# DISTRIBUTION OF AERIALLY APPLIED FERTILISER IN NEW ZEALAND FORESTS

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(Received for publication 9 December 1970)

## ABSTRACT

Ground distribution of aerially applied fertiliser was studied by means of line and random sampling points. The pattern varied considerably. Application rates over sampling areas, flown at an intended rate of 5cwt/acre, varied from 0.56 to 14.16 cwt/acre in one forest and from 1.59 to 7.16 cwt/acre in another. Uneven spacing between successive flight lines accounted for most of the variation, but an uneven release rate from the hopper contributed to a lesser extent. Multiple applications failed to improve distribution patterns appreciably.

Half Value, a new criterion for testing the evenness of ground distribution during aerial topdressing is proposed and examined. It is defined as "the percentage of sampling points which receive less than half the designated rate of application." Values of 10 or less are proposed as acceptable. Those for several aerial topdressing operations ranged from 5 to 65.

## INTRODUCTION

This paper reports studies in New Zealand forests to examine ground distribution of aerially applied fertiliser in commercial-scale operations.

Since 1957 aerial application of superphosphate has been used on a commercial scale to increase tree growth in forests on phosphate-deficient soils (Conway 1962). Uneven growth responses now evident in many stands are creating utilisation problems. Uneven responses may be caused by varying phosphate-fixation capacity of soils and other nutrient deficiencies at specific localities, but the strip effects in fertilised stands illustrated in Fig. 1 suggest that uneven fertiliser spread is the major cause. Experience in Sweden (Hagner *et al.,* 1966), Britain (Davies, 1967), and Australia (Eilert, 1967) has shown that the major cause of poor fertiliser distribution in forests topdressed from the air is uneven spacing between successive flight lines. In Sweden, concern at the uneven distribution obtained from aerial topdressing has led to the introduction in contracts of penalty clauses which may be invoked if the Uniformity Quotient is above 3.0. This Uniformity Quotient is calculated from the weights of fertiliser collected in randomly distributed collection containers.

$$\text{It is } \frac{\text{sum of fertiliser heaviest 50\% of containers}}{\text{sum of fertiliser lightest 50\% of containers}}$$

