SEASONAL GROWTH OF THE FEMALE STROBILUS IN *PINUS RADIATA*

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ABSTRACT

Growth of female strobili of **Pinus radiata** D. Don from central North Island of New Zealand is described and illustrated with photographs. The two-and-a-half year period from strobilus emergence until cone maturity comprises a seasonal period of growth in which pollination occurs, a second period of seasonal growth in which fertilisation occurs, and finally a period of cone maturation. The periods of rapid growth do not appear to result directly from either pollination or fertilisation, and the seasonal growth periods have some similarity to those of vegetative growth. The time taken to reach cone maturity in **P. radiata** (a closed-cone pine) is six months longer than that frequently described for other species of **Pinus**.

INTRODUCTION

The general pattern of female strobilus development in *Pinus* is well documented (e.g., Ferguson, 1904; Stanley, 1958; Sarvas, 1962). Broadly, a total period of two-and-a-half years is involved, leading through from strobilus determination one summer, to anthesis the following spring, to fertilisation late in the subsequent spring and finally to maturation the succeeding autumn. Seed production in *Pinus radiata* D. Don apparently follows within general limits the typical pattern for *Pinus,* but few details have been published either of its strobilus or its ovule development.

As part of a comprehensive study of the processes leading to seed production in this species, material was collected in 1968 and 1969 to enable details of strobilus development to be determined. Results of a morphogenetic study of the early stages of strobilus development, and of subsequent ovule development, which is being carried out at Canterbury University, will be published subsequently under separate authorship. This paper describes some aspects of the growth of the strobilus as a whole, from approximately the time of its emergence from its bud scales until it is mature.

MATERIALS AND METHODS

All the material used in the study was collected from seed orchard RA 1, established at Kaingaroa Forest. A description of the orchard and its climate has been given by Sweet and Thulin (1969).

Although the cycle from strobilus emergence to maturity occupies two-and-a-half years, the material was in fact all collected between July 1968 and November 1969. This was done by sampling at each harvest two or three sets of material, each a year apart in age. The material collected had thus been pollinated in four separate years, 1966-1969 inclusive. Sufficient seasonal overlap was made in the collection of material of different pollination years so that any effects, on strobilus growth, of pollination year would be apparent.

Material was collected from two clones, No. 19 and 55. The dates of anthesis for both clones were similar, and they were generally representative of the clones in the orchard. At each harvest date 12 strobili were collected of the appropriate pollination year from each clone. Collection was restricted to first order branches and to the first cluster of strobili formed on the branch in the appropriate pollination year. No more than half of the strobili collected at any one harvest was taken from the same ramet.

Of the 12 strobili collected, 10 were oven dried and their dry weights recorded: the other two, randomly chosen, were photographed and their length and width measured.

RESULTS

As growth patterns of the strobili from the two clones were essentially similar, they have not been kept separate for presentation: all the data presented are mean values from clones 19 and 55.

Fig. 1 illustrates the main changes with time in the dry weight of the strobili. The

