

THE SIGNIFICANCE OF FORKS AND MULTILEADERS IN NURSERY STOCK OF *PINUS RADIATA*

R. D. BURDON and M. H. BANNISTER*

SYNOPSIS

Forking and multileading of nursery stock of Pinus radiata often appear to occur spontaneously, generally through apical abortion, but sometimes through bifurcation. The frequency and subsequent effects of these growth anomalies, mainly as they occurred in the first two years after planting, were studied. They are essentially features of the unstable juvenile growth phase in this species, rather than being subject to close genetic control. Persistent malformation resulted infrequently (1 to 2%) from apical abortion, but more frequently among bifurcations (10 to 15%), particularly when they occurred near ground level. Among populations, the frequency of apical abortion could not be related to the subsequent standard of stem form. In general, it appears that forking and multileading in the nursery cause little malformation and do not reflect genetic quality, in the individual or in the seedlot. Therefore, it is not recommended that affected seedlings should be culled, except in extreme cases.

INTRODUCTION

Forked and multileadered nursery stock of radiata pine present the nurseryman with a problem, particularly if the incidence is high. There is the question of whether the malformation is likely to cause permanent forking, and more generally, whether it reflects a genetic tendency to fork. Quite apart from the intrinsic merits of the stock, the commercial nurseryman has to contend with the reaction of uninformed customers to the appearance of his stock. When he has a high incidence of malformation in stock grown from expensive seed orchard seed, he is faced with a hard decision in determining his culling policy.

Although very little quantitative study has been made, there is indirect evidence that the malformation is unimportant in itself, since the topping of nursery stock is routine practice in some areas and is not accompanied by a noticeably high incidence of forking near ground level. However, much of the malformation appears to arise spontaneously, rather than as a result of obvious injury, which suggests a genetic basis. This malformation can result from true bifurcation, or more com-

*Scientists, Forest Research Institute, Rotorua.

monly, from "apical abortion" (Burdon, 1969), in which the apical meristem (growing point) abruptly ceases to function, and is superseded by lateral shoots which can be either proliferated fascicles or ordinary branches.

Evidence for a possible genetic basis of seedling malformation has hitherto been inconsistent. There have been conflicting reports concerning the relative incidence of seedling malformation among different seedlots; in some cases, the effect of seedlot was confounded with other effects.

Evidence for any gross effect of environment is very sketchy, but a general impression is that apical abortion tends to be worst in long-established nurseries where heavy reliance is placed on inorganic fertilizers and/or urea. Environmental effects may well be large, if not predominant, in New Zealand.

This report covers studies of the incidence of putatively spontaneous forking and multileadering in seedlings, of the possibility of a genetic basis, and of the significance in determining ultimate stem form. Spontaneous malformations were assumed to be equivalent to comparable malformations caused by injury, in their effects on stem form. The former, however, were of greater interest because of the likelihood of a genetic cause.

MATERIALS AND METHODS

The studies were incidental to a combined provenance-progeny trial with radiata pine (Bannister, 1966; Burdon and Bannister, 1970, 1973). Fifty open-pollinated progenies from each of all five natural populations and two New Zealand populations (Kaingaroa and Nelson) have been planted on two contrasting sites in Kaingaroa Forest. One site located in Cpt 918 and designated "Goudie's Block", is a typical Kaingaroa Plateau site. The other, in Cpt 1333 and designated "Northern Boundary" is undulating, at a lower altitude, and gives faster early growth of radiata pine. One-year-old tubed planting stock was used, and any blanking was done with open-rooted 1/1 stock. Assessments were made mainly in the 1964 plantings (Stage I), although some data were collected from the 1965 plantings (Stage II).

Detailed growth assessments were made on all trees one and two years after planting—i.e., 1965 and 1966—and all growth anomalies were noted. It became clear that the loss of the apical meristem frequently occurred without any sign of injury, and this phenomenon was termed "apical abortion". Spontaneous bifurcation was also observed, but much less frequently. Sometimes it was uncertain whether apical abortion or some injury such as tortricid damage had occurred; in 1966 these doubtful occurrences were noted separately. True bifurcation was comparatively easy to identify because of the identical branching behaviour of the different forks. Occasionally occurrences were trifurcate or quadrifurcate, while very occasionally trees would bifurcate twice in quick succession. All such cases were classified as single occurrences of bifurcation.