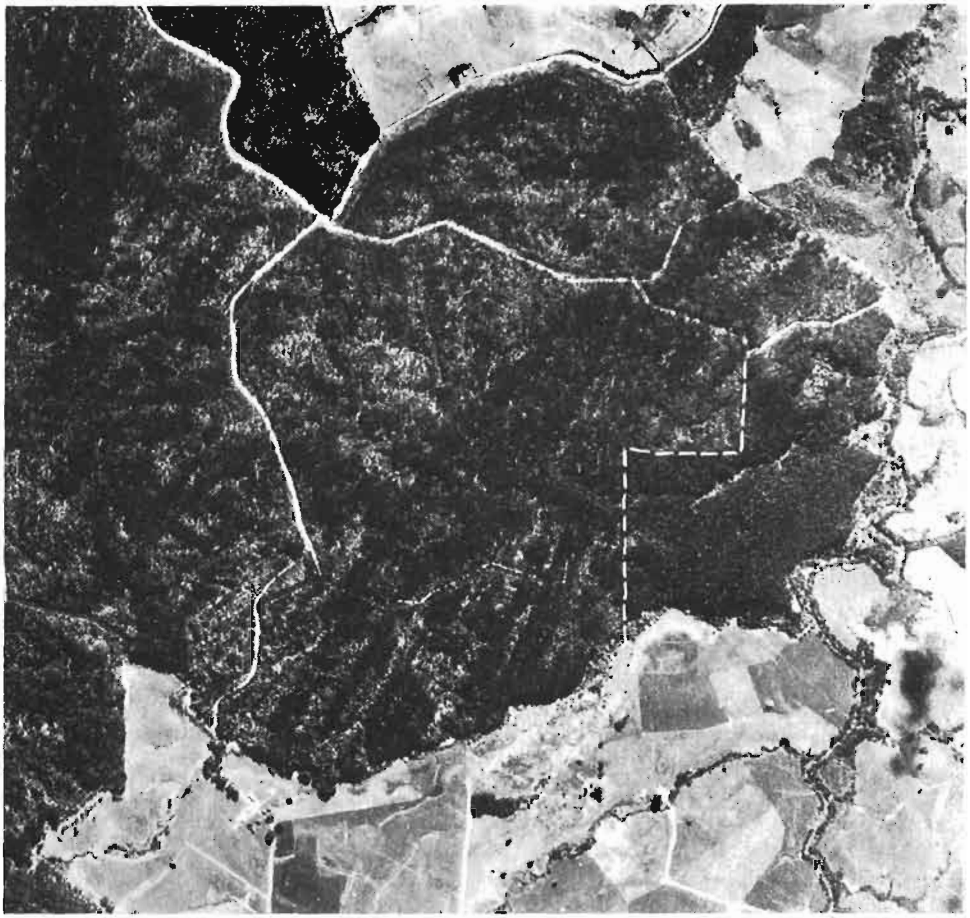

FIG. 1—Compartments 13 and 14, Riverhead Forest (1969 photo). This whole area was flown at 5 cwt/acre superphosphate in 1959 except portion to right of white dotted line. Note uneven response, particularly strip effects to lower right of and below centre.

## METHODS

### *Sample Collection*

In all studies, 2 gal plastic buckets with a collection surface of 60 sq in. were used as collection containers. "Bounce-out" from these was observed to be minimal, but possible losses in recovery from this source cannot be entirely discounted (Lynch, 1951). Buckets were placed and undergrowth cleared so that there was no obstruction to the fertiliser entering the buckets.

### *Study 1 — Maramarua Forest*

Thirteen hundred acres of mature radiata pine at Maramarua Forest were topdressed with 5 cwt/acre of superphosphate in 1969. The fertiliser was applied in two separate parallel applications of 2.5 cwt/acre each by a Fletcher topdressing aircraft not fitted with any special distributor. The intended spacing between successive flight lines was 33ft. In one section of the topdressed area, two strips normal to the flight lines were cleared of undergrowth, the first being in a firebreak (no canopy cover) and the other being parallel to the first, 1 chain directly back along the flight lines under a closed-canopy stand. Seventy-five buckets were placed at 9ft intervals down both strips and were cleared of fertiliser after each 2.5cwt run was completed. The flight lines of each run were observed from the ground and recorded.

### *Study 2 — Kaingaroa Forest*

Fifty acres of 3-year-old radiata pine at Kaingaroa Forest were topdressed with 5 cwt/acre of boronated sulphur superphosphate in 1969. The fertiliser was applied in four runs of 1.25 cwt/acre each by an aircraft fitted with a "Swathmaster" distributor. Successive runs were made at right angles to each other, with an intended spacing of 45ft between successive flight lines. One group of buckets was laid out in the form of a cross with 25 buckets on each axis spaced at 15ft intervals. Two other groups each of 25 buckets were randomly placed in positions where they should have been covered by the same flight lines as those normal to each axis of the cross. All buckets were emptied after each 1.25cwt run. The position of the flight lines was observed from the ground and recorded.

## RESULTS

### *Study 1 — Maramarua Forest*

Table 1 gives the means, ranges, Uniformity Quotients, and Half Values for the single and combined runs over the two lines of buckets.

TABLE 1—Summary of means, ranges, Uniformity Quotients, and Half Values for Maramarua Study

| Bucket position | Run | Mean (cwt/acre) | Range (cwt/acre) | Uniformity Quotient* | Half Value* % |
|---|---|---|---|---|---|
| | 1 | 1.51 | 0 - 4.50 | 3.0 | 40 |
| Firebreak | 2 | 2.77 | 0.23-12.56 | 3.6 | 31 |
| | 1 + 2 | 4.28 | 0.56-14.60 | 2.7 | 27 |
| | 1 | 1.72 | 0 - 4.90 | 3.5 | 45 |
| Closed canopy | 2 | 3.30 | 0.20-15.90 | 3.2 | 15 |
| | 1 + 2 | 5.02 | 1.15-18.80 | 3.2 | 28 |

* Calculated as defined in the text.

Fig. 2 shows the distribution patterns obtained in the firebreak. The position and direction of the individual flight lines are shown by arrows. Patterns under the closed canopy were almost identical. That there is no evidence of fertiliser interception by the tree canopy is shown by mean collection values under the closed canopy being slightly greater than those in the open firebreak.

