DIADOXUS ERYTHRURUS (WHITE) (COLEOPTERA-BUPRESTIDAE), ATTACK OF FIRE-DAMAGED *CALLITRIS* SPP.

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(Plate xvi.)

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Synopsis.

The Buprestid *Diadoxus erythrurus* (White), the cypress pine jewel beetle, whose larvae feed in the conductive tissues of trunks and branches of *Callitris* spp. and *Cupressus* spp., is recorded as a pest of these species under certain environmental conditions.

Attack by foliage-destroying insects and fire are factors considered to predispose the *Callitris* spp. and *Cupressus* spp. to infestation by *D. erythrurus*, particularly when these predisposing factors are followed by periods of low rainfall.

The biology of *D. erythrurus* and its larval parasites, and the factors contributing to the greater susceptibility of *Cupressus* spp. to attack by *D. erythrurus* are considered.

INTRODUCTION.

Attack on *Callitris* spp. by *D. erythrurus* (White), the cypress pine jewel beetle, was first recorded by von Lendenfeld (1885) when he noted its occurrence in western New South Wales. Since then the bionomics of this insect have been considered by French (1911), Froggatt (1923 and 1927), Pescott (1932), Hadlington (1951), Zeck (1955) and Brimblecombe (1956).

Diadoxus scalaris (L. & G.), a larger species, also occurs in association with *D. erythrurus*. Its coloration and feeding habits are similar to those of *D. erythrurus*, but during investigations on fire damaged cypress pine *D. scalaris* was encountered only rarely, most of the attack being due to the smaller species.

After fires have occurred in the cypress pine areas of New South Wales, timber arriving in Sydney from the burnt forests some months later has consistently shown damage by the jewel beetle. Such timber is considered suitable for normal constructional purposes and there is no danger of the insect infesting other timber, but the emergence holes are large and detract from its commercial value. There is thus a tendency to discard affected timber, or utilize it where appearance is of little concern.

Severe forest fires occurred in the Pilliga National Forest (near Baradine) in November, 1951, and in Euglo and Manna State Forests (near Forbes) in December, 1957. The fire-damaged trees were subsequently attacked by *D. erythrurus* and the observations on these infestations form the basis of this paper.

DISTRIBUTION AND HOSTS.

Froggatt (1923) stated that *D. erythrurus* probably occurs wherever cypress pine grows naturally. The distribution of *D. erythrurus* has apparently been extended on the coast and highlands of New South Wales because of the introduction of *Cupressus* spp. to those areas.

The main hosts are *Callitris hugelii* (Carr.) and *C. endlicheri* (Parl.), and French (1911) and Pescott (1932) have recorded *Cupressus macrocarpa* var. *lambertiana* Gordon, growing near Melbourne, Victoria, as a host. French (1911) collected *D. erythrurus* in an area where no *Callitris* spp. or *Cupressus* spp. occurred and concluded that *Acacia aneura* F. v. M. was a host plant. The fact that the beetles may have emerged from cypress pine brought into the area appears to have been overlooked.

BIOLOGY.

D. erythrurus has been described and figured by Saunders (1868). French (1911) records that the female beetle oviposits in crevices in the bark, but more usually attack is initiated in firescars or other injury.

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The larvae are typical of the Buprestidae, having the thoracic segments dorso-ventrally flattened and much wider than the abdominal segments. The young larvae commence to feed in the phloem and wood-cambium, and later damage the inner bark. They etch the outer surface of the sapwood while feeding and compact their faeces and chewed wood in the channels behind them. When larvae are present in large numbers, or should attack continue during successive years, the phloem and cambium around the circumference of the tree may be destroyed. When fully fed, the larvae which have been feeding in the bark bore into the sapwood to pupate. The entrance to the tunnel is closed with loosely compacted wood and faeces. The beetles emerge from the bark through oval holes measuring approximately ¼ inch across the long axis.

The time taken to complete the life cycle is variable, and is dependent on the time of the year when oviposition occurred. In summer, the period may be as short as three months, while in the case of those insects which over-winter as larvae or pupae the period may be extended to ten months or more under unfavourable conditions. From observations made in the Baradine district on the over-wintering generation, adults emerged during September and October. At least two generations are sometimes possible in one year. The beetles are present from September to April, and larvae may be found beneath the bark of attacked trees at any time during the year. Larvae have been observed in all but the very early instars during June, July and August.

