IS THERE AN INVERSE CORRELATION BETWEEN SEXUAL AND ASEXUAL REPRODUCTION IN *CRYPTOMERIA JAPONICA* ?

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ABSTRACT

The possibility of an inverse correlation of sexual and asexual reproduction of **Cryptomeria japonica**, suggested by the poor flowering of good-rooting clones, was investigated on three sets of suitable data. Clones with most reliable data showed such a relationship to be moderately strong. When forestwide data were analysed, no relationship was found, but tests of skewness and expected crown-cone bearing relationship raised questions of whether flowering and rooting records were adequate for the individual trees used. The data suggest that use of good-rooting clones should be discouraged in seed orchards if they show poor flowering ability.

INTRODUCTION

In Japan, conversion from scion gardens to seed orchards has been encouraged since 1962. This has been done to reduce single-clone cultivation and to assure abundant breeding material for further selection in subsequent generations (Toda, in press). An obstacle of considerable importance to this approach is lack of flower bearing in some clones, leading to poor seed production, unequal genetic contribution to the harvested seed, and increased self pollination.

Natural stands of *Cryptomeria japonica* D. Don apparently originate both from layering and seedlings. A parent having both good seed production and good rooting ability should, other things being equal, have a selective advantage and its type should predominate in the forest. However, the author has observed that trees displaying good flowering tend to have poor rooting ability, and vice-versa. If this is normal in *Cryptomeria,* the seed orchard approach would automatically select against good rooting ability: improved seed production in orchards would result in the elimination of poor-flowering, and hence good-rooting, clones. This study investigates the hypothesis that a strong inverse relationship exists between asexual and sexual reproduction in *Cryptomeria.*

SOURCES OF DATA AND RESULTS

The clones used in these studies were mainly from plus trees selected in central Honsyu by governmental agencies. Though not a normal sample of the population for growth, the clones may be considered an unselected sampling of reproductive abilities.

Although the author tried in 1965, 1966, and 1967 to investigate the hypothesis directly with diallel crosses of three good-rooting and three poor-rooting clones, the crosses could never be completed because of the failure of the good-rooting clones to flower. Hence, the investigation has proceeded with existing clones, first with six from the Minamikoma-Gun locality, and then from wider ranges in the Kanto Forest Tree Breeding District.

Investigation I

During pollination trials, flowering and rooting records were kept on two famous local varieties in addition to the six clones mentioned above. Each year, flower bearing was ranked independently by three investigators using the following scoring:

0 : almost non-bearing
1 : few
2 : medium
3 : abundant

Records on percent of rooting and the production of cones and seed from open and controlled pollination are shown in Table 1.

TABLE 1—A comparison of the asexual and sexual reproductive abilities of eight clones of **Cryptomeria japonica**

Clones	Age of scion stock years	Rooting % mean	(max.)	Natural flowering of ortets by open pollination: Amount of female cones	Harvested sound seed per 10 g seed	Controlled pollination: Mature cone %	Seedlings per 10 g seed
Sanbu	7	72	(94)	very few	0	—	55
YKZ-1	5	50	(86)	few	113	4.6	49
Kumotoosi	7	49	(60)	—	—	—	—
YKZ-7	5	47	(74)	few	195	7.3	86
YKZ-6	5	30	(55)	medium	180	4.9	86
YKZ-3	6	24	(48)	medium	245	7.5	108
YKZ-4	6	22	(43)	abundant	100	8.4	—
YKZ-8	6	10	(26)	medium	—	7.6	109

The flower bearing data for the clones are shown in Table 2. They were obtained from ramets propagated by grafting, and subsequently treated, either once or twice, with gibberellic acid (GA) (50 ppm).

TABLE 2—Variation in flower production of eight clones of **C. japonica** following treatment with gibberellic acid

Clones		Flower-bearing index*									
	Year	1965		1966		1967				Total	
	Treated season & times	Jul. once		Jun.-Jul. twice		Jun. once		Jul. once			
	Sex†	f.	m.	f.	m.	f.	m.	f.	m.	f.	m.
	Stem no.										
Sanbu	1	2	0	0	3	2	0	0	0		
	2	2	0	0	3	2	0	0	0		
	3	2	0	0	3	2	0	0	0		
		6	0	0	9	6	0	0	0	12	9
YKZ-1	1	1	0	0	3	2	1	2	0		
	2	2	0	0	2	2	0	2	0		
	3	0	0	0	3	2	0	2	0		
		3	0	0	8	6	1	6	0	15	9
Kumotoosi	1	1	3	3	1	1	1	1	0		
	2	1	3	3	1	1	0	2	0		
	3	1	3	3	1	1	0	1	0		
		3	9	9	3	3	1	4	0	19	13
YKZ-7	1	1	1	3	2	2	2	2	0		
	2	1	1	3	1	1	1	2	0		
	3	2	2	3	1	2	2	2	0		
		4	4	9	4	5	5	6	0	24	13
YKZ-6	1	0	0	1	2	2	2	2	0		
	2	1	0	1	1	2	0	2	0		
	3	2	1	1	1	2	1	1	0		
		3	1	3	4	6	3	5	0	17	8
YKZ-3	1	0	3	3	0	2	2	2	2		
	2	1	3	3	0	2	2	1	0		
	3	0	2	3	0	2	2	2	1		
		1	8	9	0	6	6	5	3	21	17
YKZ-4	1	3	0	2	2	2	1	3	3		
	2	2	0	2	2	2	1	3	2		
	3	3	0	1	2	1	1	3	1		
		8	0	5	6	5	3	9	6	28	14
YKZ-8	1	3	1	2	2	2	0	3	0		
	2	0	1	1	1	1	0	3	0		
	3	2	2	1	3	3	0	3	0		
		5	4	4	6	6	0	9	0	24	10

