in the bark and fresh weight of newly-emerged adults for each sample tree.

In comparing the sexes of the bark borer, not only the mean fresh weight of female adults but also the mean bored length of female larvae were superior to those of males.

Based on these results, we discussed the characteristics of the Sugi clones and population dynamics of the bark borer.

I Introduction

The cryptomeria bark borer, *Semanotus japonicus* LACORDAIRE (Coleoptera: Cerambycidae), is well-known insect as one of the most serious pests against this tree in Japan. At the Kansai Breeding Office, Forest Tree Breeding Institute, a project to find a resistant tree against the bark borer has been conducted since 1984. This project is divided into three strategies: Pin pricking test (simple test), release test (the first test) and inoculation test (the second test). The simple test has be done to select candidate trees with resistance to the bark borer from the trees in the forest, local cultivars and plus tree clones by pin pricking treatment[4]. Since 1991 the release test has been conducted to find candidate trees more precisely by setting the bark borers free in a cage planted with the trees passed simple test and after the release test, the inoculation test of hatching larvae is going to carry out at the stem of the trees.

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(1)(2) Kansai Breeding Office.

Though a few 'the first semi-test' were examined[3], population dynamics of the bark borer were not investigated. To investigate the dynamics is a very important study for confirming reproductive strategy of the bark borer more clearly because there is no report on the dynamics of the bark borer in infesting previously non-infested trees.

In this paper we report on the clonal variation against the resistance to the bark borer and the population dynamics of the bark borer.

Ⅱ Materials and methods

Field collections and observations were carried out at the Kansai Breeding Office. For releasing bark borers, nesting cage (15m long× 6 m broad× 5 m height) was established in a field. A total of 47 Sugi clones which were 7-year-old grafted trees were selected for the study and were planted in the cage from March to April in 1990. Number of planted trees were three ramets for each 46 clone, two ramets for one clone and 140 trees in total. Planting method followed 'The first test Guidance for resistant tree breeding against the bark borer'[1].

Newly-emerged adults were collected from cages containing logs infested by the bark borers in the previous year or from infested trees banded in the field by using band-trapping method[5] during the period from late March to early April in 1991. In mid-April, heights of all sample trees were measured and 70 pairs of adults were released in the nesting cage. Since number of eggs tored in female adults was correlative to their fresh weight[2], female adults whose fresh weight was less than 0.10g were not used for this treatment.

All sample trees were cut down and their heights and DBH was measured from October to December in 1991. Number of larvae boring in the bark and the sapwood, and forming pupal chamber in each sample tree were counted, and furthermore, bored length of larvae at the bark and the sapwood were measured. Sample trees in which pupal chambers were formed by the bark borer were covered with a polyethylene bag individually and the emerged adults were collected from March to April in 1992 and immediately weighed them on a microbalance.

Ⅲ Results

Mean heights and DBH of the sample trees at the time of the cut down was 3.40m and 3.71cm, respectively. One sample tree (*Kobe* 1) was dead before releasing the bark borer and fifty sample trees were dead because *Dasychira argentata* infested heavily all the sample trees in June 1991.

1. Clonal difference

Table 1 shows total number of larvae boring in the bark, in the sapwood and forming pupal chamber for each clone. In only four clones (*Hiroshima* 18, *Okayama* 61, *Okayama* 58 and *Okayama* 43), the number of larvae boring in the bark was less than 10 in all ramets. Values of three characters on Table 1 were all significantly different among the clones at 1% level. Number of larvae boring in the bark was not significantly different between the sample trees planted on the margin and those not on the margin (t=1.69, P>0.05). Number of larvae boring in the bark for each clone was neither significantly correlative to the ratio of boring in the sapwood (Fig. 1, $r=-0.08$, P>0.05) nor ratio of forming pupal room (Fig. 2, $r=-0.11$, P>0.05)

Table 2 shows mean bored length of larvae at the bark and the sapwood, and mean ratio of boring in the sapwood and forming pupal chamber for each clone. Mean bored length in the sapwood was shown for each sex. Mean ratio of boring in the sapwood for each clone was determined by dividing the larvae boring number in the sapwood by the larvae boring number in the bark and mean ratio of pupal chamber formation was determined by dividing the larvae forming pupal chamber number by the larvae boring number in the bark. All values of the characters were significantly different among the clones except for the mean bored length of female larvae in the sapwood.

Table 3 shows number of the emerged adults and mean fresh weight of them for each clone. The emerged adults were not all captured because some of them escaped from the polyethylene bag. The mean fresh weight of male adults was not significantly different among the clones, while the weight of female adults was significantly different among the clones. It was of great interest that negative correlation was obtained for each sex among the clones between the mean fresh weight of adults and the mean bored length in the sapwood ($r=-0.31$ for male and $r=-0.35$ for female, P<0.05) (Fig. 3).

