INSECT INVASION AND SURVIVAL OF DOUGLAS FIR STUMPS IN NEW ZEALAND

P. J. ALMA and R. J. van BOVEN
Forest Research Institute, New Zealand Forest Service, Rotorua

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ABSTRACT

Survival of Douglas fir stumps in thinned stands decreased irregularly until 6 years after felling and then tended to stabilise with about 20% remaining alive. These had produced extensive callus tissue and were presumably sustained by root grafts to living trees.

The most frequently occurring insects in the stumps, **Pachycctes peregrinus** and **Prionoplus reticularis** were the only wood-invading insects found. Insect attack was not found in stumps less than 4 years old, and was most active on stumps 4 - 8 years old. Evidence of insect attack was found in 50.8% of stumps older than 6 years while 29.2% of these were dead but showed no sign of insect damage. Initial insect invasion was limited to sapwood of dead or partly dead stumps which had not previously been colonized by sheets of fungus under the bark.

Platypus apicalis, which is frequently found attacking Douglas fir log stockpiles in thinned stands, was not found in the stumps in this study.

In view of the limitations imposed on insect attack by the survival of stumps, by their apparent resistance to attack when less than 4 years old, and by the unattractiveness to insects of stumps with mycelium under bark, it was concluded that Douglas fir stumps in thinned stands of the type examined are, as a source of insect pests, not a threat to forest operations.

INTRODUCTION

Extensive attack of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) logs by large numbers of *Platypus apicalis* White (Coleoptera: Platypodidae) within days of felling has been recorded in areas of Kaingaroa State Forest (Central Plateau region, North Island, New Zealand) which lacked obvious breeding material such as slash, waste, and windrows. This suggested that stumps left from previous thinning operations could be the source of these insects in Douglas fir stands. In Kaingaroa Forest, also, an apparently increased incidence of live insects in export consignments of logs has resulted in the rejection or fumigation of large quantities of forest produce. New Zealand regulations prohibit the export of forest produce bearing or containing living insects. During 1972-73, 43 067 m^3 of timber (3% of the total logs exported), was rejected or fumigated at the main loading port as a result of insect infestation (Bailey, 1973). The insects involved, which included *Prionoplus reticularis* White (Coleoptera : Cerambycidae), *Hylastes ater*

Paykull, *Pachycotes peregrinus* Chapuis (Coleoptera : Scolytidae) and *Platypus apicalis,* infested the logs at forest skid sites shortly after felling.

Little detailed study has been made of the significance of stumps left after thinning operations in conifer plantations as a source of living insects. Martin (1965), investigating *Pinus resinosa* Ait. stumps in a thinned stand in Ontario, found that stumps kept alive by natural root-grafting to living trees were not attacked by insects, and that attack was usually confined to a small proportion of stumps that died in the first year after thinning. Stumps dying in subsequent years appeared to succumb to fungal attack only. Graham and Bormann (1966) extensively reviewed the phenomena of natural root-grafting and living stumps, and their implication in forest management practices, but did not discuss the importance of living stumps in relation to insect pests.

In order to assess the importance of Douglas fir stumps as a source of potentially harmful insects and to determine the origin of *P. apicalis* attacking log stockpiles, a study was made of stumps in thinned stands of Douglas fir. The observations reported below also provide some information on the longevity and mortality rates of stumps in these stands.

MATERIALS AND METHODS

The study was carried out in 12 Douglas fir compartments in the northern part of Kaingaroa State Forest. They were planted during 1923-28, and different areas had been production thinned at different times over the past 14 years, when the stands were 37-45 years old. These thinning-age classes provided an opportunity to examine insect and fungal attack, and survival of stumps of different ages. All the stands were on similar volcanic ash soil type. Stockings after thinning were 271-497 stems/ha, with a mean, over all the compartments examined, of 390 stems/ha. Mean height of the trees in the compartments was 30.1-36.1 m.

A transect was taken across each part of the compartment within the thinning age class on sites as level as possible, and all the stumps along the line were examined. To avoid margin effects, stumps within 10 m of the compartment edge were not included in this study, as casual observations had indicated that stump mortality was unusually low in such areas. The spacing of stumps allowed transect lines of about 250 m to be followed for 25 stumps. Two transect lines in separate compartments were taken for each age class, giving a total of 50 stumps per age class. Only one thinning area was available for each of the 10-, 12-, and 14-year-old stump classes. Two transect lines in these stands were taken as far apart as possible.