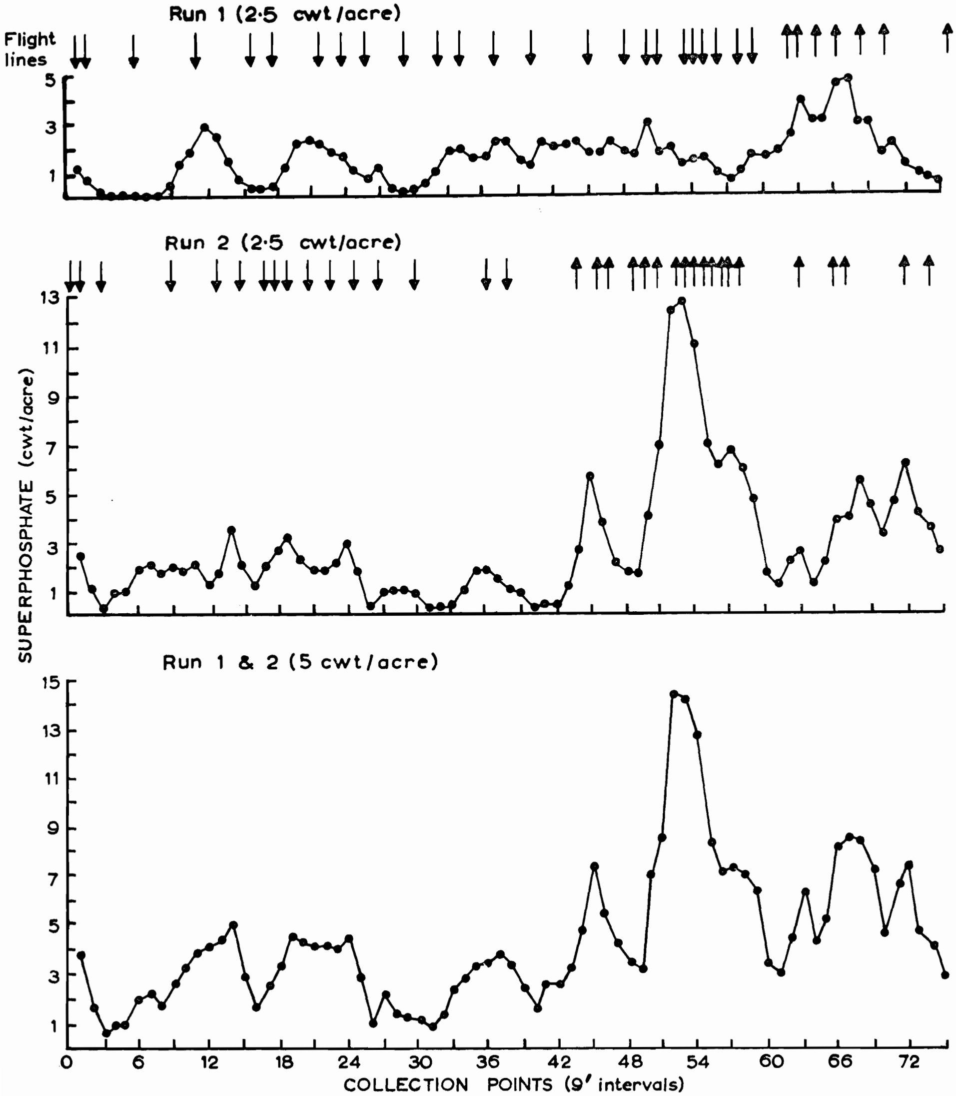


FIG. 2—Fertiliser distribution patterns for collection points normal to flight lines on a firebreak, Maramarua Forest

*Study 2 — Kaingaroa Forest*

Table 2 gives the means, ranges, Uniformity Quotients, and Half Values for the single and combined runs normal and parallel to the two axes of the cross. Also, in parentheses, are the corresponding values obtained from the set of random buckets flown over by the same flight lines.

Distribution patterns for single runs normal and parallel to the two axes are shown in Figs. 3 and 4 respectively. The position and direction of the individual flight lines are shown by arrows.