Table 1. Number of larvae boring in barks, number of larvae boring in sapwoods and number of larvae forming pupal chambers for each clone.

Clone	Number of larvae boring of forming		
	In barks	In sapwood	Pupal chamber
Nishiikukijin 36	77	34	15
Nishiikumatsushita 2	71	51	12
Hyougo 26	38	33	23
Hyougo 27	57	48	48
Hyougo 25	60	44	41
Hyougo 24	82	60	28
Hiroshima 19	22	14	13
Hiroshima 18	17	10	1
Hiroshima 17	49	32	19
Hiroshima 16	27	17	9
Hiroshima 12	42	29	17
Hiroshima 9	64	24	15
Hiroshima 6	27	24	20
Hiroshima 5	55	45	25
Hiroshima 3	40	20	5
Hiroshima 1	28	22	15
Okayama 65	31	11	8
Okayama 64	66	60	50
Okayama 63	76	41	22
Okayama 62	45	37	33
Okayama 61	11	7	1
Okayama 60	24	16	8
Okayama 59	32	22	4
Okayama 58	11	10	7
Okayama 57	23	5	3
Okayama 51	52	27	14
Okayama 45	57	46	34
Okayama 43	8	7	7
Okayama 41	63	12	2
Okayama 38	33	17	9
Okayama 33	50	45	27
Okayama 32	81	71	20
Okayama 31	63	43	14
Okayama 30	38	20	10
Okayama 27	43	24	18
Okayama 23	29	24	16
Okayama 22	29	20	12
Okayama 18	40	27	3
Okayama 17	57	48	42
Okayama 15	54	36	30
Okayama 13	43	20	10
Okayama 9	57	32	6
Okayama 8	43	35	21
Okayama 7	70	36	3
Okayama 3	37	29	33
Shinngu 4	62	31	21
Kobe 1[1]	52	37	20
F	2.27**	2.26**	2.15**

1: only one ramet
** significant at 1% level.

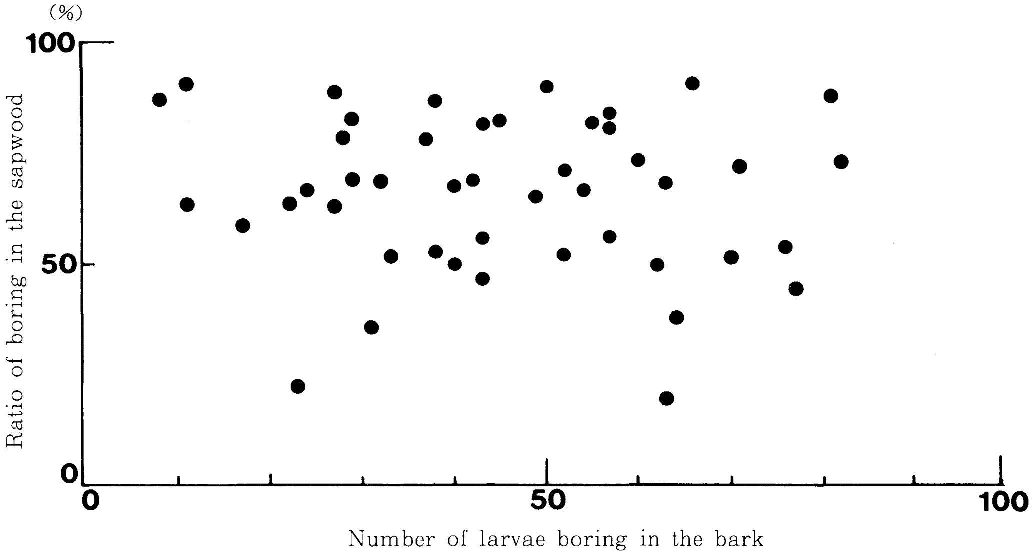

Fig.1 Relationship between the number of larvae boring in the bark and the mean ratio of larvae boring in the sapwood for each clone.