The stumps and large diameter roots at the base of the stumps were dissected by splitting off the bark and sapwood with an axe, and examining each part as it was opened. The stumps were classified as either living, partly living, or dead. This was most readily determined by the condition of the cambium layer, which changes from a pale pinkish colour when alive, to a brownish colour, and then decomposes upon dying. The presence and extent of callus tissue development was also noted.

Where insect attack occurred, the species, location, and extent of attack were recorded. Fungal colonization which showed as white sheets of mycelium under the bark, and which could possibly influence insect attack, was also noted. In most cases the fungus found in this situation was *Armillaria mellea* (Vahl ex Fr.) Kummer. No attempt was made to extract or identify micro-arthropods.

The root systems of two living stumps and adjacent crop trees were excavated and confirmed that root grafts were present between these stumps and standing trees.

RESULTS

The survival of stumps and the incidence of callus, under-bark mycelium, and insects in the different-aged stumps are shown in Table 1.

The proportion of dead stumps increased with age after felling, although considerable variation was found. The percentage of living stumps showing callus formation increased with stump age. All stumps that survived longer than 6 years were callused, which suggested that stumps do not survive unless this ocurs (Fig. 1). Between 10 and 30% (mean 20%) of stumps older than 6 years survived. The callus appeared in young stumps as a ring on top of the cambium. In older stumps the callus had grown over the cut surface and in some cases completely covered it. The incidence of callus was fairly constant throughout the age classes, suggesting that it developed soon after thinning.

No under-bark mycelium was seen in any stump which was alive around a complete circumference. Where the mycelium was noted in dead or partly dead stumps it appeared to have spread from the roots upwards, between the bark and the cambium. This agrees with the observations of Wallace (1953) on fungal attack of *Pinus sylvestris* L. and *P. nigra* Arnold stumps. The presence of this fungal mycelium in partly dead stumps suggested that they were unlikely to survive, and probably represented the initial colonization by the fungus and the death of the stump. The frequency of attack by

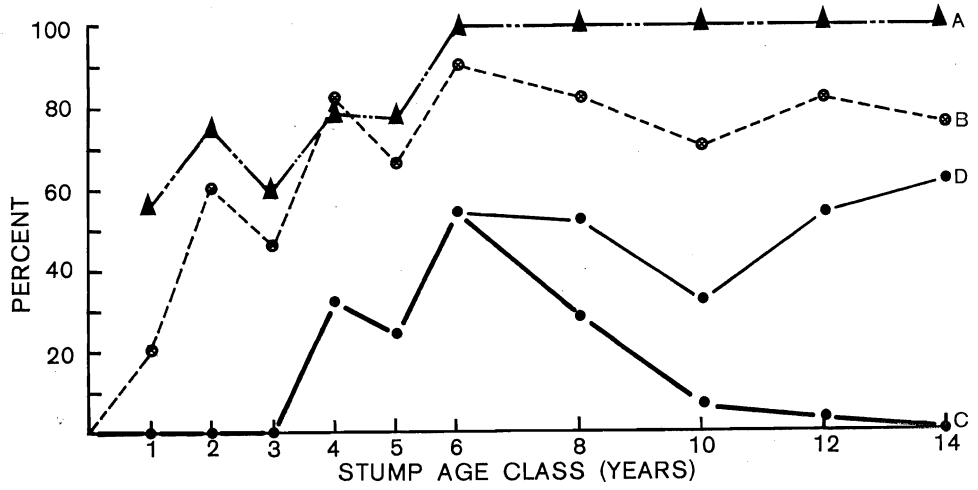

FIG. 1—The percentage, in relation to age class, of living stumps with callus tissue (A), and of total dead stumps (B); together with incidence of living insects in stumps (C) and of total insect attack, including stumps from which insects have emerged (D).