TABLE 2—Summary of Means, Ranges, Uniformity Quotients, and Half Values for Kaingaroa Study

| Bucket position | Run | Mean (cwt/acre) | Range (cwt/acre) | Uniformity Quotient | Half Value (%) |
|---|---|---|---|---|---|
| (a) **Flight lines normal to buckets** | | | | | |
| Axis 1 | 1 | 0.94 | 0.20-3.86 | 4.1 | 56 |
| | | (1.25) | (0.26-3.79) | (2.7) | (24)* |
| | 3 | 0.86 | 0.43-1.48 | 1.7 | 16 |
| | | (2.20) | (0.53-2.21) | (1.8) | (12)* |
| | 1 + 3 | 1.80 | 0.90-4.67 | 1.9 | 36 |
| | | (2.35) | (1.05-4.72) | (1.7) | (4)* |
| Axis 2 | 2 | 1.24 | 0.39-2.54 | 1.9 | 8 |
| | | (1.08) | (0.53-1.64) | (1.8) | (8)* |
| | 4 | 0.73 | 0.04-2.42 | 5.5 | 56 |
| | | (1.30) | (0.12-3.02) | (2.3) | (12)* |
| | 2 + 4 | 1.97 | 0.63-3.84 | 2.2 | 20 |
| | | (2.38) | (0.95-4.44) | (1.8) | (6)* |
| (b) **Flight lines parallel to buckets** | | | | | |
| Axis 1 | 2 | 1.00 | 0.22-2.25 | 2.7 | 28 |
| | 4 | 0.21 | 0.06-0.41 | 1.8 | 100 |
| | 2 + 4 | 1.21 | 0.46-2.49 | 2.3 | 52 |
| Axis 2 | 1 | 0.60 | 0.30-1.32 | 1.9 | 72 |
| | 3 | 1.03 | 0.61-1.93 | 1.5 | 4 |
| | 1 + 3 | 2.63 | 0.63-2.76 | 1.7 | 20 |
| (c) **All flight lines** | | | | | |
| Axis 1 | 1+2+3+4 | 3.02 | 1.59-7.16 | 1.9 | 48 |
| Axis 2 | 1+2+3+4 | 3.60 | 1.87-6.42 | 1.7 | 8 |
| Random 1 | 1+2+3+4 | 4.18 | 2.04-12.13 | 1.8 | 4 |
| Random 2 | 1+2+3+4 | 4.90 | 2.64-9.93 | 1.8 | 0 |

* Random buckets.

