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Flowering of *Pinus rigida* Mill. and *Pinus taeda* L. in an F_1-Hybrid Seed Orchard[1]

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雜種採種園에서의 리기다소나무와 테다소나무의 開花[1]

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ABSTRACT

Flowering time of *Pinus rigida* Mill. and *Pinus taeda* L. in an F_1-hybrid seed orchard was investigated for five years from 1971 through 1975. The two tree species flowered during late April to early May at the observation site. Flowering patterns of the two species or different sex of the same species changed yearly during the five observation years. Floral development of the two species appeared to depend largely on temperature factor during the period of the initiation of floral organs up to flowering provided that other environmental factors are normal. Six-days difference in flowering time between female inflorescence of pitch (flower later) and male inflorescence of loblolly (flower earlier) pines effectively isolated the two species reproductively on population levels. Not all of selected trees of the two species for their synchronized flowering appeared to be useful as parental trees for the establishment of F_1-hybrid seed orchards. With the result from this investigation the author suggested to use a modified simple recurrent selection method for pitch-loblolly hybrid pine breeding.

Key words: pine hybridization; hybrid seed orchard; pine flowering, Pinus rigida Mill.; Pinus taeda L.

要 約

1959년 서울대학교 농과대학 광양 연습림에 조성한 雜種採種園에서 리기다소나무와 테다소나무의 開花期를 1971년부터 1975년까지 조사하였던 바 다음과 같은 결과와 결론을 얻었다. 兩親樹 리기다소나무와 테다소나무는 4월 말에서 5월 초 사이에 開花하였다. 兩樹種의 開花樣相은 매년 다르게 나타났으며 같은 수종의 암수에 따라서도 다르게 나타났다. 환경조건이 정상적일 때 兩親樹에 있어서 꽃의 發達은 花芽分化時부터 開花時까지의 溫度因子에 의해 크게 영향 받는 것으로 나타났다. 리기다소나무의 암꽃과 테다소나무 숫꽃의 開花期 差異는 平均 6일 이었으며 兩親樹種에 있어서 이러한 6일간의 開花期의 差異는 集團水準에서 效果的으로 두 樹種을 生殖的으로 분리시키는 것으로 나타났다. 리기다소나무 및 테다소나무의 兩親樹에 있어서 開花期가 一致되는 個體들을 數十本 선발할 수 있었으나 선발된 개체들의 상당수가 生長特性이 不良하여 잡종 채종원 조성을 위한 兩親樹로서 적합하지 못하였다. 이상과 같은 결과로서 본 著者는 雜種 소나무인 리기테다소나무의 育種에 있어서 Modified Simple Recurrent Selection方法을 이용할 것을 제시한다.

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INTRODUCTION

The successful growth performance of *Pinus rigida* x *Pinus taeda* F1-hybrid in Korea has been reported elsewhere by various authors[2,3,4,5,6]. To produce a large quantity of the F1-hybrid seed an F1-hybrid seed orchard (In this paper the term "F1-hybrid seed orchard" is designated for a seed orchard consisting of two parental tree species aiming at the production of F1-hybrid seeds by open pollination between the two species) consisting of pitch(*Pinus rigida* Mill) and loblolly (*Pinus taeda* L.) pines was established by row to row planting of 2-0 seedlings of the two species at Kwang Yang Experimental Forest (Approximately 35°N, 127.5°E.) of Seoul National University in 1959. In 1966 some of the loblolly pines began to flower (male inflorescences) though the amount of loblolly pine pollen was to small to affect the effective pollination of pistillate strobili of neighbouring pitch pine trees that had already begun to flower (female inflorescenes) since 1960, the following year of the seed orchard's establishment.

During the subsequent years of flowering since 1966 pine seedlings originating from individual pitch pine trees of the F1-hybrid seed orchard were raised every year for the observation of the proportion of F1-hybrid seedlings. However, most of the pitch pine (maternal parent) trees produced not a single F1-hybrid seedling. Only a few pitch pine trees produced very few F1-hybrid seedlings among several hundreds of the progenies. It was suspected that the failure of F1-hybrid seed production in this F1-hybrid seed orchard might be due mainly to the difference in flowering time of the two parental tree species.

The aim of this study was to investigate flowering time of the two parental tree species and to select parental trees with synchronized flowering for future use in establishing F1-hybrid seed orchards.