* See page 427 for definition of this index.

† f = female m = male flowers

Analysis of the data in Tables 1 and 2, to examine the relationships between rooting percentage and several indices of sexual reproductive abilities, provides the following correlation coefficients:

Female flowers initiated	r = −0.7246, d.f. 6, signif. at 5% level
Male flowers initiated	r = −0.3027, d.f. 6, non-significant
Male + female flowers initiated	r = −0.6336, d.f. 6, non-significant
Sound seed harvested	r = −0.6862, d.f. 6, signif. at 5% level
Seedlings produced	r = −0.8660, d.f. 6, signif. at 5% level
Mature cones produced	r = −0.5661, d.f. 4, signif. at 5% level

Investigation II

Expanding the investigation to the whole Yamanashi Prefecture, 23 clones were available with records of both mean rooting percentage over a 5-year period and flowering records for a single year (Fig. 1). Correlation coefficients were:

Female flowers	r = −0.2547, d.f. 21, non signif.
Male flowers	r = −0.5204, d.f. 21, signif. at 5% level
Male + female flowers	r = −0.4505, d.f. 21, signif. at 5% level

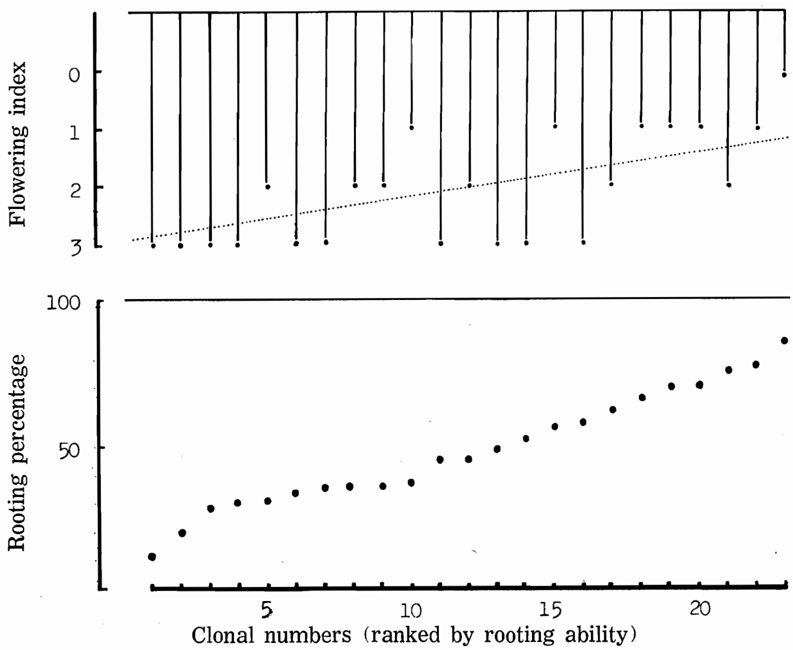

FIG. 1—Comparison of the rooting and flowering abilities of 23 clones of **C. japonica** in Yamanashi Prefecture. (The flowering index is defined on p. 427.)

Investigation III

Expanding the investigation to Kanto Forest Tree Breeding District provided a total of 154 trees for which some estimates of rooting percentage and flower production were available. In most cases maximum yearly survival percentage over a 5-year period from field data (Kanto Forest Tree Breeding Station, 1970) was used for rooting percentage. Flowering data were based upon number of flowers and male clusters on 1-year-old twigs treated with GA (50 ppm). Only 142 trees were available for male flowering data. Correlation coefficients computed for the entire body of data for the District were:

Female flowers $r = 0.0461$, d.f. 152, non-signif.
Male flowers $r = 0.164$, d.f. 140, non-signif.

The next examination allotted the above data among the 13 prefectures of the Kanto District. Correlation coefficients, given in Table 3, show a lack of relationship in most districts.