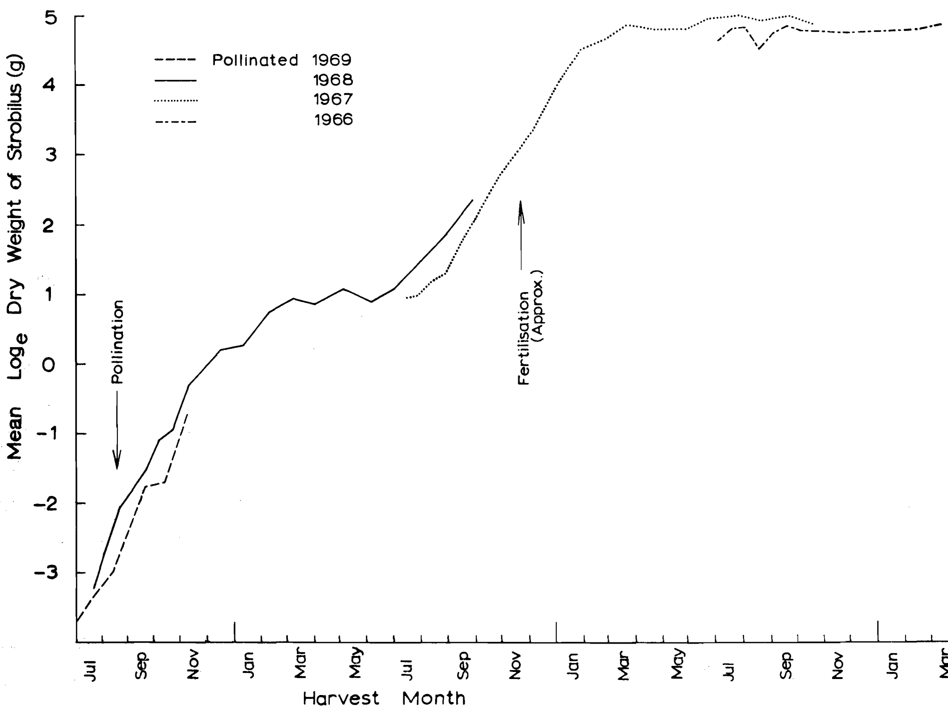

FIG 1—Changes in log$_e$ strobilus dry weight (g) during the period from emergence to cone maturity. Each point is a mean of 20 values. 10 from strobili of clone 19, and 10 from those of clone 55.

dry weight data have been presented as their natural logarithms because the great degree of increase in dry weight (some 3,500 times in the period examined) made some form of transformation essential to illustrate it. Additionally, however, the use of natural logarithms has the advantage that the slope of the graph provides an indication of the relative growth rate of the organs involved (Van den Driessche, 1968). Fig. 2 illustrates changes with time in strobilus length and width, and Figs. 3 and 4 illustrate the appearance of the strobili of clone 55 at intervals over the period sampled.

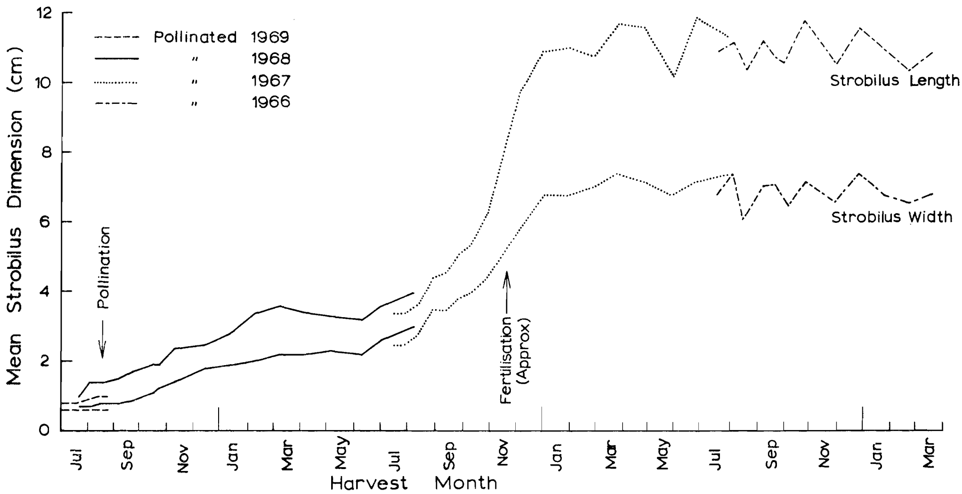

FIG. 2—Changes in strobilus length and width (cm) during the period from emergence to cone maturity. Each point is a mean of four values, two from strobili of clone 19, and two from those of clone 55.

Relative growth rates (RGR) of the strobili, defined as the mean rates of dry matter production per unit of dry weight, have been calculated on an approximately monthly basis and the data are presented in Table 1.

