THE ABORTION OF CONELETS IN PINUS RADIATA

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SYNOPSIS

Observations and records collected over a six-year period show that, in a seed orchard of Pinus radiata *at Kaingaroa Forest, approximately half of all female strobili initiated abort during the first year after pollination. For an average clone this process of conelet drop starts at the time of receptivity, reaches a peak some four to six weeks later, and then decreases in intensity. This time sequence differs somewhat in individual clones. By four months after pollination the process has effectively stopped and very few conelets drop subsequently.*

There are significant differences between clones in the percentage of strobili which abort; this factor appears to be in part correlated with differences in growth rate, but it is unlikely that all the clonal variation in conelet drop is explicable in these terms. The amount of conelet drop occurring is effectively the same after both open and controlled pollinations. Within a tree there is some indication that the percentage of strobili dropping is greater in the lower part of the crown than in the upper part.

INTRODUCTION

In this paper data are presented on the abortion of conelets in *Pinus radiata.* The data are both quantitative and descriptive but no attempt is made here to consider what mechanisms may be involved in the process.

To date in New Zealand all plantation establishment with *Pinus* has been by direct sowing or by planting seedlings and it is probable that, in the foreseeable future, a large part of the establishment will continue to be with seedlings. Thus, in the genetic improvement of *P. radiata,* emphasis has been placed on the establishment of orchards for the production of genetically improved seed.

The testing of progeny raised from seed of known parents plays an important part in such a breeding programme and, while making the necessary controlled crosses, one may expect to obtain considerable information about the processes of flowering and seed production in the species. One aspect on which such data have been obtained concerns the abortion of strobili and developing conelets during the period between pollination and fertilization (a period of approximately one year). This process has been called conelet drop (Sarvas, 1962) and, in *P. radiata* seed orchards, it is potentially of some economic importance. In 1968, 300 lb of seed were collected

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from seed orchards in New Zealand and it is planned that by 1975 this figure will be increased to 10,000 lb per annum. Suitable land for seed orchards is generally both expensive and difficult to obtain: it must be flat, fertile, easy of access, close to seed extraction plants, and isolated from other trees of the same species. If the loss of strobili is heavy, potential seed yield is reduced: the area of land required for seed production must be increased, and the collection of a given amount of seed must be spread over an increased number of trees. Both these factors increase costs and, with such a high investment in the production of orchard seed, conelet drop is thus economically important.

However, it is only in seed orchards that the forester wishes to increase the seed production of *P. radiata*. In plantations, stem cone holes are an important cause of timber degrade in the higher logs *(e.g.,* Fenton, 1967) and, if the number of stem cones in these logs could be reduced, grade out-turn would be improved. Clearly it is potentially possible to accomplish this by increasing the incidence of conelet drop in a stand, and thus an understanding of the process is important for plantation as well as for seed orchard management.

This paper merely describes the process of conelet drop but it is hoped, in subsequent papers, to consider some of the mechanisms which may be involved.

MATERIALS AND METHODS

All the data presented in this paper were obtained in *Pinus radiata* seed orchard RA 1 established at Kaingaroa Forest in 1957-8. This orchard is at an altitude of 1,800 ft above sea-level; it has an evenly distributed mean annual rainfall of 58 in., an average of 55 screen frosts a year, and a mean annual temperature of 50.3°F. Mean monthly temperatures range from 41.0 to 59.4°F (Hinds, H. V., unpubl. data, Forest Research Institute, Rotorua). The orchard has been, in part, an experimental one and, although establishment commenced in 1957, the orchard was not completely stocked until 1961. Currently there is considerable variation in height between trees, but the average tree used in these experiments was, in the winter of 1968, approximately 45 ft high with a d.b.h. of 10.5 in. The orchard, which is 10 acres in area, contains 14 clones and spacing is at 16 × 16 ft. Each clone is represented 126 times.

EXPERIMENTAL DATA

The data presented here have been collected in five separate series of observations.

(1) *Controlled Pollinations made in 1962*

The first detailed information on conelet drop was obtained from this series of pollinations in which four male parents were crossed individually with each of nine female parents. The number of clusters of strobili isolated was counted (a) at the time of pollination, (b) when the pollination bags were removed, (c) 11 months later when surviving conelets were one year old and (d) at the time of seed collection. The mean number of clusters bagged for each cross was 25: that is, an average of 100 clusters was bagged for each female parent. On average, 18.3% of the whorls present at pollination had been lost by the time they were debagged, and a year later this figure had increased to 38.4%. By seed collection time, 48.9% of the original clusters had been lost, but this final increase was, it is believed, in large part due to damage from repeated climbing. The percentage loss of complete conelet cluster between times (a) and (c), expressed by individual clones, was:

Clone No.	*No. of clusters pollinated*	*% of clusters lost (a-c)*
7	145	54.5
99	56	53.6
96	107	44.8
88	87	42.5
91	138	36.2
80	99	35.4
90	66	34.8
19	131	25.2
97	81	18.5

These values were angularly transformed and an analysis of variance showed the clonal differences to be significant at the 1% level. The effect of pollen parent was also examined, but there were no significant differences in conelet drop between the strobili pollinated by different parents.