MATERIALS AND METHODS

Flowering observations were made for five years from 1971 through 1975 on pitch and loblolly pine trees in an F1-hybrid seed orchard established in 1959. Seed sources of parental trees are Suweon (The pitch pine was introduced from North America in 1920. Specified locality name of the seed source is not known) for pitch pine and Delaware and Louisiana(Alexandria), U.S.A. for loblolly pine. In the investigation of flowering time main emphasis was given to male inflorescences of loblolly(paternal parent) and female inflorescences of pitch(maternal parent) pines for practical application in selecting late or early flowering loblolly or pitch pine individual trees, respectively.

Flowering time of staminate strobili was recorded individually, one tree as a whole, at three developmental stages, "beginning of pollen shedding", "maximum pollen shedding", and "the end of pollen shedding". In case of pistillate strobili the beginning of receptive period (the time of ovuliferous cone scale opening) was recorded for their flowering by collecting and observing three to five developing strobili from upper crown of each parental tree at every observation. In most cases flowering was recorded individually every day except for a few days during the maximum flowering periods of the parental trees in 1974 and 1975. Approximately one half of the trees were observed in a day and the others on the following day alternatively during those days due to the large number of trees to be observed in 1974 and 1975. The number of trees observed is presented in Table I.

Daily mean temperatures were calculated as follows;

$$\text{Mean temperature} = \frac{\text{Daily maximum temp.} + \text{Daily minimum temp.}}{2}$$

RESULTS AND DISCUSSION

During the five observation years most of pitch pine trees flowered rather abundantly either male, female or both of inflorescences. On the other hand, less than half of the investigated loblolly pine trees

Table 1. Proportions of flowering trees and temperature sums (Σ+5°C) in degree day (d.d.) for flowering in each year.

Year	Spp. and sex of inflorescence	No. of trees investigated	No. of trees flowered	% of trees flowered	Temp. sum (d.d.)** for flowering $\bar{x}\pm$sd.
1971	*Pinus rigida* ♀	162	122	75.3%	331.6± 7.5
	Pinus rigida ♂	162	161	99.4%	325.8±18.4
	Pinus taeda ♂	151*	59	39.1%	288.8±23.7
1972	*Pinus rigida* ♀	414	313	75.6%	333.9±16.9
	Pinus rigida ♂	414	355	85.7%	346.3±19.1
	Pinus taeda ♂	1372	326	23.8%	272.6±12.3
1973	*Pinus rigida* ♀	414	278	67.1%	335.4±18.2
	Pinus rigida ♂	414	366	88.4%	354.9±18.8
	Pinus taeda ♂	1372	407	29.7%	273.9±16.2
1974	*Pinus rigida* ♀	453	278	61.4%	277.5±22.3
	Pinus rigida ♂	453	401	88.5%	282.9±21.4
	Pinus taeda ♂	1642	835	50.8%	229.0±11.9
1975	*Pinus rigida* ♀	453	318	70.2%	333.9±15.0
	Pinus rigida ♂	453	405	89.4%	333.5±21.3
	Pinus taeda ♂	1286	566	44.0%	263.3±20.9

*In addition to this number of trees fifty eight male flowering trees were also observed.
**Temperature sums were calculated from February up to flowering.

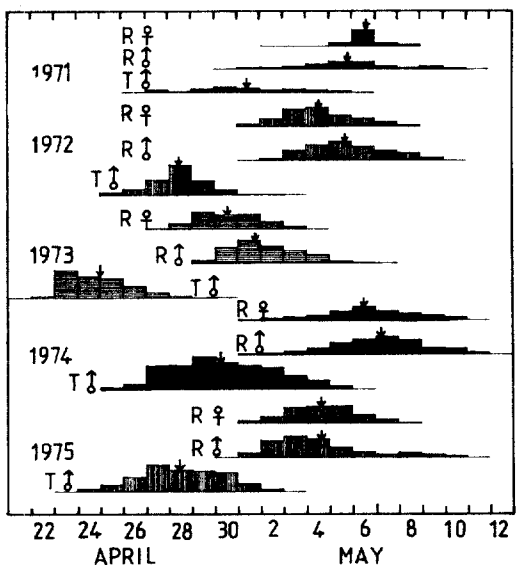


Fig. 1. Date of flowering of pitch and loblolly pines during the five observation years from 1971 through 1975. Arrow indicates the population mean in each year. R: *Pinus rigida*. T: *Pinus taeda*. Abscissa: flowering date. Ordinate: flowering frequency (from baseline of the histogram).

flowered male inflorescences (Table 1). The parental trees flowered during late April to early May (Fig. 1). Flowering patterns of the two parental tree species or different sex of the same species (in case of pitch pine) during the five observation years changed yearly. Flowering patterns of individual trees also fluctuated yearly. However, many of the early (female inflorescence of pitch pine) and late (male inflorescence of loblolly pine) flowering trees had, respectively, the same tendency of early or late flowering behavior every observation year. Thus it was possible to select twenty five of early and thirteen of late flowering individuals of pitch and loblolly pines, respectively.