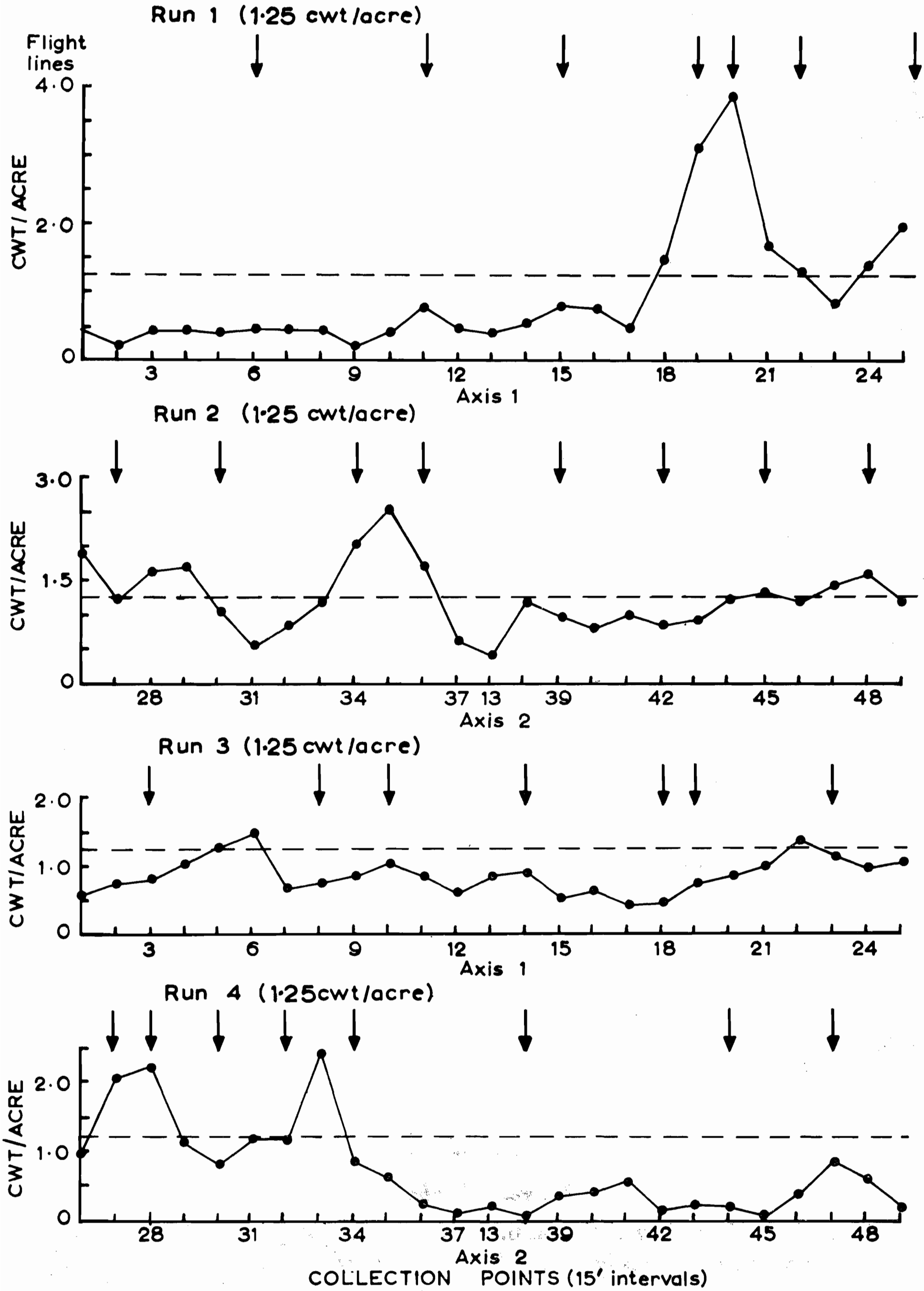


FIG. 3—Fertiliser distribution patterns for collection points normal to flight lines, Kaingaroa Forest.