(2) *Controlled Pollinations made in 1966*

This second series constituted a repeat of the 1962 pollinations but this time the data were recorded, not as clusters of strobili, but by counting individual strobili. Two counts only were made — (1) when pollination bags were removed (about a month after pollination), and (2) a year later: there is therefore no record from this series of the loss of strobili between pollination and debagging. A total of 2,186 strobili were present at debagging, an average of 243 per clone. A year later only 1,167 strobili remained, a loss of 46.6%. Expressed on a clonal basis the data were as follows:

Clone No.	*No. of strobili at debagging*	*% of strobili lost one year later*
7	334	62.3
88	265	58.9
96	371	56.1
99	104	55.8
90	93	43.0
97	338	38.2
80	159	34.6
91	317	32.5
19	205	30.2

Following angular transformation, the data were examined statistically by analysis of variance. Differences between clones were significant at the 1% level and a comparison of these data with those from the 1962 pollinations gave a correlation coefficient $r = 0.81$ (significant at the 2% level) indicating that the clonal differences in conelet drop were repeatable from year to year.

Size differences between clones exist in the seed orchard where these counts were made and, to examine the effect of these, height and diameter measurements were made in 1968 on six trees in each clone, selected as being representative of those used for controlled pollinations. Volumes were calculated for these trees and the relationship was examined between tree volume and the incidence of conelet drop. Using mean values for each clone a correlation coefficient was calculated between 1968 tree volume and the percentage conelet drop in 1966, angularly transformed. r equalled — 0.70, significant at 5% for 7 degrees of freedom. It thus seems possible that some of the clonal variation present in conelet drop can be explained in terms of tree size differences, with more vigorous clones showing less conelet drop. It is, however, unlikely that all the clonal variation is explicable in these terms.

In this series also, there were differences in conelet drop between the strobili pollinated by different parents. Data from the four pollen parents used were as follows:

Pollinating clone No.	*Total No. strobili pollinated by that clone present at debagging*	*% conelet drop one year later*
7	591	54.6
19	571	51.0
55	564	49.8
121	460	27.0

An analysis of variance of angularly transformed data showed that the strobili pollinated by clone No. 121 had significantly (1% level) less conelet drop than those pollinated by any of the other three clones.

(3) *Open Pollinations in 1966*

While the data under the headings (1) and (2) demonstrated the incidence of conelet drop under conditions of controlled pollination, they gave no information of its occurrence during normal open pollination. For this reason a study was made using open pollinated material. Three ramets within each of five clones were selected for study: initially they bore a total of 245 strobili, and counts were made regularly for a period of five months from the time of receptivity. During the observations, 56% of all strobili initially present aborted, and clonal variation was again very marked with the amount of drop in different clones ranging from 23 to 78%. Three of the clones selected had been included in the previous two experiments and, as expected, there was a correlation between the amount of conelet drop which occurred after open and after controlled pollination.

These observations also gave some information on the time-course of the process of conelet drop. Abortion was shown to start during the period of receptivity of the strobilus, to accelerate markedly once pollination was complete, and to be effectively complete after a further six weeks.

(4) *A 1967 Study of Two Clones*

Both the two clones examined, numbers 88 and 96, were known to have a high incidence of conelet drop. In clone 88, nine ramets were selected and on each ramet eight clusters of strobili, comparable in size and position, were marked and observed — a total of 389 strobili. In clone 96 only three ramets were selected and, on each of these, nine comparable clusters of strobili were marked and observed — a total of 97 strobili.

The strobili first became receptive towards the end of August, with clone 96 being seven to ten days ahead of clone 88 in this respect. The clusters were not bagged and thus the strobili were probably naturally pollinated. However, to ensure adequate pollination, they were also dusted with pollen from a single clone (No. 19) on 30 August. Their behaviour subsequent to pollination is shown in Fig. 1.