TABLE 1.

Denobolie State Forest. Area burnt 15/11/51.			Euglo State Forest. Area burnt 2/12/57.		
Date.	Rainfall.	Recovery.	Date.	Rainfall.	Recovery.
1951—			1957—		
November	95 points	Nil	December	138 points	Nil
December	73 ,,	Nil	1958—		
1952—			January	217 ,,	Nil
January	39 ,,	Nil	February	126 ,,	Nil
February	312 ,,	Nil	March	421 ,,	Nil
March	434 ,,	Evident	April	99 ,,	Evident
April	146 ,,	Evident			

HOST SUSCEPTIBILITY.

Pescott (1932) states that in Western Australia landholders had been advised not to plant *C. macrocarpa* var. *lambertiana* where *Callitris* spp. had previously grown.

D. erythrurus does not attack living trees of the native *Callitris* spp. unless they have been weakend or injured, and thus predisposed to attack.

The following factors may render a tree liable to infestation:

A. *Injury by Fire*: Forest fires occurred on the Pilliga National Forest in 1951 and on Euglo and Manna State Forests in 1957. *D. erythrurus* adults oviposited in the damaged bark of *C. hugelii.* Where the fire was most intense the cambium and phloem regions around the circumference of the tree were often completely destroyed, producing conditions which were unfavourable to the development of the larvae. In trees which were only slightly burnt and the damage to the phloem and cambium was localized the larvae were able to develop and encroach into the healthy tissue as the damage to the phloem and cambium was localized, while in trees which had been affected on one side only, larvae were able to develop on the edges of the damage. Negligible infestation occurred in the branches and upper portions of the bole since these parts of the tree were unaffected by fire damage. In this way, fire produces favourable conditions within the tree for the development of *D. erythrurus.*

B. *Mechanical Injury*: During normal logging operations, damage to the boles of trees occasionally occurs, rendering the tree susceptible to infestation.

C. *Rainfall*: When investigating the incidence of *D. erythrurus* in the Lachlan River area, von Lendenfeld (1885) indicated a correlation between low rainfall and the abundance of the beetle. He records that in 1883 *Callitris* spp. had taken possession of areas near the Lachlan River, superseding the broad-leaved tree species which had previously constituted the forest. He states that official rainfall data were not available for inland areas for that period, and relates Sydney rainfall to that of the interior, suggesting that the lower rainfall recorded at Sydney indicated an isochrone drought for that area. For the period 1840 to 1863 (Sydney rainfall 48 inches) von Lendenfeld indicates that *D. erythrurus* was not unusually abundant. From 1862–1880 (Sydney rainfall 55 inches) he states that *Callitris* spp. were spreading, and for the period 1880–1884 (Sydney rainfall 40 inches) he observed that *Callitris* spp. were being heavily attacked by *D. erythrurus*. He concluded that periods of low rainfall are favourable to *D. erythrurus*, while periods of high rainfall favour the growth of *Callitris* spp. and reduce the incidence of *D. erythrurus*.

Pescott (1932) suggests that a wet winter followed by a hot summer caused mortalities of *Callitris* spp. in the mallee areas of Victoria. The trees weakened by excessive water were later attacked by *D. erythrurus* which caused their death.

D. *Insects*: *Callitris hugelii* growing at Pennant Hills, a suburb of Sydney, has been attacked by buprestid larvae following defoliation by *Zenarge turneri* Rohwer, the cypress pine sawfly. Trees which had been affected previously by *Z. turneri* on Corringle State Forest, near West Wyalong, were similarly attacked by bark feeding insects. Froggatt (1923) records *Z. turneri* as a pest of cypress pine.

Neochmosis juniperi de Geer,* the cypress pine aphid, at times has occurred in large numbers, and Froggatt (1927) stated that *Callitris* spp. were so severely infested that the foliage of large trees was wilting and turning yellow. Hartigan and Taylor (unpublished report—Forestry Commission of New South Wales, 1949), while investigating a disease of *Callitris* spp. in the Baradine and Grenfell areas, recorded that severe infestation by *N. juniperi* was followed by yellowing of the foliage, general die-back, defoliation and death of the trees. They indicate that *N. juniperi* was a precursor to a sooty mould which developed on the sugary secretion produced by the aphids. The years prior to their investigation had been wet, and they considered that the sooty mould was encouraged by moist weather and aphid infestation. They suggest that the mould growing in the necrotic tissue functioned as a wound parasite. They also found that where a tree had suddenly died after it had shown promise of recovery, *D. erythrurus* was present under the bark, and it appeared that death was due to the destruction of the phloem and cambium by the larvae of this insect.