TABLE 1—Stump survival, callus incidence, insect and under-bark fungal attack

Stump Age (years)	Planting year	Mean d.b.h. (cm)	Mean height (cm)	SURVIVAL CLASS			CALLUS INCIDENCE				FUNGAL ATTACK				INSECT ATTACK			
				A	B	C	A	B	C	D	A	B	C	D	A	B	C	D
1	1927	38.8	27.9	80	8	12	55	—	—	44	—	—	—	—	—	—	—	—
2	1927-28	42.7	30.6	40	20	40	75	—	15	36	—	10	35	16	—	—	—	—
3	1927-28	33.0	23.7	54	26	20	59	—	—	32	—	—	40	8	—	—	—	—
4	1928	37.1	21.9	18	58	24	78	17	—	24	—	14	67	24	—	41	33	34
5	1923	35.2	16.7	34	18	48	77	22	—	30	—	—	50	24	—	11	46	24
6	1924-25	40.5	18.8	10	42	48	100	43	—	28	—	43	75	54	—	67	54	54
8	1925	37.9	19.2	18	24	58	100	75	—	36	—	25	45	32	—	58	69	52
10	1923	32.5	18.0	30	14	56	100	71	—	40	—	29	54	34	—	43	46	32
12	1923	33.4	17.6	18	20	62	100	70	—	32	—	30	55	40	—	50	71	54
14	1923	35.9	18.9	24	18	58	100	89	—	40	—	22	41	28	—	100	76	62

Columns give percentage incidence for: A, living stumps; B, partly living stumps; C, dead stumps; D, all stumps.

insects on different age classes is shown in Table 2. The most frequently encountered insects were *Prionoplus reticularis* and *Pachycotes peregrinus,* both of which destroyed considerable quantities of sapwood with their tunnel systems. These were the only wood-invaders found in this study, although a number of other species have been recorded from Douglas fir stumps (e.g., *Platypus apicalis, Anagotus helmsi* Sharp). The apparently lower incidence of *Pachycotes peregrinus* attack in older stumps may have been due to extensive decay rendering the small diameter tunnels unrecognisable. The Formicidae (*Mesoponera castanea* Mayr and *Chelaner antarcticus* White) were found in the bark and decayed wood of dead stumps, the Tipulidae larvae were in decayed wood associated with moss on the stump tops, and the Elateridae were found as larvae in rotten wood. The Elateridae were probably predacious, but little is known of the New Zealand Elateridae and it is not yet possible to identify many of the species from larval stages.

No insect attack was seen in any stump less than 4 years old. The developmental stages of the insects in stumps older than this indicated that it was unlikely that they had been attacked within 3-4 years of thinning, and also suggested that perennial re-invasion is limited. This is corroborated by the failure to find active attack by *Prionoplus reticularis* and *Pachycotes peregrinus* in most of the stumps older than 8 years. As it was not possible to determine when the stumps had died (severance of the trunk not necessarily leading to immediate stump death), it is not known how long after death the stumps were invaded.

Evidence of insect attack was apparent in a fairy constant proportion (32-62%, mean 50.8%) of dead or partly living stumps older than 6 years, the most active insect attack being found in stumps 4-6 years old (Fig. 1). Living stumps of all ages were resistant to attack, which was confined to the sapwood of dead stumps or to dead sectors of partly living ones. Insect attack was absent on stumps where sheets of mycelium were present under the bark, except on some older insect-attacked stumps from which the insects had emerged. In these the fungus appeared to have invaded from the top of the stump, as the sheets became discontinuous lower down.

TABLE 2—Frequency (percent) of attack by different insect taxa

STUMP AGE:	1	2	3	4	5	6	8	10	12	14
Prionoplus reticularis	—	—	—	22	8	24	22 (14)	— (26)	2 (50)	— (58)
Pachycotes peregrinus	—	—	—	10	16	40	4 (14)	— (2)	— (6)	— (8)
Formicidae	—	—	—	4	—	6	2	6	—	—
Elateridae	—	—	—	—	—	10	2	—	—	—
Tipulidae	—	—	—	—	—	6	—	—	—	—

( ) Indicate evidence of early attack where the insects have emerged

No insects were found in the large-diameter roots below ground level. The stump dissections and root excavations indicated that Douglas fir roots in Kaingaroa radiate more or less horizontally from the stump base, normally 10-30 cm below ground level. The largest roots had diameter one quarter that of the stump tops, and provided little additional potential breeding material to the main stump trunks.

