REGIONAL VARIATION IN DOUGLAS FIR SEED YIELDS

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SYNOPSIS

Douglas fir cones were collected from a number of different areas in New Zealand over a four-year period, and their seed yield was assessed. The number of full seeds per cone was generally fewer for cones from North Island than from South Island plantations, with Kaingaroa and Hawke's Bay districts having the lowest values. For Kaingaroa the data suggest that only a small percentage of the ovules in the strobilus were initially fertile, and that pollination and/or subsequent development of these ovules was restricted. In Hawke's Bay, while the percentage of fertile ovules was apparently higher, their subsequent development was still limited. The only North Island area with particularly high seed yields per cone was Ngaumu. This area, along with most parts of the South Island, would be acceptable, on the basis of seed yield per cone, for the establishment of seed orchards of Douglas fir.

INTRODUCTION

A breeding programme is currently in progress at the Forest Research Institute to improve the genetic quality of Douglas fir in New Zealand. It is still uncertain whether this programme will utilize clonal or seedling seed orchards, or both, but it is likely that the production of fairly large quantities of genetically improved seed will be necessary.

Wilcox (1968) presented limited data to suggest that both cone production and seed production per cone may differ considerably from region to region in New Zealand, and he pointed out that this has important implications in the planning of seed orchard locations.

Certainly the more important of the two factors Wilcox mentions is cone production. It is well known that Douglas fir has a marked periodicity of seed years, and if it is correct that not only the degree of periodicity varies regionally within the country, but also the size of the seed crop in a productive year, then it is important to understand the pattern of this variation. Unfortunately, the sampling and manpower problems involved in obtaining soundly-based data on cone production over the country, for the necessary period of time, make it unlikely that such a study will be undertaken. It is more probable that information on this aspect will be drawn

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from past cone collection records and from experience accumulated in conservancies.

In contrast to the difficulty in obtaining data on the size of the cone crop, it is relatively easy to get information on regional variation in seed yields per cone; and it is with such information that this paper is concerned. With the assistance of conservancy and forest staff in many parts of the country, a series of Douglas fir cone collections was made in the years 1968-1971 inclusive. The cones were examined to determine whether the seed content did vary in different parts of New Zealand and, if so, whether such differences persisted from year to year.

METHODS

Cones for the study were obtained by two different methods. Where possible, a random selection was made from cones air drying after routine conservancy collections: at times, or in areas where there was no routine collection, special collections were made. An attempt was made to obtain five collections from different locations in each conservancy in each year. This was unsuccessful for a number of reasons which ranged from lack of cone production in some areas to human error in others. In fact, the total number of collections made was: 1968 (9), 1969 (19), 1970 (7), 1971 (17).

Each collection comprised 50 cones. Where these were collected especially for the study, the number was made up of 10 cones from each of five trees. With one exception, the trees were selected only for the fact that they bore a reasonable cone crop. The exception was in the 1969 conservancy collection in the Kaingaroa area. There an attempt was made by conservancy staff to increase the percentage of sound seed extracted by further restricting collection to those trees whose pre-sampled cones had four or more sound seeds on a cut face.

Where routine collection was involved, the 50 cones were selected at random from several different parts of the area where they were drying, to increase the probability that they came from different parent trees. After preliminary drying, the cones were sent by air to Rotorua where the following data were recorded.

1. Cone lengths and widths were measured with calipers to the nearest millimetre.
2. The number of cone scales was counted and multiplied by two to give the potential number of seeds in the cone.
3. The seeds were extracted by drying and dissection of the cones. They were then sorted by an air blower into full and empty seeds.
4. The weights were recorded of (a) 100 full seeds, (b) 100 empty seeds, (c) the total full seeds in the sample, and (d) the total empty seeds in the sample.
5. From the data in (4) the number of full and empty seeds in each 50-cone sample (and thus in the mean cone of each sample) was calculated.
### TABLE 1: ASSESSMENT DATA