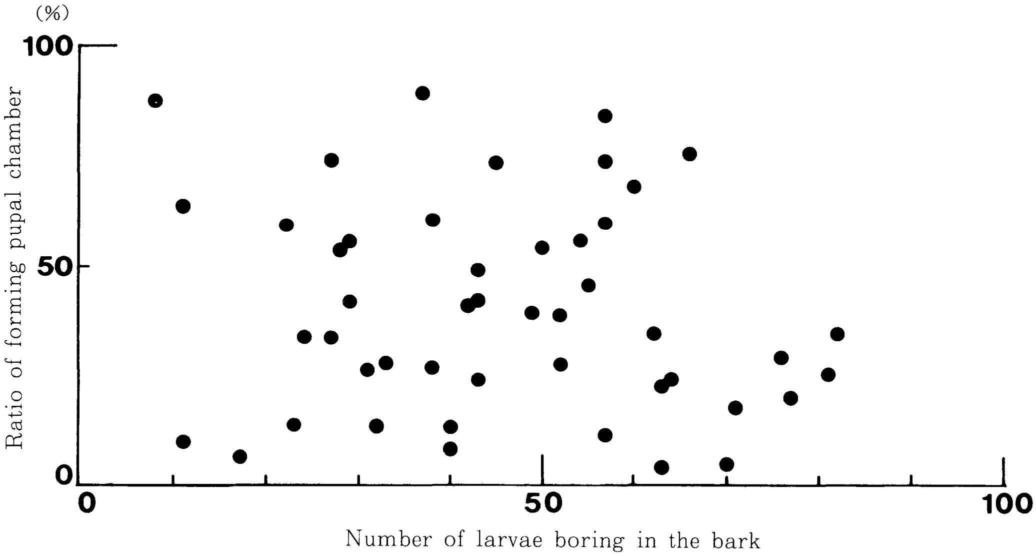

Fig.2 Relationship between the number of larvae boring in the bark and the ratio of larvae forming pupal chamber for each clone.

Table 2. Mean bored length at the bark, mean bored length at the sapwood and mean ratio of boring in the sapwood and forming pupal chamber for each clone.

Clone	Mean length (cm)			Ratio (%)	
	At the bark	At the sapwood		In sapwood	Pupal room
		Male	Female		
Nishiikukijin 36	12.4	58.4	64.2	43.6	19.2
Nishiikumatsushita 2	13.2		62	53.5	16.9
Hyougo 26	7.8	53.7	63.5	92.5	57.5
Hyougo 27	16.9	34.3	40 8	89.5	84.2
Hyougo 25	7.8	40	48.4	76.6	62.5
Hyougo 24	10.0	51.7	41	73.2	34.1
Hiroshima 19	8.9	55.6	76	63.6	59.1
Hiroshima 18	7.2			58.8	5.9
Hiroshima 17	10.8	46.7	47.8	67.3	38.8
Hiroshima 16	12.8	36	37	62.9	33.3
Hiroshima 12	10.3	36.5	43	69.0	40.5
Hiroshima 9	16.5	32	49.2	37.5	23.4
Hiroshima 6	7.3	62	45.8	88.9	74.1
Hiroshima 5	9.3	42.1	55.4	83.6	45.5
Hiroshima 3	9.0		28	50.0	12.5
Hiroshima 1	12.7	27.8	42.7	78.6	53.6
Okayama 65	8.4	29.5	44	38.7	25.8
Okayama 64	9.0	40.4	50.6	90.9	75.8
Okayama 63	8.0	41.8	50.8	56.6	29.0
Okayama 62	8.2	38.7	37	87.0	71.7
Okayama 61	9.2			63.6	9.1
Okayama 60	8.2	37	47.3	66.7	33.3
Okayama 59	7.6	32	34.5	61.1	11.1
Okayama 58	12.8	47.5	51	90.9	63.6
Okayama 57	5.6	76	50	21.7	13.0
Okayama 51	8.1	28	34	51.9	26.9
Okayama 45	13.1	32.1	40	80.7	59.6
Okayama 43	7.0			84.6	69.2
Okayama 41	9.1		25	19.0	3.2
Okayama 38	11.6	26	51	51.5	27.3
Okayama 33	8.9	41.6	47.1	90.0	54.0
Okayama 32	9.0	45.4	63.7	87.7	25.0
Okayama 31	15.1	27	36	68.3	22.2
Okayama 30	10.7	28	46	53.8	25.6
Okayama 27	10.0	45.4	42.4	55.8	41.9
Okayama 23	7.8	44	58.5	78.1	50.0
Okayama 22	14.2	40.3	30.5	64.5	38.7
Okayama 18	11.3		31	67.5	7.5
Okayama 17	10.1	38.6	47.1	84.2	71.9
Okayama 15	8.6	29.8	36.3	66.7	55.6
Okayama 13	10.5	31	44.8	46.5	23.3
Okayama 9	10.8	52	50	56.1	10.5
Okayama 8	9.6	28.3	48.6	81.4	48.8
Okayama 7	11.1			51.4	4.3
Okayama 3	7.9	53.2	56.3	78.6	78.6
Shinngu 4	8.5	36.4	38.2	50.0	33.9
Kobe 1[1]	10.2	39	43	71.1	38.5
F	2.43**	1.67**	1.07^{ns}	1.75*	2.02**

1: only one ramet
** significant at 1% level
*: significant at 5% level
ns: not significant