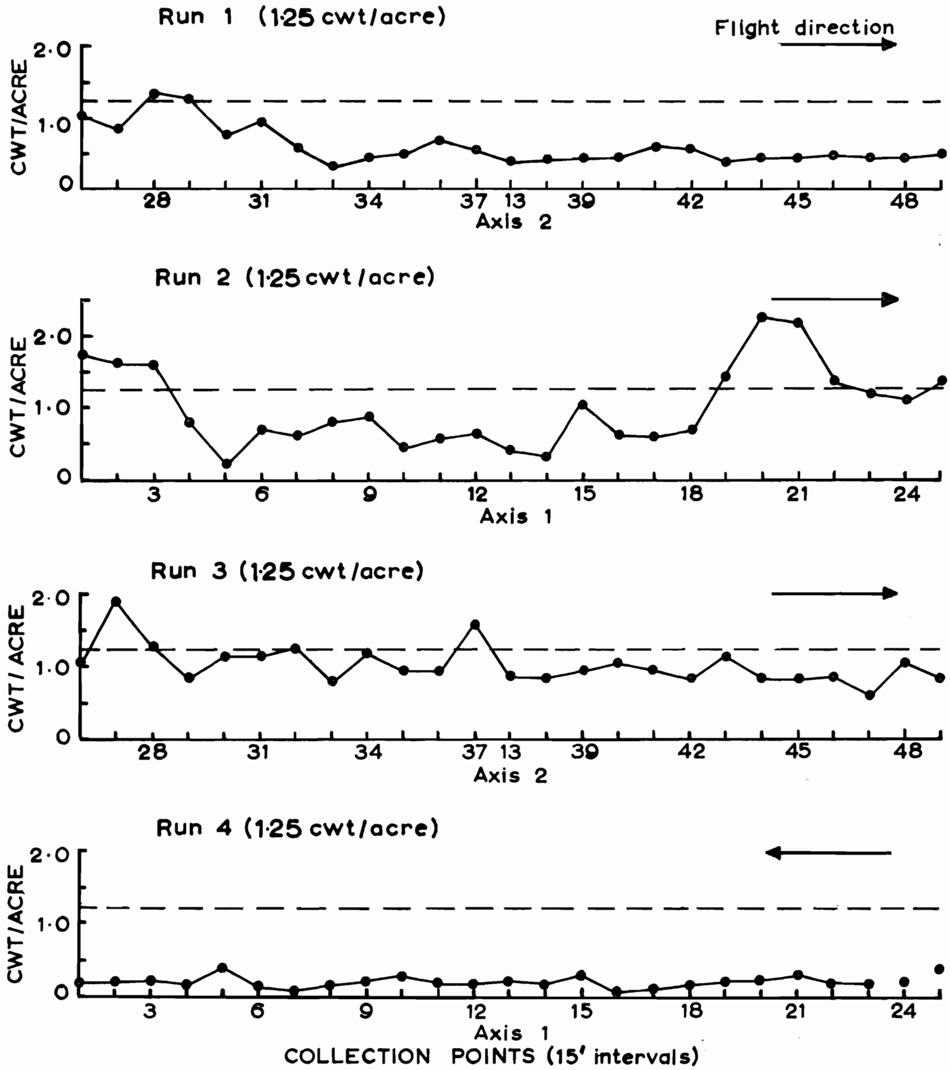


FIG. 4—Fertiliser distribution patterns for collection points parallel to flight lines, Kaingaroa Forest.

## DISCUSSION

### *Lateral Distribution*

There is considerable variation in the lateral distribution patterns. In the Maramarua study, rates vary from virtually no fertiliser to 15 cwt/acre along a collection strip of 10 chains where the intended application rate was 2.5 cwt/acre. Use of double parallel application fails to even out the general distribution appreciably, although the average for the two runs does provide an application rate closer to the specified rate (5cwt) than do either of the single runs (2.5cwt). Strips of high and low coverage in one application tend to coincide with similar strips in the other, suggesting that flight path errors in one run tend to be repeated in the next. This could be expected if the same landmarks are used for alignment in both runs.

In the Kaingaroa study, variability in the lateral spread is not as gross as that recorded at Maramarua; rates varied for a nominal application rate of 2.5 cwt/acre from 0.9 to 4.7 cwt/acre over a 6-chain strip.

Variability in spacing between successive flight lines appears to account for the majority of the variation in lateral distribution at both study sites. Where a special distributor was used to increase the swath width, as at Kaingaroa, deviation from intended flight lines did not appear to have such a pronounced effect on the distribution pattern. Ground observations of variability in the intensity of the shower under the various passes suggest that an uneven release rate from the hopper was probably responsible for variability not related to the frequency of flight lines. The longitudinal distribution obtained from flights parallel to the sampling lines supports this contention.

### *Longitudinal Distribution*

Variability in longitudinal distribution (Fig. 4) is not as pronounced as that for the lateral distribution, although it is considerably greater than one would expect if the flow rate from the hopper was constant. The physical condition of the fertiliser used at Kaingaroa left much to be desired, as the pilot had to manipulate the flow control continuously in an attempt to maintain a constant flow rate. The use of either more evenly granulated fertiliser or an agitator in the aircraft hopper could alleviate this problem.

### *Uniformity Quotient*

Applying the Swedish Uniformity Quotient (Hagner *et al.*, 1966) to our results shows that for Maramarua all the single runs are either on the Swedish limit of 3.0 or exceed it. Combining the individual runs does not appreciably lower the Quotient value, i.e., split applications fail to compensate for deficiencies in individual runs.

For Kaingaroa, two of the individual runs exceed the Quotient limit of 3.0, but all other individual and combined runs are well within the 3.0 limit. The Quotient values for the combined runs being in no instance better than the Quotient value for the best of the individual runs shows again the doubtful value of split applications.

A weakness of the Uniformity Quotient method is that it provides a relative and not an absolute measure of distribution. For instance, the Quotient value for Run 4 over axis 1 is 1.8—very acceptable—yet the mean for this run is 0.21 cwt/acre (intended 1.25 cwt/acre), with a range from 0.06 to 0.41 cwt/acre, which is quite unacceptable in absolute terms.

### *Half Value*

A method that better indicates the variation relative to the intended application rate is to take the percentage of sampling points which receive rates outside a set fraction of the intended application rate. Since areas receiving an "over" application are usually balanced by areas receiving an "under" application and it is the latter that particularly concerns forestry, the following "Half Value" method was defined and examined.