<table>
<thead>
<tr>
<th>Conservancy or Area</th>
<th>No. of Samples</th>
<th>No. of Scales</th>
<th>Mean Weight 100 Full Seeds (g)</th>
<th>Mean No. Full Seeds</th>
<th>Mean No Total Seeds as percentage of Total Extracted</th>
<th>Total Seeds as % of Total Possible</th>
<th>% Seeds containing Megastigmus Larvae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaingaroa, excluding</td>
<td>8</td>
<td>50</td>
<td>1.22</td>
<td>14</td>
<td>47</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>1969</td>
<td>5</td>
<td>52</td>
<td>1.15</td>
<td>29</td>
<td>62</td>
<td>47</td>
<td>29</td>
</tr>
<tr>
<td>Hawke's Bay</td>
<td>5</td>
<td>50</td>
<td>1.14</td>
<td>15</td>
<td>68</td>
<td>23</td>
<td>16</td>
</tr>
<tr>
<td>Ngaumu, 1969</td>
<td>1</td>
<td>51</td>
<td>1.20</td>
<td>6</td>
<td>65</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Ngaumu, 1970, 1971</td>
<td>2</td>
<td>52</td>
<td>1.22</td>
<td>52</td>
<td>79</td>
<td>67</td>
<td>51</td>
</tr>
<tr>
<td>Nelson</td>
<td>13</td>
<td>53</td>
<td>1.16</td>
<td>31</td>
<td>67</td>
<td>46</td>
<td>29</td>
</tr>
<tr>
<td>Canterbury</td>
<td>7</td>
<td>57</td>
<td>1.20</td>
<td>31</td>
<td>76</td>
<td>41</td>
<td>27</td>
</tr>
<tr>
<td>Southland</td>
<td>11</td>
<td>53</td>
<td>1.20</td>
<td>32</td>
<td>65</td>
<td>49</td>
<td>30</td>
</tr>
<tr>
<td>Highest value in the 52 samples of the survey</td>
<td>67</td>
<td>1.48</td>
<td>53</td>
<td>100</td>
<td>71</td>
<td>58</td>
<td>87</td>
</tr>
</tbody>
</table>

Statistical significance of differences between conservancies:

<table>
<thead>
<tr>
<th></th>
<th>1969</th>
<th>1971</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaingaroa Seed Stand</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Beaumont, Southland</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Ngaumu &amp; Golden Downs</td>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>Geraldine Golden Downs</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Ngaumu</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Ngaumu</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Hanmer</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS = not significant
(6) Additional data calculated were:

(a) The total number of seeds per cone.
(b) The number of full seeds per cone as a percentage of the total number of seeds.
(c) The number of full seeds per cone as a percentage of the potential number of seeds per cone (see 2).
(d) The total number of seeds per cone as a percentage of the potential number of seeds per cone.
(e) The percentage of seed containing larvae of *Megastigmus spermotrophis*.

Analyses of variance were carried out on the 1969 data (5 conservancies × 3 samples per conservancy) and the 1971 data (3 conservancies × 4 samples per conservancy), using, where necessary, angularly transformed values. Results from these analyses are presented in Table 1.

**INTERPRETATION OF DATA**

In Douglas fir, as in many other conifers, a proportion of the ovules (normally at the base of the cone) are incompletely formed and are incapable of development. Such ovules are frequently called deficient (Sarvas, 1968), while ovules capable of normal development are classified as fertile. Fertile ovules in Douglas fir develop into normal-sized seed regardless of whether or not they are pollinated (Allen, 1942; Orr-Ewing, 1957). The total number of seed thus gives a count of the number of fertile ovules in the cone, while the number of full seed gives a count of those fertile ovules which have developed normally. Lack of pollination and/or a high incidence of self-pollination are major factors contributing to the incidence of empty seed in Douglas fir (Allen, 1942; Kozak et al., 1963). Thus calculation 6 (d) (Methods) measures the percentage of ovules in the cone which are fertile while 6 (b) records the percentage of fertile ovules which developed normally to form full seed (and it may give some indication of viable pollen levels). Item 6 (c) is a composite factor which takes into account both the percentage of fertile ovules and the percentage of these which subsequently develop.

**RESULTS**

The results are presented in summarized form in Table 1. (They are much more fully detailed by both sites and years in N.Z. Forest Research Institute *Genetics and Tree Improvement Report* 56, 1971, unpublished). The South Island data have been grouped by conservancies. This does not imply a belief that conservancy boundaries constitute biological boundaries; rather it utilizes a grouping which, though artificial, seemed appropriate in terms of the data. In the North Island, Kaingaroa data are presented (a) excluding the 1969 collection and (b) for 1969 alone. This is because of the tree selection criteria which were used by conservancy officers in Kaingaroa in 1969 (see Methods), criteria which were not used
elsewhere in the study. Ngaumu collections have also been broken down by years.

The factor in the table of main interest to the seed collector is the number of full seeds obtained per cone (column 4). This value was uniformly fairly high throughout the South Island sites sampled, averaging 31 seeds. Comparatively, Kaingaroa and Hawke's Bay regions (14 and 15 full seeds) had low values, except in 1969 in Kaingaroa where the number of full seeds increased to 29. Ngaumu behaved quite differently from the forests in Hawke's Bay and, in two years out of three, averaged 52 full seeds per cone. There was evidence to suggest that the number of full seeds per cone is higher in a productive cone-year than in a non-productive year, and that regional differences are less apparent in a productive year. Although 1969 was a good cone year, it is probable that the striking increase in the number of full seeds per cone in Kaingaroa that year was the result of the tree selection described under Methods. Regional differences in the mean number of full seeds per cone were statistically significant in 1969, but not in 1971.