Table 3. Mean fresh weight of newly-emerged adults for each clone

Clone	Male		Female	
	Number	Weight (g)	Number	Weight (g)
Nishiikukijin 36	13	0.12	10	0.19
Nishiikumatsushita 2	4	0.17	3	0.20
Hyougo 26	8	0.11	17	0.16
Hyougo 27	25	0.14	21	0.21
Hyougo 25	11	0.11	26	0.20
Hyougo 24	6	0.12	9	0.19
Hiroshima 19	5	0.15	6	0.19
Hiroshima 18	0		1	0.36
Hiroshima 17	9	0.14	12	0.25
Hiroshima 16	7	0.14	2	0.29
Hiroshima 12	6	0.15	8	0.24
Hiroshima 9	5	0.15	8	0.20
Hiroshima 6	9	0.11	13	0.15
Hiroshima 5	26	0.10	13	0.12
Hiroshima 3	0		3	0.24
Hiroshima 1	10	0.12	6	0.20
Okayama 65	2	0.14	4	0.19
Okayama 64	19	0.09	16	0.19
Okayama 63	19	0.12	15	0.19
Okayama 62	15	0.15	11	0.22
Okayama 61	0		0	
Okayama 60	1	0.15	4	0.18
Okayama 59	1	0.18	2	0.23
Okayama 58	3	0.14	3	0.18
Okayama 57	1	0.13	3	0.21
Okayama 51	2	0.15	8	0.20
Okayama 45	15	0.15	14	0.22
Okayama 43	0		6	0.12
Okayama 41	0		1	0.19
Okayama 38	2	0.15	6	0.27
Okayama 33	11	0.11	13	0.22
Okayama 32	5	0.11	6	0.18
Okayama 31	3	0.14	6	0.29
Okayama 30	5	0.15	4	0.31
Okayama 27	10	0.11	6	0.19
Okayama 23	10	0.14	6	0.22
Okayama 22	7	0.15	5	0.23
Okayama 18	0		1	0.32
Okayama 17	17	0.10	29	0.15
Okayama 15	13	0.15	10	0.19
Okayama 13	3	0.13	7	0.22
Okayama 9	1	0.14	3	0.19
Okayama 8	6	0.12	9	0.21
Okayama 7	2	0.18	0	
Okayama 3	6	0.13	16	0.21
Shinngu 4	8	0.10	6	0.16
Kobe 1[1]	9	0.08	5	0.16
F		0.97^{ns}		2.00**