Half Value is defined as,

"the percentage of sampling points which receive less than half the designated rate of application."

Half Values for the various runs at Maramarua and Kaingaroa are shown in Tables 1 and 2. They range from 0 to 100. The Half Value for the best individual run at Kaingaroa (run 2, axis 2) is 8, while those for the combined runs over the line and random buckets are all below 10 except for axis 1 which received an average rate well below that designated. On the basis of these results it is suggested that a Half Value of 10 or below be taken as acceptable. This standard is not very strict, but if all future topdressing operations meet this requirement it will be a considerable improvement on previous operations. The Half Values and other relevant data obtained from several other aerial topdressing operations using random sampling points are shown in Table 3.

TABLE 3—Fertiliser distribution parameters of commercial scale aerial topdressing operations in some New Zealand forests

| Location | Application rate (cwt/acre) | Mean (cwt/acre) | Range (cwt/acre) | Uniformity Quotient | Half Value (%) |
|---|---|---|---|---|---|
| Whangapoua | 5 | 3.8 | 0- 8.1 | 2.4 | 33 |
| Whangapoua | 5 | 3.3 | 0- 11.6 | 2.9 | 38 |
| Maramarua | 5 | 2.6 | 0.1- 12.4 | 4.1 | 65 |
| Kaingaroa | 2.5 | 2.1 | 0.4- 6.4 | 3.7 | 38 |
| Kaingaroa | 2.5 | 3.3 | 0.9- 6.9 | 2.1 | 5 |
| Westland | 35 lb/acre | 41 lb/acre | 14.9-104.2 lb/acre | 2.1 | 10 |

This method is suitable for inclusion in tenders as it provides a rapid indication of the distribution. It is superior to the Uniformity Quotient method in that the measurement of sample weights and calculations are considerably simplified, as sample weights over the set limit can be automatically discarded. However, before the Half Value can legitimately be used in tenders, it would be necessary to establish a sampling procedure which would give an accurate indication of the distribution obtained over the whole area topdressed. A comparison needs to be made between the use of fixed line, grid, and random sampling points and the intensity of sampling required within each procedure.

### *Practical Considerations*

The only reported sampling of fertiliser distribution under a commercial agricultural aerial topdressing operation is that by Lynch (1951). Analysis of his results in terms of our methods gives a Uniformity Quotient of 2.9 and a Half Value of 25. The Half

Value being worked out against an intended application rate of 1.2 cwt/acre to correct for the reported 40% loss in recovery from bounce out. This distribution would not meet our proposed uniformity standards, yet according to Lynch it was "an exceptionally good distribution". Distribution standards acceptable to an Agriculturalist may, however, be lower than ours, as variability in a single topdressing operation will, over a relatively short period, tend to be evened out by successive topdressing operations and fertility transfer by stock.

Most of the current agricultural research is being directed to improving the evenness of application across each swath. However, this is not of prime importance in forests where extensive lateral spread of roots and grafting (Will, 1966) obviate the need for uniform spread of fertiliser over relatively small areas. Our main concern is the difficulty pilots have in spacing successive flight lines at regular intervals. This results in strips, sometimes chains wide, which receive either very low applications or rates up to five times the nominated rate. Over a period of 10 years or more, the usual interval between successive topdressings in New Zealand phosphate-deficient forests, such differences will produce gross differences in productivity with associated management and utilisation problems, and the reduced efficiency of utilisation of the applied P where non-linear responses are obtained. Thus our first concern in topdressing forests must be to obtain an improvement in the spacing of successive flight lines. One approach is to put pressure on topdressing firms by specifying uniformity standards in tenders. This approach, although justifiable, is negative and a more positive one of assisting pilots pick their flight lines over the tracts of relatively uniform forest land would probably yield more rapid and beneficial results. The provision of line markers in the form of flags, balloons, and moving vehicles has been attempted but is tenable only for young stands with good road access, which are a minority of areas topdressed. Other alternatives appear to be the use of radio guidance systems which have been used with success overseas but have yet to be evaluated in New Zealand, or the use of special spreaders. Spreaders which provide a wider more uniform swath would reduce the influence of flight line errors on distribution.

## ACKNOWLEDGMENTS

The assistance of Maramarua and Kaingaroa field staff is gratefully acknowledged, as also is the co-operation of the two aerial topdressing firms involved.

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