TABLE 1—Mean relative growth rates (mg/g/day) for strobili of clones 19 and 55 for the main periods of strobilus development

Period	RGR in first year	RGR in second year
19 Jul — 1 Aug	38.0	3.4
1 Aug — 3 Sep	27.8*	16.2
3 Sep — 2 Oct	24.6	24.9
2 Oct — 6 Nov	22.6	20.1
6 Nov — 8 Jan	9.6	19.2†
8 Jan — 4 Mar	11.8	12.5
4 Mar — 2 May	2.2	2.6
2 May — 30 Jun	–0.7	2.0

* Pollination occurred during this period.
† Fertilisation occurred during this period.

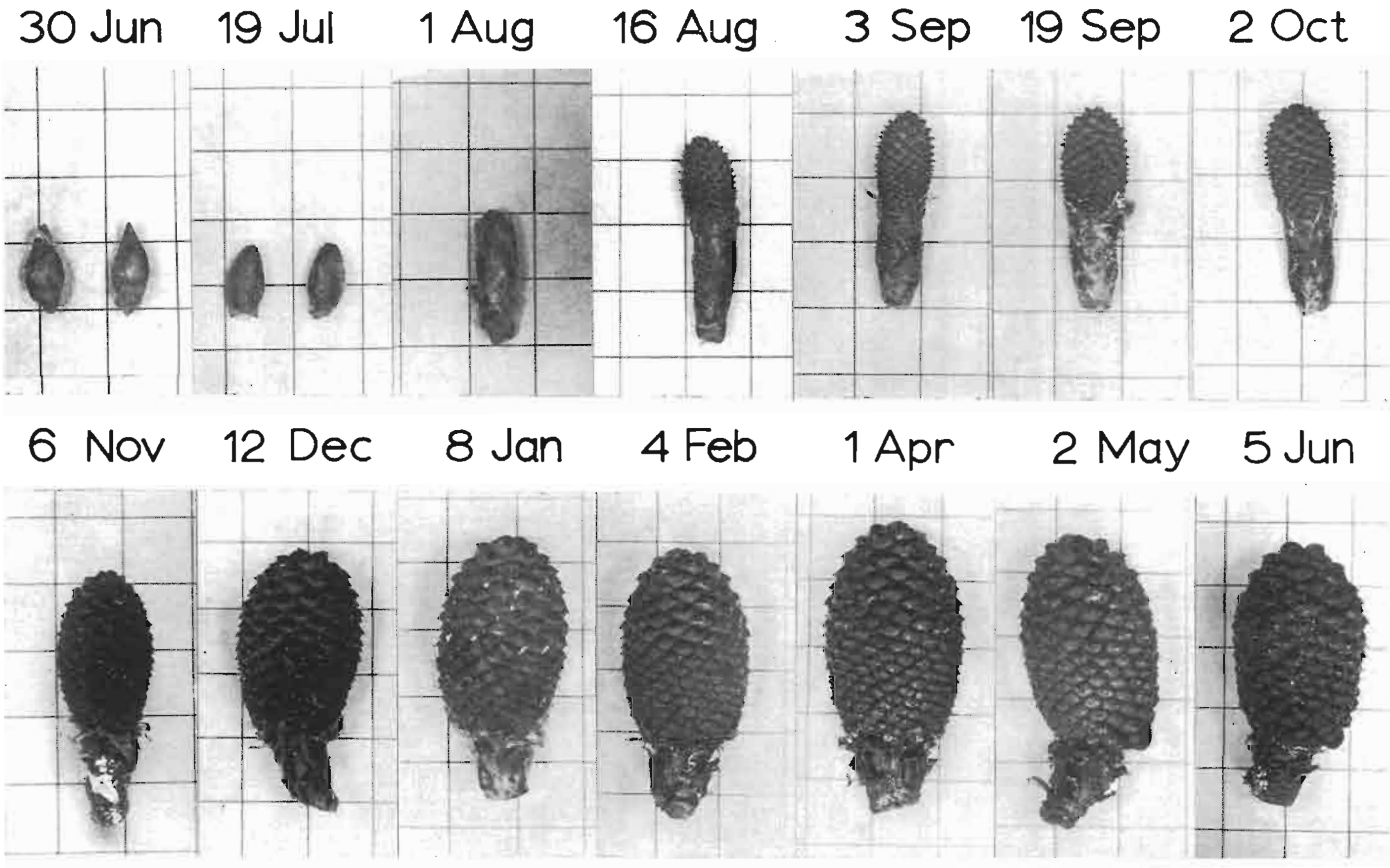

FIG. 3—Strobili of clone 55 photographed at successive intervals during their first year of development. The background grid in the photographs was 1cm × 1cm.