1: only one ramet
ns: not significant
** significant at 1% level

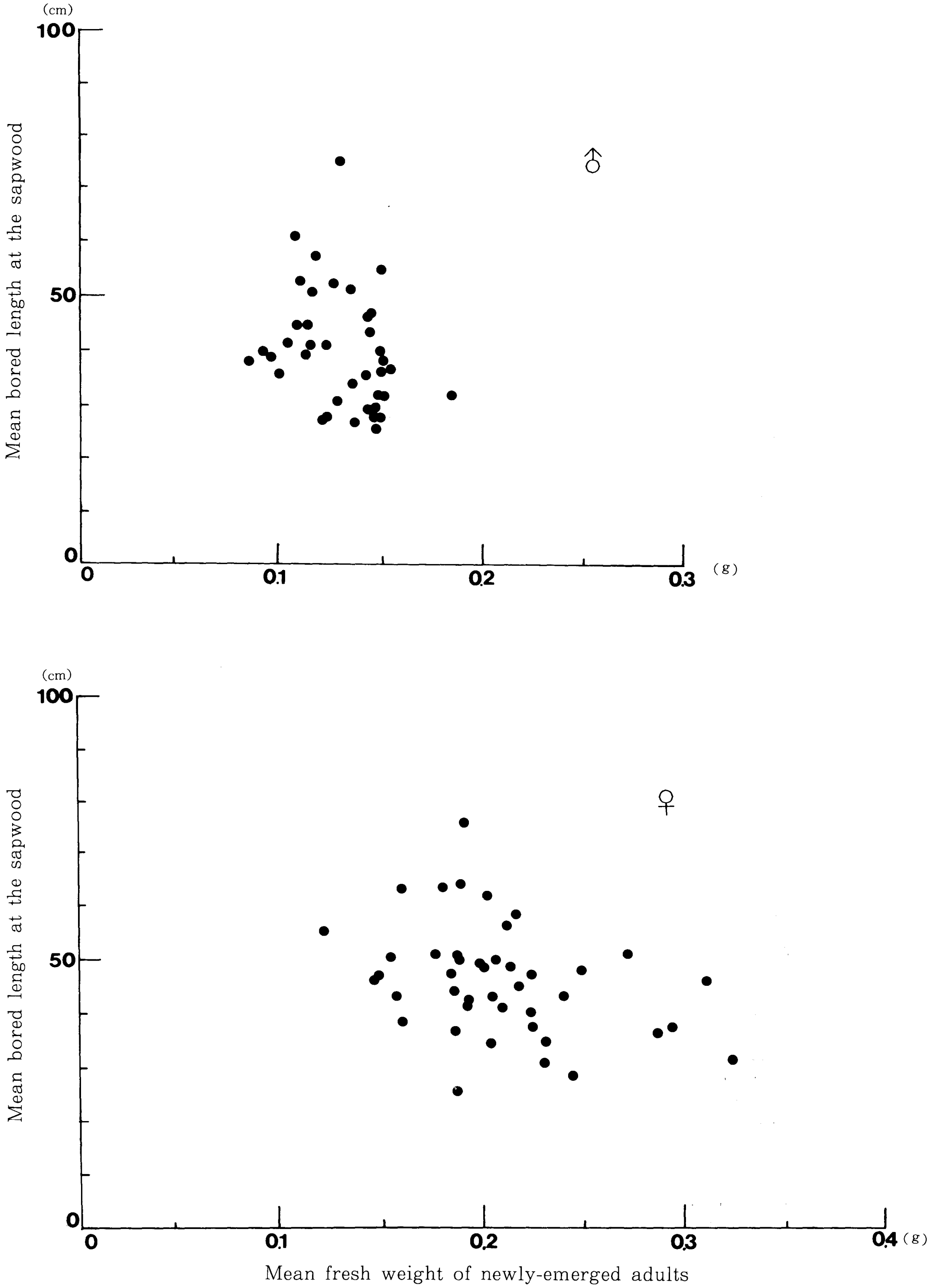

Fig.3　Relationship between the mean fresh weight of newly-emerged adults and the mean bored length at the sapwood for each clone.

2. Factors affecting relative growth rate of the sample trees

Though number of larvae boring in the bark was neither correlative to the mean ratio of boring in the sapwood nor forming pupal chamber (Figs. 1 and 2), the number of larvae boring in the bark was significantly correlative to relative growth rate of the sample trees (Kendall's $\tau = -0.22$, $P < 0.05$)(Fig. 4). The relative growth rate was determined by dividing the sample tree height at the time of cutting down by the sample tree height at the time of releasing the bark borer. The relative growth rate was also significantly correlative to the number of larvae forming pupal chamber (Kendall's $\tau = -0.38$, $P < 0.01$)(Fig. 5).

3. Sexual difference of the bored length at the sapwood

Since mean fresh weight of female adults of the bark borer has been suggested to be larger than that of male adults[6], it can be considered that bored length in the sapwood by female larvae should be longer than that by male larvae. Table 4 shows mean fresh weight for each sex of newly-emerged adults and the mean bored length. Significant differences were obtained not only between mean fresh weight of female adults and that of male adults but also between mean bored length in the sapwood by female larvae and that by male larvae. But comparing with each sex, significant difference was not obtained between mean fresh weight of the adults and mean bored length at the sapwood for both sexes (Kendall's $\tau = -0.07$ for males and $\tau = -0.04$ for females, $P > 0.05$)(Fig. 6).

4. Relationship between the number of larvae boring in the bark and fresh weight of newly-emerged adults

Relationship between the number of larvae boring in the bark and mean fresh weight of the emerged adults for each sample tree was illustrated on Fig. 7. For both sexes, mean fresh weight of the emerged adults was negatively correlative to the number of larvae boring in the bark (Kendall's τ -0.19 for males and $\tau = -0.16$ for females, $P < 0.05$).

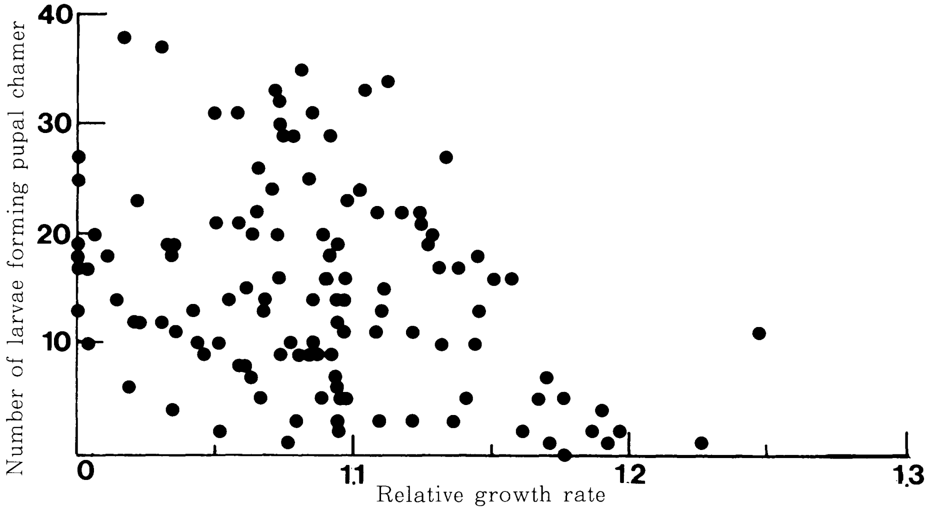

Fig.4 Relationship between the relative growth rate and the number of larvae boring in the bark for each sample trees.