In 1968, during an assessment for known and possible symptoms of boron deficiency, the presence or absence of definite apical abortion was noted on all trees in Stages I and II, that is at four and five years, respectively, from seed.

All trees in Stage I, Goudie's Block, were assessed in 1969 for persistent malformation. Another such assessment was made in 1971, and all trees which had bifurcated in 1966 were examined for possible repeat bifurcations.

In Stage I, Northern Boundary, a tree form assessment was made in 1971, and the percentage of good quality stems (of satisfactory branching habit and straightness, of acceptable vigour, and free from die-back) was evaluated for each population. Following this assessment a sample of the trees was measured during a systematic thinning. This included recording all occurrences of bifurcation, and apical abortion, definite and suspected separately, on the leader during the sixth to eighth years of growth from seed.

In addition to the main experiment, some seedlings which had produced spontaneous bifurcation in the sowing boxes were pricked out, raised, and planted in Stage II, Goudie's Block. Thirty-eight survived, although only 30 grew vigorously; these were assessed for ground level forks and for any repeat bifurcations 5½ years after planting. Quite apart from the provenance-progeny trial, data from a trial with first-year nursery seedlings (Burdon, 1969) are incorporated in the results.

RESULTS

Incidence of Apical Abortion

Figure 1 shows the percentage incidence of definite and suspected apical abortion at different ages from seed in all populations combined. Figure 2 shows the same information for a composite ("New Zealand equivalent") population comprising Kaingaroa, Nelson and Ano Nuevo. These three populations were accepted as being roughly equivalent genetically. The first-year nursery seedlings, which have been described elsewhere (Burdon, 1969), were of local commercial stock. The occurrences of apical abortion in years 6 to 8 at Northern Boundary were not readily assignable to individual years, so a mean incidence per year was calculated for this period.

For years 2 to 5 each point in Figs. 1 and 2 was based on approximately 2000 and 1200 individuals respectively. For years 5 to 8 the corresponding figures were 627 and 327. The first-year seedlings (Fig. 2) totalled 2379. Hence, the sampling error involved in any comparison is very small.

Both graphs show a clear trend, regardless of any uncertainties of diagnosis. During the first four years the incidence was at least 9 to 10%, and possibly as high as 25%; thereafter it fell rapidly to a very low level, certainly less than 5%, and possibly less than 1% in local stock. This confirms that apical abortion is essentially a phenomenon of the juvenile growth phase. The higher percentages when all populations are considered together are due to the contributions of the Monterey

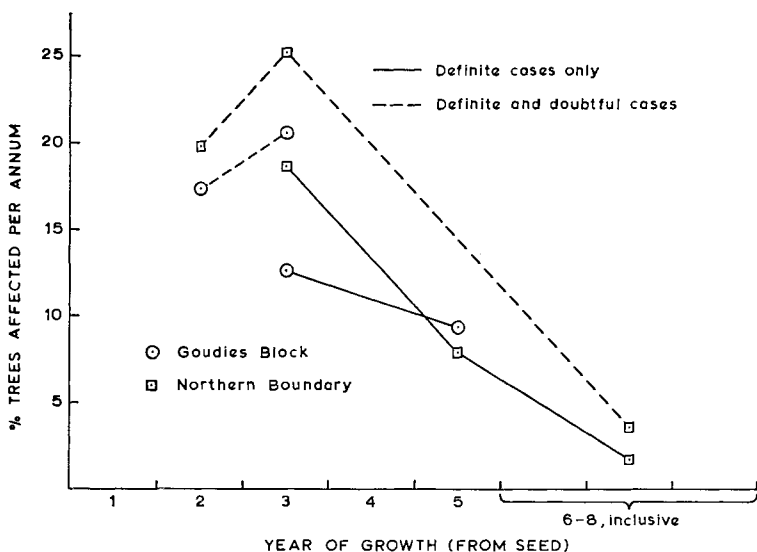


FIG. 1: Percentage of trees showing apical abortion in successive years of growth for all populations combined.