DISCUSSION

The rate of mortality of stumps found in this study is similar to that reported for *Pinus strobus* L. by Bormann (1961), who found that 25% of the stumps in one partially cut stand were alive 10 years later. The work of Martin (1965) on *P. resinosa* indicated a much higher level of survival (41% at 7 years), but his alternate row thinning regime may have increased the probability of the stumps being grafted to the remaining trees and thus increased their chance of survival. Although root grafting between stumps occurred in the stands examined, the proportion of stumps grafted to living trees is not known. The relatively high mortality of young stumps may be due to a lack of root grafting onto supporting trees before thinning.

In contrast to *P. resinosa* stumps, which were attacked by insects during only the first year following thinning (Martin, 1965), in this study no insect attack was recorded in stumps of Douglas fir less than 4 years old, and the development stages of the insects on older stumps suggested that they too had not been invaded until about this age. The final proportion of *P. resinosa* stumps attacked by insects was also much lower (about 10%) than in the older Douglas fir stumps (32-62%). The larval tunnel system in all primary insect attack in this study was limited to dead sapwood.

The susceptibility of the stump seemed to depend on the accessibility of the sapwood to insects, via either the bark or the cut surface. The cut surface would appear to be most vulnerable to insect penetration, but the resin exuded soon after felling rapidly formed a hardened layer which may have deterred attack.

No insect attack was recorded in any completely living stump. Live stump tissue appears to present an effective barrier to insects, as would be expected from lack of attack on living trees. This living tissue often extended completely over the cut surface in the form of a callus dome, ensuring permanent protection of the sapwood. Dead portions of partly living stumps, however, were evidently attacked after the cambium layer had died and broken down at the dead sector, although many dead stumps were found which had no insects in them.

Compared with the 5 colonizing xylophagous insects and the further 122 species of macro-arthropods found by Wallace (1953) in his study of *P. sylvestris* and *P. nigra* stumps in thinned and clear-felled areas in England, the fauna of Douglas fir stumps in thinned stands in Kaingaroa was impoverished. This may be due in part to the isolation of Douglas fir in New Zealand from its Northern Hemisphere conifer faunal associations and to the failure of many indigenous insects to invade the new niche from the native gymnosperms (*Phyllocladus, Podocarpus, Dacrydium, Libocedrus* and *Agathis*).

The only apparent factor which inhibited insect invasion of dead or partly dead stumps was the presence of sheets of under-bark fungus. Whether it was the fungus itself or the possible increased rate of decay of the wood associated with this type of fungal attack that deterred insects is not known, but no attack was observed in fungus-

infested stumps which would in all other respects be classed as insect-susceptible. Some of the stumps were well broken down in the earlier-thinned stands. As most of the insects found in the dead stumps were in the sapwood (*Prionoplus reticularis* and *Pachycote peregrinus*) or in already decayed wood (Formicidae, Tipulidae and Elateridae), it is probable that fungi or micro-arthropods were responsible for most of the breakdown of stumps in Douglas fir stands. This must certainly have accounted for the decay of approximately 30% of stumps (the difference between curves B and D, Fig. 1) which were older than 6 years and which showed no sign of insect attack.

Platypus apicalis was seen in two stumps in one of the compartments examined, but its absence from the 500 stumps which fell within the transects in this study indicated that such attack was rare. This was surprising, particularly in view of the attack of this species on recently felled Douglas fir logs in these compartments. This suggests that extensive flights of *P. apicalis* must occur from breeding sites outside these Douglas fir stands, and that Douglas fir stumps and logs differ in their attractiveness to this insect.

The most significant factors limiting insect utilization of Douglas fir stumps were:

1. Living stumps appeared to be as resistant to attack as the healthy tree.
2. Stumps up to 4 years old were not susceptible to insect attack.
3. Insects were apparently not attracted to stumps with sheets of fungal mycelium under the bark.

Considering the natural reduction in available breeding material caused by these factors, Douglas fir stumps in stands thinned at this age do not appear to pose a threat to forest operations as a major source of the insect pests that are at present established in New Zealand.

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