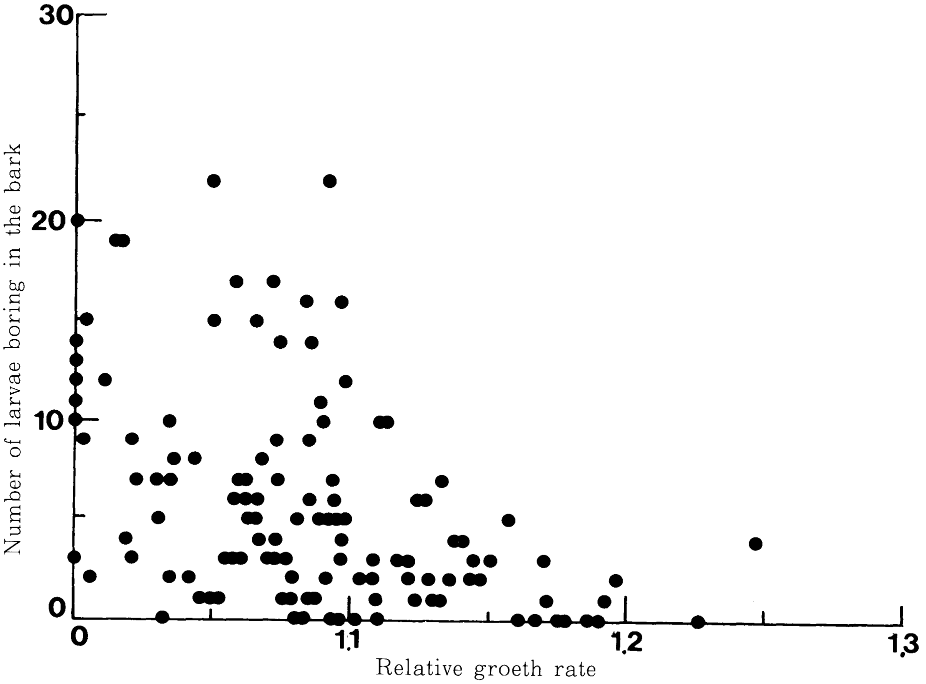

Fig.5 Relationship between the relative growth rate and the number of larvae forming pupal chamber.

Table 4. Mean fresh weight of adults and mean bored length at sapwood for each sex of the bark borer

	Mean fresh weight of adults (g ± S.D.)	t	Mean bored length at sapwood (cm ± S.D.)	t
♂	0.13±0.04	7.68＊＊	40.4±12.9	4.87＊＊
♀	0.20±0.06		46.7±15.4	