TABLE 3—Analysis of correlation between flowering and rooting in Kanto Tree Breeding District

Prefecture No.	Prefecture Name	Female flowers r	Male flowers r
1	Hukusimu	0.0389	0.3362
2	Totigi	- 0.0435	0.2321
3	Gunma	0.0416	- 0.1572
4	Ibaraki	0.0578	0.2941
5	Saitama	0.4194	0.2793
6	Tiba	0.2600	- 0.5079
7	Tokyo	- 0.0193	- 0.2451
8	Kanagawa	0.0555	0.2102
9	Nagano	0.2752	- 0.1126
10	Yamanashi	- 0.5356*	- 0.2728
11	Gihu	- 0.2995	- 0.3986
12	Sizuoka	- 0.6625*	0.0245
13	Aiti	0.4917	- 0.1685

* Significant at 5% level.

Because the results were so different from those in Investigations I and II, questions arose concerning the adequacy of flowering and rooting data. Rooting results from field data and flowering results based on a single year's estimate may not properly characterise the clones. An analysis of skewness of the distributions is shown in Fig . 2. Both rooting and flowering abilities show considerable skewness (g. (−0.7469) for rooting ability and g. (+3.7376) for flowering), suggesting caution in use of the data. As another check, the author used the suggestion reported by Arita and Tomita (1964) in which flowering was positively related to broadness of crown. From ortet data, b values were computed for 147 trees by the suggested equation $b = B/(D + 12)$ where B = crown diameter, and D = stem diameter. This value should have a positive relationship with the female flowering data, but provided an r value of 0.0420 (d.f. 145, non-significant). The expected negative relationship with rooting ability was also not found to be significant ($r = -0.0153$, d.f. = 143). Thus, it is not clear whether the lack of support for the inverse relationship of rooting and flowering abilities represents the situation in nature or merely lack of good data.

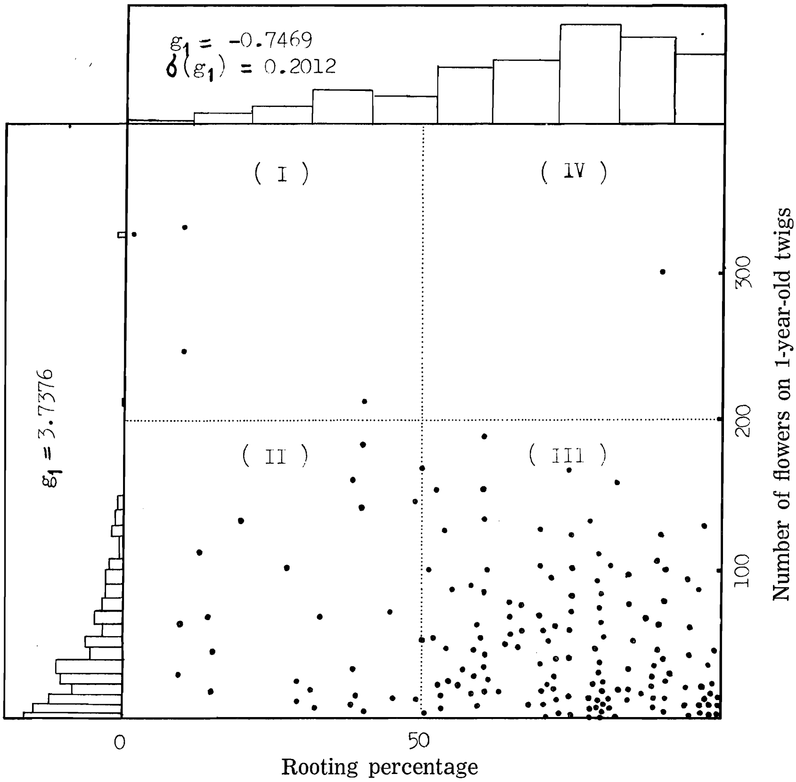

FIG. 2—Scatter diagram and frequency distribution of rooting and flowering ability.

CONCLUSIONS

Considerable support for the hypothesis was provided by the material on which best records of rooting and flowering were available, that is, from Investigations I and II. The lack of relationship in Investigation III from a much larger sample based upon less reliable individual tree data serves as a note of caution in accepting the hypothesis for the present. Further, as more clones are included, even in the Yamanashi Prefecture the proportion of the relationship explained by the regression drops. This could also be due to less exact estimates of flowering and rooting abilities of the individual trees. But it may also suggest that natural selection for a phenotype with essentially equal total reproductive ability divided between rooting and flowering potentials is not overwhelmingly important. Reproductive capacity may be only one of many traits that permits survival in the ecological niches occupied by *Cryptomeria japonica* in nature.

Nonetheless in *Cryptomeria* seed orchards selection will obviously be in the direction of good flowering ability, since good-flowering clones contribute more genes to the harvested seed. In addition, there is enough indication in this study to suggest that good-rooting clones should probably be avoided in seed orchards if they show any signs of poor flowering since they can probably contribute little in seed and in genes for future breeding.

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