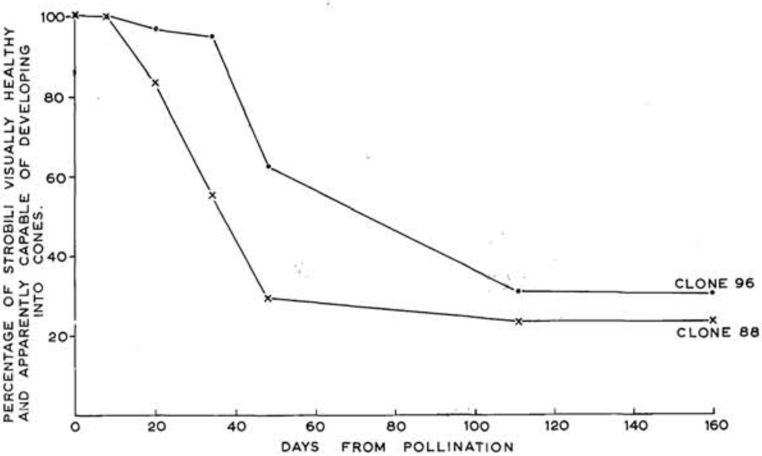

FIG. 1: *The time-course of conelet drop in two clones of* Pinus radiata.

The first indication of future drop came on 19 September, 20 days after pollination, when roughly 17% of the strobili marked in clone 88 showed a small brown resinous marking on one or more of the scales. Two weeks later, on 3 October, these "spots" were no longer visible on most strobili, but where they had been present the strobili were smaller and less "plump" than normal ones. Some other strobili which had not shown brown spots on 19 September now showed them. Of the original 389 strobili, 169 were at this stage showing some unhealthy symptoms, a further five were clearly dying and four more were dead. Thus the potential mortality 33 days after pollination was 44.7%. Figure 2 (photographed at that date) shows three strobili, a normal healthy plump one on the right and, on the left, two less plump ones which had a fortnight earlier shown a brown spot. Two weeks later (17 October) 55.5% of the original strobili were classified as

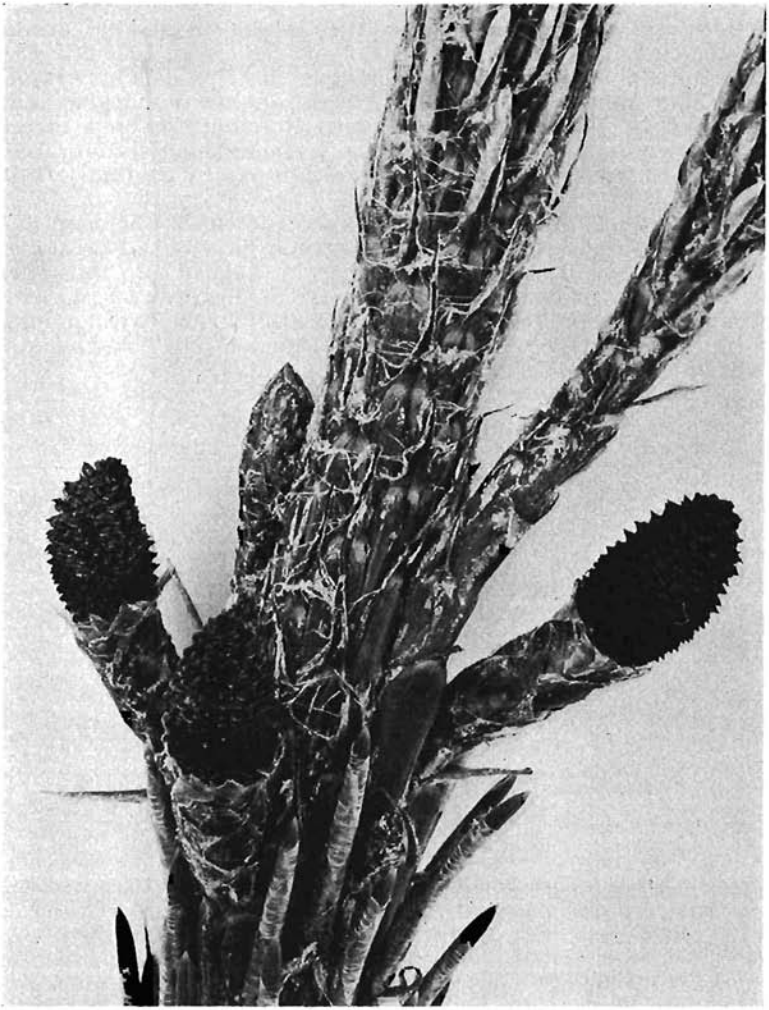

FIG. 2: *Strobili of clone 88, 33 days after pollination. The strobilus on the right is healthy; the other two strobili which are smaller and less "plump" will abort.*

dead or dying, and a further 15.1% showed either brown spots or a slight reduction in their size. Thus the potential mortality 48 days after pollination was 70.6%. 114 strobili still appeared healthy at this stage, but two months later (19 December) a further 22 of these were either dead or dying. The actual and potential mortality at that stage was thus 76.4%. This marked the end of the mortality and the 92 remaining healthy strobili were still alive and healthy two months later (mid-February, 1968). No further counts have been made but subsequent mortality is expected to be slight.