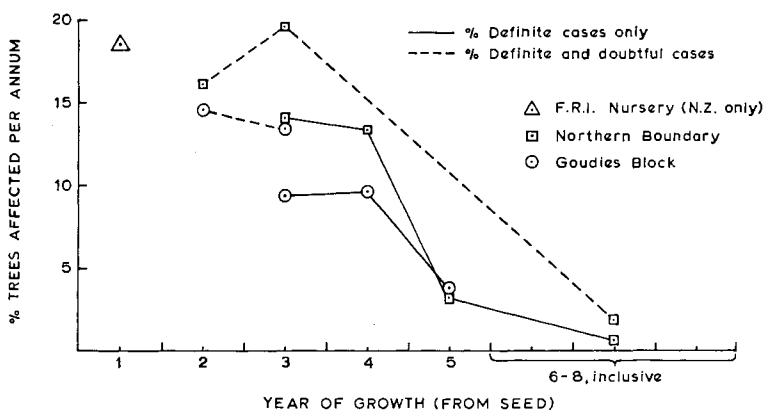


FIG. 2: Percentage of trees showing apical abortion in successive years of growth for Kaingaroa, Nelson and Ano Nuevo populations combined.

and Cambria populations which have a persistent juvenile phase (Burdon and Bannister, 1970).

During the first four years the incidence was lower at Goudie's Block, probably reflecting the slower growth there. However, this situation does not persist, presumably because the faster growth at Northern Boundary brings the trees through the juvenile phase at an earlier age.

TABLE 1: FREQUENCY DISTRIBUTION FOR NUMBERS OF OCCURRENCES OF APICAL ABORTION, DEFINITE AND SUSPECTED, PER TREE

No. of Occurrences within Tree	No. of Trees		
	Observed	Expected (Poisson distribution)	Observed-Expected
0	232	219.1	+12.9
1	83	105.5	-22.5
2	33	25.5	+ 7.5
3	6	4.9	+ 2.1
4	1		

Table 1 shows the frequency distributions for the number of occurrences per tree in the New Zealand equivalent population in Stage I, Northern Boundary, and the corresponding Poisson distribution. The latter distribution would be expected if apical abortion occurred at random among individuals. A significant departure from this distribution ($P < 0.02$), with a slight deficit of single occurrences, indicates that predisposing factors were operating in certain trees. These factors were, presumably, in part genetic. However, any predisposition can be regarded as only a minor effect superimposed upon an essentially random occurrence of apical abortion.

Incidence of Bifurcation

Of 4907 trees studied at three years from seed, 149 had bifurcated. The overall percentage was thus 3.6, the incidence being slightly but not significantly (χ^2 test, $P > 0.05$) higher at Northern Boundary (4.05%), than at Goudie's Block (3.0%). Differences between populations were not significant overall, although Monterey and Cambria which have a more persistent juvenile phase showed a 4.5% incidence compared with about 3% in the other populations. At Northern Boundary 627 trees were studied over the period of five to eight years from seed, and only 10 (1.6%) showed bifurcation. This incidence was significantly lower ($P < 0.01$) than in year 3 alone.

If bifurcation recurs at random the expected number of repetitions on the basis of the above figures, among the sample reassessed at Northern Boundary would be 0 or 1. For Goudie's Block, Stage I, the number would be 2 or 3, and 2 for Stage II. In fact the observed incidence was 0, 2 and 0, respectively, for certain recurrences plus 0, 2 and 1 for suspected occurrences. Thus there is no evidence for more than a random incidence of recurrence among trees that are initially affected.

Effects of Apical Abortion and Bifurcation

The incidence of persistent malformation resulting from definite and suspected apical abortion in trees at Goudie's Block, Stage I, was very low. Of 363 trees affected in 1965, only five (1.4%) had resultant forks in 1969. Again, among 564

trees initially affected in 1966, resultant forks numbered 15 (2.7%) in 1969, and only 5 (0.9%) in 1971. The total number of forks and moderate stem deformations resulting at that stage numbered 10 (1.8%).