Figures 2a-e show cumulative frequency sums of flowering with the progress of daily mean temperature sums above +5°C[7,8]) in each year. Flowering temperature sums (degree day) above +5°C were calculated from February (Temperature sums were calculated from February because temperature sums above +5°C in January fluctuated considerably and relatively longer cold spells often come in February at the observation area.) up to flowering

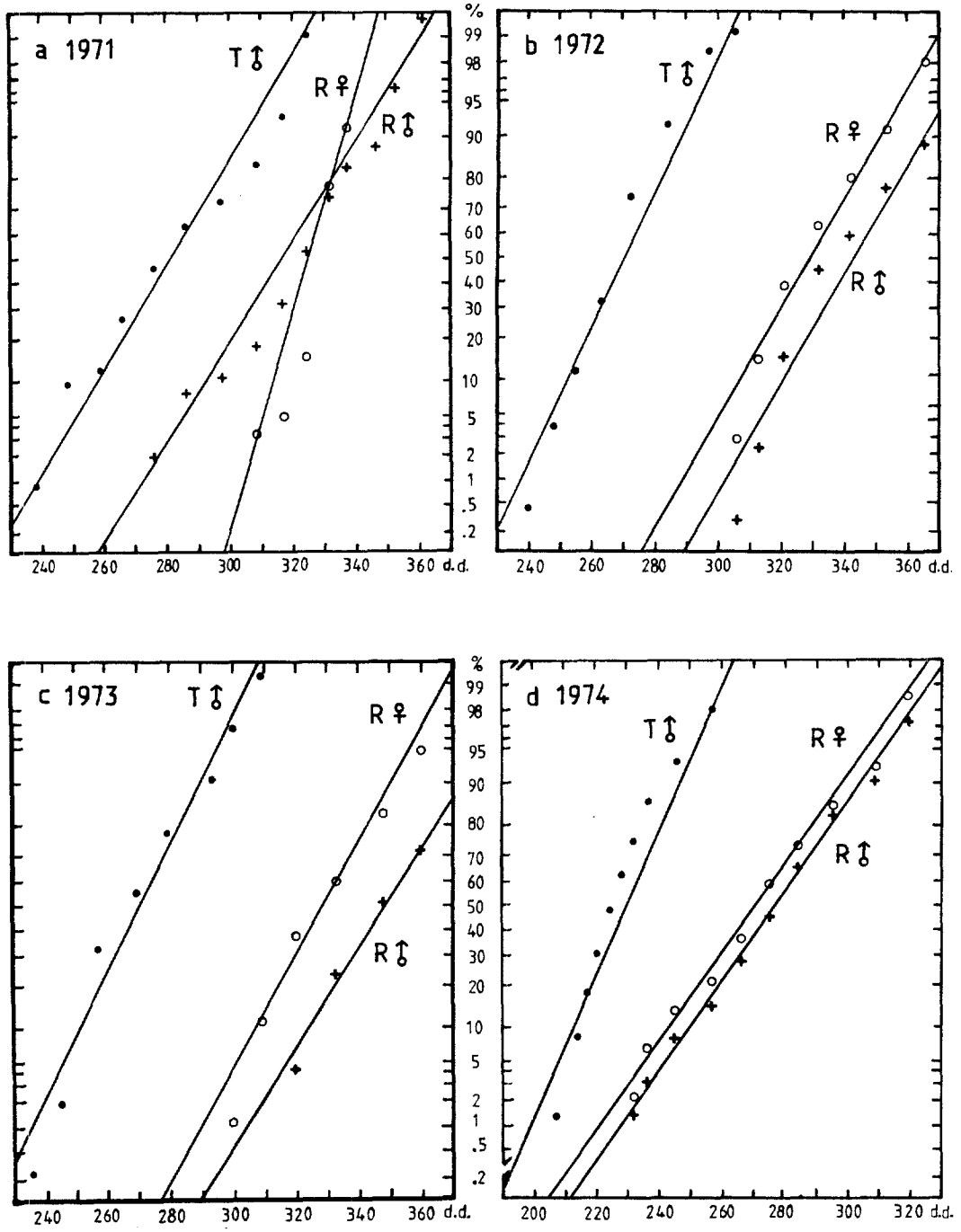
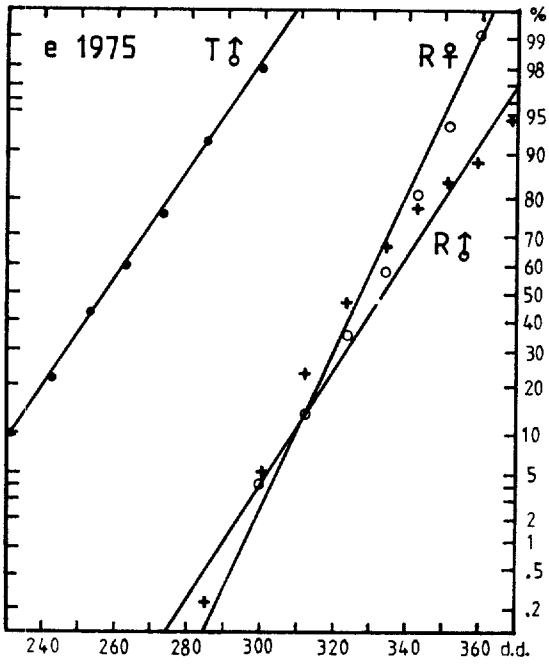