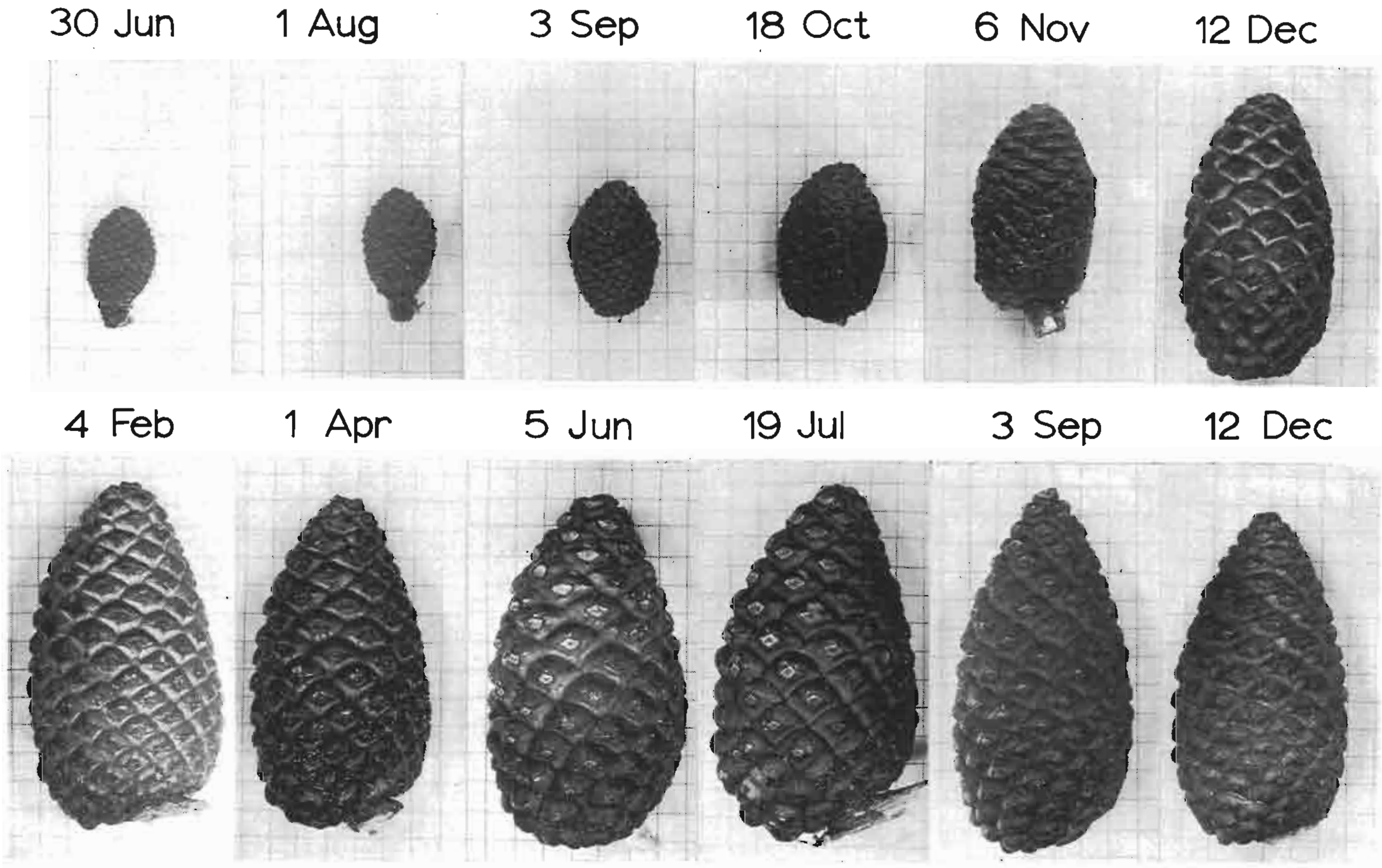

FIG. 4—Strobili of clone 55 photographed at successive intervals during the final 18 months of their development. The background grid in the photograph was 1cm × 1cm.

The figures and the table indicate a rapid rate of dry weight increase from the time of strobilus emergence, through the pollination period and lasting through the spring until November. From then on the rate of dry weight increase declined, slowly until March and then more rapidly. Early winter growth of the strobili was very limited, but growth accelerated again from the end of July; it reached a plateau in the second season by September and this was maintained through until the following January. In the 54 days between 18 October and 12 December, the cones showed a 250% increase in dry weight; fertilisation occurred during that period (Miss B. Henderson, pers. comm.). A comparison of Figs. 1 and 2 shows a general parallel between changes in dry weight and those in size of the strobili. By June of the second year the cones had reached their full size and dry weight, but they were still green and appeared immature; extracted seeds had a high moisture content and showed a relatively smooth whitish coat. From June of the third year until the following December, the cones gradually changed in colour from green to brown and the seeds matured, developing their typical rough black testa.

DISCUSSION

Examination of the data presented shows that strobilus growth broadly followed a seasonal pattern with some similarity to that of vegetative growth (Pawsey, 1964). However, the timing of the stage of maximum RGR was perhaps some six weeks earlier in the first year of strobilus development than in the second, suggesting that endogenous factors also exert a measure of control over strobilus growth patterns.

In many species, pollination and/or fertilisation act as a trigger to rapid development of the ovule (Leopold, 1964). The RGR data from this study offer no evidence to suggest that this happens in *Pinus radiata;* in each year of development the RGR had reached its maximum level prior to pollination or fertilisation, and there was no subsequent increase.