Figure 1 also indicates that, while the final strobilus survival of the two clones was quite similar, their time-course patterns of conelet drop were rather different. As an additional point of difference, brown spots were noted in only 5 out of the 97 strobili in clone 96. The first indications of potential conelet drop in that clone were generally shown only by a reduced size and lack of plumpness.

(5) *A Study of Within-tree Variation in Conelet Drop*

In the second study carried out in 1967, a detailed examination was made of three ramets of each of two clones. The trees were climbed on 7 September when the strobili were receptive. Every cluster of strobili was numbered, its position recorded, and a count made of the strobili it contained. The clones examined were Nos. 7 and 97 and the measurement data for the trees were as follows:

	Clone No.	
	7	97
Mean height (ft)	32.5	52.5
Mean d.b.h. (in.)	9.0	12.2
Total No. of strobili	239	143
Mean No. of strobili per cluster	4.1	3.1

The trees were not then examined again until 29 February, 1968 (almost six months later), when a second count was made of the strobili.

The total number of strobili which dropped was very much heavier in clone 7 (84%) than in clone 97 (21%) and these differences were statistically significant at the 0.1% level. There was no evidence from the data to suggest that horizontal aspect in the crown had any effect on the incidence of conelet drop, but vertical position in the crown was possibly important. The percentage of conelets which aborted in the clusters above the median one was 49% while abortion in the clusters below the median was 63%. These differences were not statistically significant and whether or not they are real is uncertain. A comparison of the two clones showed that the pattern of distribution of the strobili which dropped was very similar.

DISCUSSION

All the data presented in this paper were collected from grafts grown on one site in one area of New Zealand. The only other quantitative data recorded were obtained from the same clones in another seed orchard 90 miles to the south-east, at Gwavas State Forest in Hawke's Bay. Those data (unpubl.) show that the loss of complete clusters of strobili between pollination and fertilization was 53% in 1964-5 and 42% in 1965-6. The figures are comparable with those obtained from Kaingaroa and they suggest that the process of abortion described in this paper is not just a response to local site factors.

Unfortunately, no quantitative data based on seedling material are available. However, since becoming aware of the problem of conelet drop in *P. radiata,* the writers have looked for, and have observed, the phenomenon frequently in seedling plantations in different parts of the country. While these observations have not been quantified, it is believed that the process of conelet drop, as it has been described for grafted trees in Kaingaroa, is fairly typical of that occurring in many plantations in New Zealand.

The precocious abscission of flowers and young fruits is known to occur very widely throughout the plant kingdom, and in some species less than 0.1% of the flowers which are produced ever form fruit (Leopold, 1964). Sarvas (1962) has previously shown that *Pinus* is no exception to the general rule of "flower" loss, and he has discussed the process in some detail. He showed that, in mature stands of *P. sylvestris,* dropping of strobili began immediately after receptivity. This first dropping often comprised 20 to 30% of the total drop and, following this, dropping continued with lesser intensity and at a steady rate until late autumn, winter and the next spring. This pattern is very similar to that demonstrated in this paper. Sarvas also showed that the amount of conelet drop depended in large part on the number of ovules pollinated in each strobilus, and he demonstrated this for several species of *Pinus*. However, even under conditions of abundant pollination, he found that some 25% of the developing strobili and conelets aborted, so the problem is more complex than a simple reflection of pollen levels. Dengler (1940) has shown that frost can cause conelet drop, and Wright (1953) has invoked fungal and insect agencies.

Sarvas found no effect of latitude or climate on the incidence of conelet drop, but found less drop in younger than in older stands and also less drop on high fertility sites. This latter fact he related directly to the quantity of pollen produced.

We are currently investigating, in several studies, possible causes of conelet drop in *P. radiata* and these studies are, in turn, part of a wider investigation of the whole process of flowering and seed production in *Pinus* (Sweet, 1967). As indicated earlier, it is suggested that, with an improved understanding of the "flowering" process in *P. radiata,* it may be possible to increase seed production in seed orchards and seed stands, but decrease cone production in plantations where the presence of stem cone holes causes serious timber degrade.

ACKNOWLEDGEMENT

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