＊＊: significant at 1% level

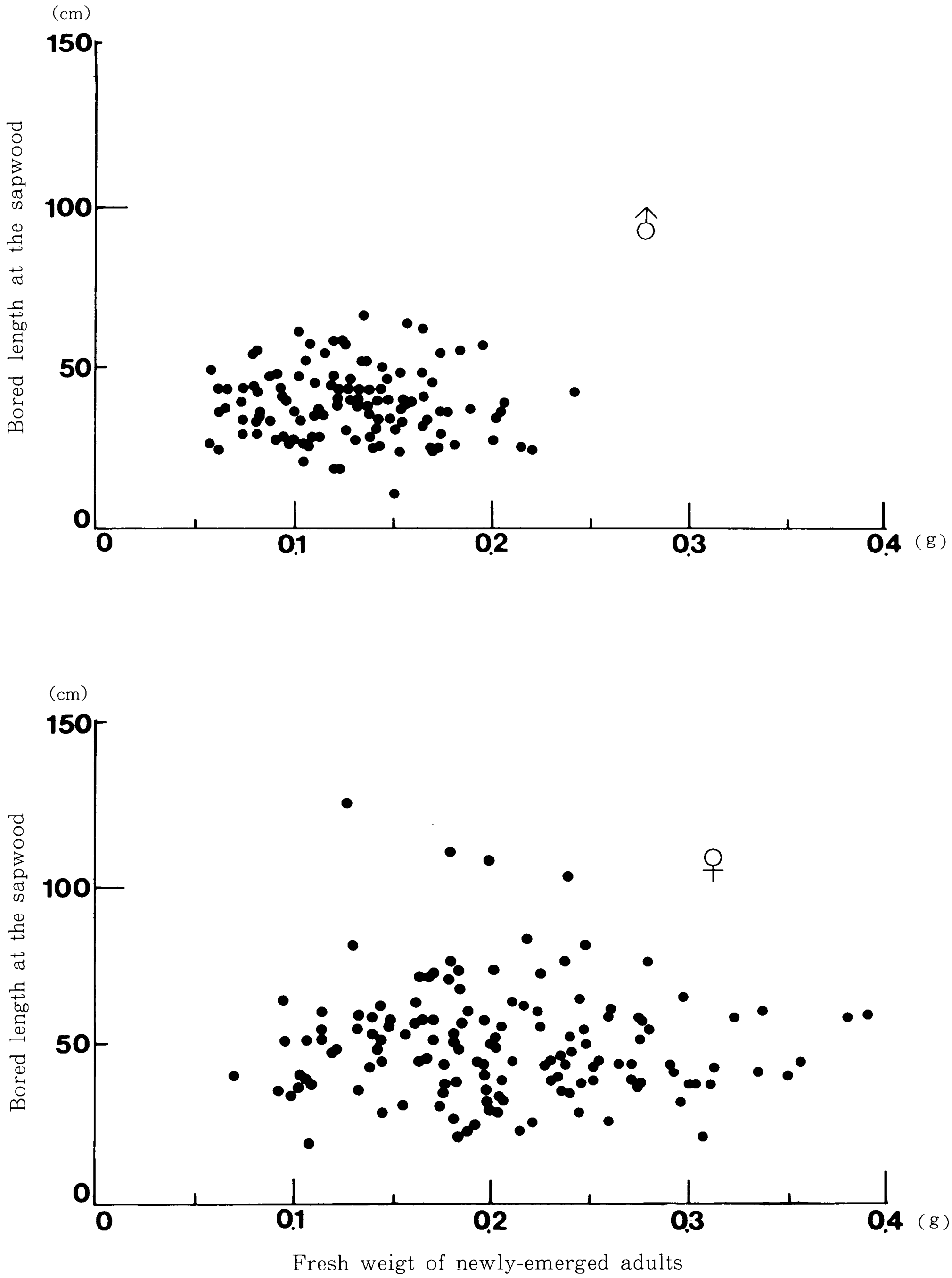

Fig.6 relationship between the fresh weight of the adults and bored length at the sapwood for each sex.