The seasonal data in Figs. 1 and 2 show that the size and the dry weight of the strobili at any given time reflect in part their year of anthesis. The time of anthesis differs from year to year, and it could be suggested that strobili developing in a season where this is early may obtain and maintain a growth advantage. Such a suggestion is probably an over-simplification, but it is borne out by the times of anthesis for the clones in the relevant years. Records show that this was earliest in 1968 (2 August) followed by 1969 and 1967 (14 August and 18 August) and latest in 1966 (31 August).

One of the main respects in which *Pinus radiata* differs from the general development pattern for *Pinus* (Stanley, 1958) is that, at least in central North Island of New Zealand, the cones do not mature in the autumn following fertilisation. Rather they take a further nine months to mature. In this respect it is interesting that the cones are full sized well before they mature. Dickmann and Kozlowski (1969 a, b) demonstrated in *Pinus resinosa* a gradual loss of water from cones and seeds between the attainment of full size and the time of maturity, accompanied by a conversion of starch stored in the cone to cellulose. It is probable that similar changes occur in *P. radiata,* as they have also been reported for a number of other species (e.g., Beaufait 1960; Pfister, 1967). From our observations on other *Pinus* species such as *P. patula, P. greggii, P. serotina* and *P. attenuata* it seems possible that the delayed cone ripening shown by

P. radiata in central North Island may be characteristic of closed cone pine species generally. With *P. radiata* and three of these other species, however, we have found it possible, by careful pre-curing of the cones, to extract viable seed some six months before cone maturity.

ACKNOWLEDGMENT

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