TABLE 2: INCIDENCE OF PERSISTENT FORKS RESULTING FROM BIFURCATION

<i>Parameter</i>	<i>Stage I Northern Boundary</i>	<i>Stage I, Goudie's Block</i>	<i>Stage II, Goudie's Block</i>
	<i>Date of Initial Occurrence</i>		
	<i>1966</i>	<i>1966</i>	<i>1965</i>
No. of trees initially affected	79	64	38
Year (from seed) of initial occurrence	3	3	1
	<i>Date of Reassessment</i>		
	<i>1971</i>	<i>1971</i>	<i>1971</i>
Equal forks	No data	No data	6 (16%)
All forks	9 (11%)	9 (14%)	14 (37%)

Table 2 lists the incidence of persistent malformation resulting from bifurcation five or six years after the initial occurrences. In this case the malformation rates were higher, being upwards of 10%. This was particularly so in Stage II, Goudie's Block, where the initial bifurcations had occurred very close to ground level. Of these latter trees, approximately one-third had ground-level forks of varying severity. This was a significantly higher frequency than in the other two blocks combined ($P < 0.01$).

TABLE 3: FREQUENCY OF APICAL ABORTION AND SUBSEQUENT STEM QUALITY AMONG CALIFORNIAN MAINLAND POPULATIONS

<i>Parameter</i>	<i>Age from Seed (yr)</i>	<i>Population</i>			
		<i>Ano Nuevo</i>	<i>Monterey Cambria</i>		
% trees showing apical abortion	4	15	33	60	
	5	4	10	24	
% high quality stems	8	6	15	16	

Table 3 shows, among the Californian mainland populations, the incidence of apical abortion and the subsequent percentages of high quality stems, at Northern Boundary. Roughly 300 trees per population were assessed in each case. Ano Nuevo, although showing far less apical abortion in years 4 and 5, was found to have the lowest percentage of good stems, despite more frequent leader dieback in the Cambria population (Burdon and Bannister, 1973).

DISCUSSION

The results are consistent with the common observation that young radiata pine can survive severe mutilation through deliberate topping or animal damage, without a significant rate of malformation resulting. One may assume that malformation arising in the nursery would, in general, have no more permanent effects than the bifurcations and apical abortions that arise in the first two years after planting. The one situation in which appreciable malformation did result was when seedlings were forked equally very close to ground level. This occurred with tubed stock which would have had only a minimal check on transplanting, and might not have happened if the stock had been open-rooted. However, if a seedling is forked co-equally, a decisive advantage should be given to one of the shoots by pinching off the tip of the other.

It appears that the genetic basis for spontaneous nursery malformation is not sufficient to be of practical importance, and it would be even less so for malformation resulting from most forms of mechanical injury. At the age of four to five years from seed there are big differences among natural populations in the incidence of apical abortion, but this can be interpreted as reflecting differences in the duration of the unstable juvenile growth habit. There will also be individuals of genotypes which produce repeated apical abortion or bifurcation, but normally these would be too uncommon to matter. Among the New Zealand equivalent stock there are slight differences between the component populations (Burdon and Bannister, 1973) which would tend to inflate estimates of tree-to-tree variation within a population. The general indications are, however, that local differentiation is only slight in New Zealand radiata pine (*loc. cit.*). The important genetic implication is that any culling of individual seedlings will be an inefficient way of selecting against any character that shows an "all-or-none" expression (as in the nursery) which is governed largely by chance. If any selection were to be made against apical abortion it would need to be done on the basis of provenance or progeny trials.

The comparison between the Californian mainland populations shows dramatically that in a seedlot the incidence of apical abortion may be quite unrelated to subsequent general stem quality.

The significance of seedling malformation would be influenced by the propensity of an individual to produce a single dominant leader from several competing shoots. Genetic variation of this sort would be expected, and, in fact, clonal differences have been shown by Brown (1971). An improvement programme would involve some degree of selection for this attribute. It would, therefore, seem inappropriate to sacrifice expensive seed orchard stock because of apical abortion which may have been caused mainly by factors of the nursery environment.