Fig. 2. The distribution of cumulative frequency sums of flowering in relation to temperature sums. All lines have been drawn free hand. R: *Pinus rigida*. T: *Pinus taeda*. Abscissa: temperature sums in degree day. Ordinate: Gauss integral. a. 1971 flowering. b. 1972 flowering. c. 1973 flowering d. 1974 flowering. e. 1975 flowering.



(Table 1). The lines for frequency sums of flowering on each year in Figures 2a-e indicate that floral development depends largely on temperature factor as Sarvas(7,8,9,10) reported. The figures 2a and 2e also indicate that floral development of the male and female inflorescences of pitch pine in 1971 and 1975 responded differentially to the progress of temperature sums from other years.

It is interesting that even though the two tree species are not native to Korea they flowered astonishingly at about the same temperature sums every year except the year 1974 (Table 1). In those years maximum fluctuation of temperature sum for female flowering of pitch pine was 0.6% from the average temperature sum of the four years. In 1974 the parental trees flowered at 16.9%, 16.8% and 16.6% lower temperature sums, respectively, for pistillate and staminate strobili of pitch pine, and staminate strobili of loblolly pine than averages of the four years. The reason why the same tree populations flowered at much lower temperature sums in 1974 can not be explained except that the previous year had 6.8% (or 226.5 d.d.) larger mean annual temperature sum than average (3310.4 d.d.) of the five years, 1970 through 1974.

In 1973 first frost was recorded on October 15th and temperature sum after this frost was 300 degree day. This temperature sum is indicative for the shift of dormancy I to dormancy II (9, 11) and for the subsequent development of floral organs to more advanced stages than usual before severe winter frosts to come. If climatic conditions in the autumn of 1973 had shifted the development of newly formed floral organs to much more advanced developmental stages than usual before entering winter dormancy, the trees might have flowered at lower temperature sums in the following year 1974. Unfortunately, floral developments at early stages were not checked either in late autumn of 1973 or in early spring of 1974.

Average difference in flowering time between female inflorescence of pitch and male inflorescence of loblolly pines was six days in time scale. Even though flowering of some trees of the two parental species synchronized, six-days difference in flowering time between female inflorescence of pitch and male inflorescence of loblolly pines effectively isolated the two species reproductively on population levels. A few synchronized flowering parental trees of the two species can not effectively cross-pollinate each other if they were distributed sporadically over a few tenths of meters in a two-species mixed stand.

One problem in selecting early flowering trees was that most of the early flowering pitch pine trees were slow growing ones (most probably, that have lower growth potential) of which the character is doubtful as to whether they can be used for parental tress for the establishment of F_1-hybrid seed orchards in the future. On the contrary, many of the late flowering loblolly pine trees showed a relatively good growth. Two of the selected late flowering trees were suspected to be hybrids between *Pinus taeda* L. and *Pinus serotina* Michx. in their cone and seed characteristics.

In the future F_1-hybrid seed production is expected to be possible from seed orchards established with selected parental trees for their synchroni-

zed flowering. However, in considering the efficiency of breeding method and the time requirement for the breeding program, the author suggests to use a modified simple recurrent selection method for pitch-loblolly hybrid pine breeding with intermittent gene introductions to the breeding populations of this program by a separate modified reciprocal recurrent selection of the two parental species. (Namely, modified forms of recurrent selection method from Comstock et al. 1949(1). Selfings are substituted by intercrossings between individuals within breeding populations in those modified recurrent selection methods).

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