The number of full seeds obtained per cone depends on (1) the number of scales in the cone (this number multiplied by two gives the number of ovules), (2) the percentage of the ovules that are fertile and thus develop into seed, and (3) the percentage that are pollinated and subsequently develop normally. These data are presented in Table 1 in columns 2, 8 and 7, respectively.

There is little evidence of large regional variation in the number of scales, and thus the number of ovules per cone (column 2): differences present were not significant in 1969 or 1971. While the data in column 8 suggest that there are not major regional differences in the percentage of the ovules in each strobilus which are fertile and capable of development, they do show values which are particularly high at Ngaumu and low in unselected trees in Kaingaroa. The 1969 data from Kaingaroa suggest that the type of selection used that year made a substantial improvement in this factor.

The percentage of the total number of ovules per cone which develop into sound seed (column 6) does show a marked variation from region to region. Generally there was little difference between the South Island areas, but the North Island collections (with the exception of Ngaumu in 1970 and 1971) have a considerably lower value. Again, the selection carried out in Kaingaroa in 1969 was apparently effective in increasing this factor.

Column 7 combines data from columns 6 and 8 to give the percentage of the ovules which were fertile, pollinated and subsequently developed normally. As these data sum up the factors determining the incidence of full seed, the figures closely parallel those for full seed counts in column 4.

The final factor of importance is the incidence of Megastigmus larvae in the seed. Collections from Wellington and Nelson conservancies showed a much lower incidence of this than those from Rotorua, Canterbury and Southland: no
Megastigmus larvae were found in the 1,600 seeds cut open from cone samples from Hawke’s Bay.

The two factors with potentially less relation to seed production, namely, mean cone length and cone width, were not strongly variable regionally, and did not differ at a statistical level in 1969 or 1971. They are not presented in the table.

DISCUSSION

To obtain consistently high seed production per cone in both productive and non-productive cone years, it is apparent from the data that one should avoid locating seed orchards in either Rotorua or Hawke’s Bay districts. In the former area only a low percentage of ovules is fertile, and pollination and/or subsequent development of these ovules are limited. In the latter region the percentage of fertile ovules is high, but their subsequent development is restricted.

The data do not suggest any strong reason for preferential location of seed orchards in any one South Island conservancy. Nelson shows a lower incidence of Megastigmus, but this may not be true in fact as Nelson was not represented in the collection of 1970 when infestation was heavy elsewhere. The choice of seed orchard location within the South Island will thus probably be determined by factors which have not been examined in this report. Particularly important will be the relative size of the cone crops, periodicity of coning, and the effect of quarantine regulations on the movement of plant material from Rotorua.

In two years out of three, Ngaumu forest produced Douglas fir cones with a very high yield of sound seed. Of the 52 cone lots sampled over the four-year period, a Ngaumu collection had the highest percentage of fertile ovules and the third highest percentage of such ovules which developed to form sound seed. Also, we were not able to detect any Megastigmus larvae in the 600 seeds examined. There was, however (in 1969), one collection from Ngaumu with very few full seeds per cone, primarily because of the failure of pollination and/or subsequent ovule development. How much importance should be given to this is uncertain: elsewhere in the study there was one other example of a very low seed yield in one year, which was not repeated subsequently (Kikita, Nelson, in 1968) and there was other evidence of lesser variation in areas from year to year. Bearing in mind that Ngaumu had high seed yields in a very unproductive cone year (1970), it seems reasonable to regard 1969 as an aberration, and to accept the Ngaumu district as potentially a useful seed orchard area, provided that periodicity of seeding and cone crop production are satisfactory.

A point worthy of comment is the apparent success of the cone collection procedure used at Kaingaroa in 1969. Either 1969 was an atypically favourable seed year (a suggestion for which there is little evidence) or else the restriction of collection to trees whose sampled cones had four or more full seeds on a cut face increased markedly the number of full seeds per cone: it did this by giving an increase in both the
percentage of ovules which were fertile, and the percentage of those which subsequently developed into sound seed. It is likely to be about 1985 before New Zealand’s requirements for Douglas fir seed are fully met from seed orchards (Wilcox, 1968) and meanwhile there will need to be considerable collection both from seed stands and other areas. It would seem sensible in all collections during this period to use procedures similar to those used in Kaingaroa in 1969.

Finally, it is pertinent to query whether a tree-breeding programme can utilize some of the individual-tree variation present in seed yields. Work by Allen and Sziklai (1962) and Roeser (1942) suggests a fairly high genetic component in seed yields, and seed criteria have been included for selection purposes in the current genetics and tree improvement programme for Douglas fir at the Forest Research Institute.

ACKNOWLEDGEMENT

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REFERENCES