CONCLUSIONS

- (1) Forking and multileadering occurring in radiata pine nursery stock appear to be of little significance in causing persistent stem malformation. However, persistent ground-level forks can result from co-equal forks originating close to the root collar.
- (2) Spontaneous bifurcation of radiata pine seedlings does not, in general, appear to reflect any strong genetic predisposition within individuals.
- (3) Spontaneous multileadering or "rosetting", resulting from "apical abortion", appears to be under partial genetic control; but not sufficiently to permit effective genetic selection among individuals.
- (4) Spontaneous bifurcation and apical abortion are essentially features of the unstable juvenile growth phase of radiata pine.
- (5) Among seedlots, the incidence of apical abortion can be unrelated to subsequent stem quality.
- (6) The culling of nursery stock for forks and multileaders or rosettes appears to be unwarranted, except in extreme cases. This would be particularly so when the seed has come from an expensive programme of selective breeding.
- (7) Even co-equal forks occurring near ground level should be acceptable provided one leader is sturdy enough and the other is mutilated.

ACKNOWLEDGEMENTS

Special acknowledgement is due to the assistance of C. B. Low.

REFERENCES

- Bannister, M. H., 1966: A genetic survey of *Pinus radiata* (Part 1). *N.Z. For. Serv., For. Res. Inst., Silviculture Rep.* 85 (unpubl.).
- Brown, A. G., 1971: Experience in management of a radiata pine seed orchard at Tallaganda State Forest, New South Wales. *Aust. For. Res.*, 5: 15-30.
- Burdon, R. D., 1969: Apical abortion and needle crinkle in *Pinus radiata* seedlings: description and a preliminary investigation of causes. *N.Z. For. Serv., For. Res. Inst., Soils & Nutr. Rep.* 9 (unpubl.).
- Burdon, R. D.; Bannister, M. H., 1970: The natural populations of *Pinus radiata*: their early development and a provisional evaluation of their silvicultural potential in New Zealand. *N.Z. For. Serv., For. Res. Inst., Genetics & Tree Improvement Rep.* 49 (unpubl.).
- ; ——— 1973: Provenances of *Pinus radiata*: their early performance and silvicultural potential. *N.Z. Jl For.*, 18 (2).

GRASS UTILIZATION DURING FOREST ESTABLISHMENT

B. A. BROOK*

SYNOPSIS

This paper is a summary of an investigation into alternative systems of grass harvesting and their comparative economics during the establishment of trees on an area where contour permits the use of farm machinery. The establishment period is taken as three years from planting, assuming that after this period the area may be grazed by cattle without fear of damage to the trees. The systems of utilization considered were the making of hay or silage, and the cutting and carting of fresh grass.

After allowing for such factors as the area covered by the trees, the loss of fertility, efficiency of utilization of the grass grown, costs of harvesting and feeding out, the value of the grass grown was assessed in each of the three years. The profit margin was then assessed on a per hectare basis, and findings due to the systems of utilization envisaged were: Year one, profit of \$24.30/ha; year two, break even; year three, loss of \$17.30/ha.

INTRODUCTION

A client, Mr Grazier, was given the opportunity to utilize the grass from an area to be planted in pine trees. The district is one in which sheep are rarely grazed, and Mr Grazier is a dairy farmer whose property lies on the Rangitaiki Plains in the eastern Bay of Plenty. The area to be planted is situated at Matahina on very light pumice country. There was no intention of combining grazing with forest production throughout the rotation. Mr Grazier also has access to an area which was planted four years previously. He winters his dairy herd on this area which is only 5 km from the area to be planted. Mr Grazier envisaged storing the grass grown on the newly planted area as winter feed and feeding it to the dairy herd whilst grazing the nearby four-year-old plantation.

The owners of the planted areas, Messrs F. O. R. Owner, requested that Mr Grazier make an offer on a per hectare basis for the use of the area to be newly planted. The offer was then to be arrived at by considering the value of the grass utilized together with the cost of handling (i.e., harvesting and feeding out). The unit for determining the grass yield is a kilogram of dry matter.

*Farm Management Consultant, Whakatane.