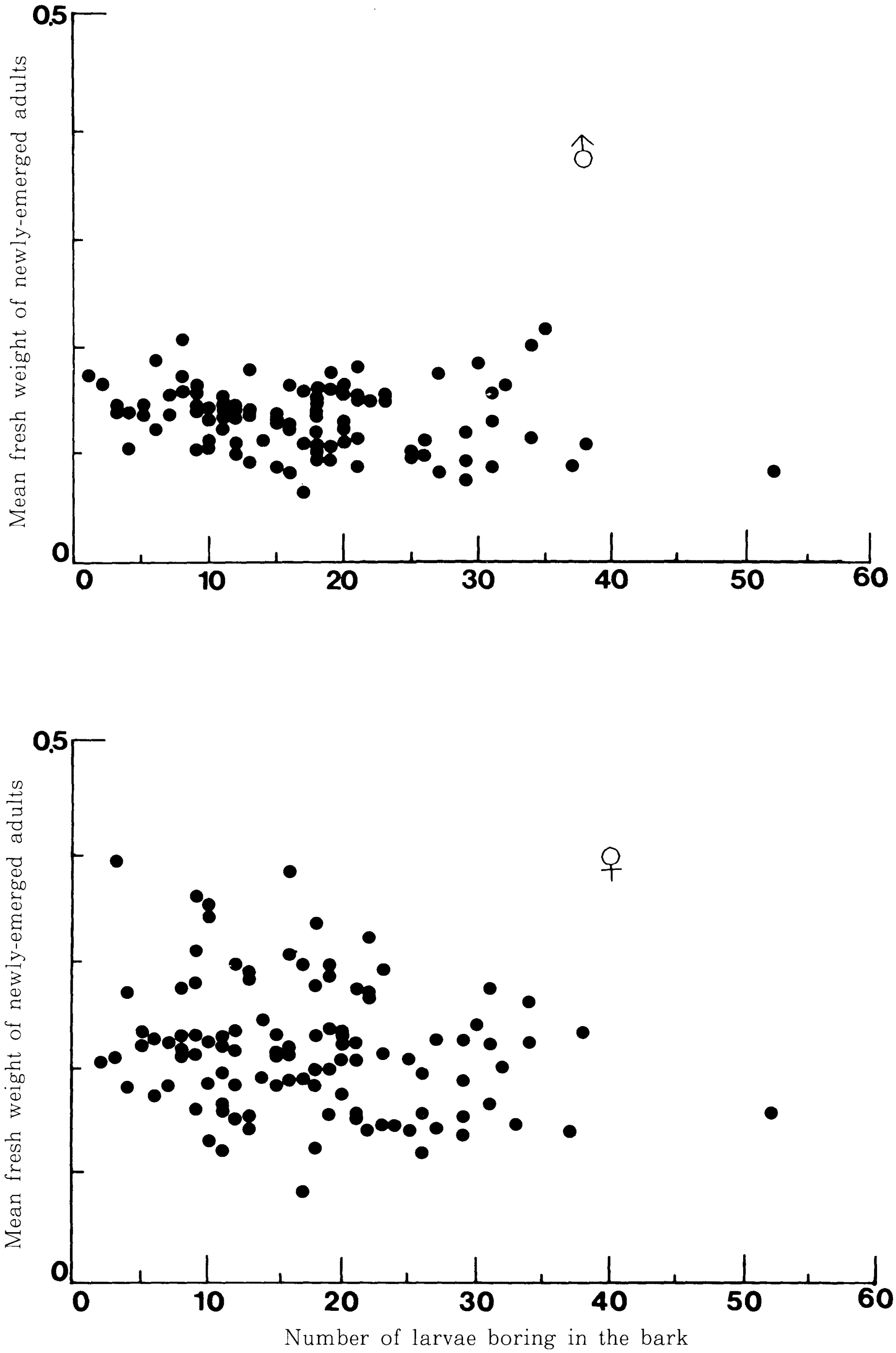

Fig.7　Relationshiop between the number of larvae boring in the bark and mean fresh weight of newly-emerged adults for each sample tree.

Ⅳ Discussion

It has been well known that resistivity of Sugi against the bark borer is very different among cultivars. So in the field, it is probable that a Sugi tree with resistance to the bark borer exists in some proportion. Our results suggest that there are clonal variations of the sample trees concerning the number of larvae boring in the bark and the sapwood, forming pupal chamber, the mean bored length at the bark and the sapwood, and the mean ratio of boring in the sapwood and forming pupal chambers (Tables 1, 2 and 3), and some clones (*Hiroshima* 9, *Okayama* 15 and so on) are considered to have a strong resistance to the bark borer because the mean ratio of pupal chamber formation is showed low levels (Table 2).

However, as the mean bored length in the sapwood for female larvae is not significantly different among the clones (Table 2) and also mean fresh weight of male adults is not among the clones (Table 3), these components may be influenced more strongly by other factors, for example number of larvae boring in the bark (Fig. 7), rather than the clones of the host tree. Our interest is rather in the result of the negative correlation of Fig. 3. In general, it is assumed that positive correlation should be obtained between the mean fresh weight of adults and the mean bored length in the sapwood, but in fact the results showed a negative correlation. We must make clear whether the negative correlation is caused by clonal characteristic or not.

Both number of larvae boring in the bark and the number of larvae forming pupal chamber are negatively correlative to the relative growth rate of the host trees (Figs. 5 and 6) though number of larvae boring in the bark was neither correlative to the ratio boring in the sapwood nor forming pupal chamber (Figs. 1 and 2). This fact demonstrates that the energetic cost for defending the larvae decreases the relative growth of the host tree, so we must thus select the clones to have not only resistance to the bark borer after boring but characteristics to prevent oviposition by the bark borer .

As shown in Table 3, mean bored length at the sapwood by female larvae is longer than that by male larvae. This result suggests that female larvae do more serious damage to host trees. Though length of pupal chamber is not measured in this study, the length by female pupa will be also longer than that by male pupae because length of pupal chamber is considered to be correlative to the size of pupae.

For female adults of the bark borer, it is not profitable to bore with too many larvae into one host tree because the fresh weight of adults is correlative to the number of larvae boring into barks (Fig. 7). This is especially important for female progenies because number of eggs stored in them is correlative to the fresh weight of them (It, 1992).

Accordingly, our results suggest that there are clonal differences concerning the resistivity against the bark borer and the population dynamics of it. However our object to find the Sugi clones which have perfect resistance to the bark borer, that is, the ratio of boring in the sapwood of 0%, has not been achieved in this test and the population dynamics of the bark borer are not yet sufficiently clear, so further observations will be needed.

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スギカミキリ抵抗性一次検定（網室による放虫検定）から得られたスギカミキリに対するスギの抵抗性のクローン間差とスギカミキリの個体群動態

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1991年４月から1992年４月にかけて，林木育種センター関西育種場に設置された網室内においてスギカミキリ抵抗性候補木45クローン，精英樹２クローンを用いて一次検定を行い，スギカミキリに対する抵抗性のスギのクローン間差およびスギカミキリの動態を調査した。その結果，スギカミキリ幼虫の穿孔数，辺材部穿孔率，蛹室形成率などにクローン間差がみられたが，さらに羽化成虫の生体重や辺材部穿孔長にも同様に差が認められた。1991年の６月には検定網室内に大量のハマキガが発生したために樹勢が衰え，蛹室形成率ゼロのクローンは２つしか得られなかった。

試験木の相対樹高生長率は，幼虫の穿孔数と蛹室形成数に対して負の相関を示し，幼虫の穿孔数の多い試験木からは生体重の小さい成虫が得られた。

スギカミキリの雌雄での比較を行うと，生体重も辺材部穿孔距離も雌の方が大きかった。

考察では，これらの結果を踏まえてスギのクローン特性とスギカミキリの個体群動態について検討を行ってみた。

(1)(2) 林木育種センター関西育種場