Mortality Factors.

(*a*) *Parasites and Predators.*

The incidence of parasitism was studied in June, 1952, following the fires of 1951 on the Pilliga National Forest. These studies were confined to observations and rearing of larvae. Most of the parasites were obtained by removing sections of the bark and collecting the larvae and pupae of the parasites. The effect of these parasites was reflected in the small number of *D. erythrurus* larvae actively feeding at the time of the observations. The determinations of the parasites which are located in the collection of the Forestry Commission of New South Wales were made by the Commonwealth Institute of Entomology. These parasites are now discussed:

(1) *Doryctes diadoxi* Nixon (Braconidae): This was the most abundant species, and occurred singly during the early instars, but pupated in cocoons which each contained six to eight larvae. The cocoons were located in the channels of *D. erythrurus* larvae. *D. diadoxi*, which was described by Nixon (1954), appeared to be ectophagous. Thompson (1953) records species of this genus as parasites of the Buprestidae.

(2) *Polymoria* sp. (Eupelmidae): The larvae of this species occurred singly in the various instars. They were probably ectophagous, and may have been either parasitic

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or hyperparasitic on *D. erythrurus*. The females possessed a jumping habit which appeared to be their principal method of locomotion. The pupae were collected singly. Thompson (1954) records a species of this genus to be parasitic on the Buprestidae.

(3) *Metapelma* sp. (Eupelmidae): This larger species occurred in association with *Polymoria* sp. Thompson (1954) records species of this genus to be parasitic on the Buprestidae.

(4) *Megalyra* sp. (Megalyridae) Species A: These larvae occurred singly in the channels of *D. erythrurus*. Rodd (1951) recorded *Megalyra* sp. to be parasitic on the larvae of Coleoptera.

(5) *Megalyra* sp. (Megalyridae) Species B: Collected from the channels of *D. erythrurus*.

(6) *Thaumasura* sp. (Cleonymidae): The larvae of this species occurred singly in the channels of *D. erythrurus*. Thompson (1954) has recorded parasitism of the Curculionidae by species of this genus.

(7) *Pristaulacus* sp. (Evaniidae): This species was collected on the surface of the bark of *C. hugelii*. Thompson (1954) has recorded a species of this genus to be parasitic on the Cerambycidae.

(8) *Cleridae*: Larvae of this family were found active in the channels.

(*b*) *Sandarac Resin.*

Following the fires at Baradine in 1951, observations were made on tree recovery which was evident during 1952 on Pilliga National Forest (Pickaxe and Denobolie sections). During 1958 at Forbes (Euglo South and Manna State Forests) a study was made of the association of *D. erythrurus* with cypress pine damaged by fire in 1957. In all areas many trees were killed by the effect of fire on the cambium and phloem tissues, after which they produced no green foliage. Other trees less affected produced new foliage and appeared to be alive. Some trees in the latter group showed a temporary recovery before dying, while others continued to produce foliage. For some months after the fire it was not possible to determine, by superficial examination, which trees would die, except those which had no functional bark around the circumference of the tree. The recovery of trees followed appreciable rainfall, as shown in Table 1. It was observed also that resin exuded from the bark of many of the trees after such rainfall.

When the bark was removed from trees which had shown temporary recovery and then death, extensive damage by *D. erythrurus* larvae was evident, and in all cases the girdling of the tree was complete. The trees which continued to produce foliage frequently showed evidence of *D. erythrurus* attack, but the larvae were flaccid and translucent, their digestive tract being devoid of food. Dead larvae showed no evidence of parasitism and were generally confined to the area adjacent to the healthy tissue. The compacted faeces in the channels close to the living tissues and at the margins of infestation had been invaded by sandarac resin,* which prevented further encroachment on living tissues by the larvae. This material was not produced in quantity during the early stages of attack and only after appreciable rain was the resin evident along the margins of the attack.

In the Pilliga National Forest the trees commenced to produce foliage during March and April. This recovery was accompanied by the production of resin which was evident as drops on the surface of the bark. Removal of the bark showed the resin to be present in the galleries, although more particularly it had accumulated along the margins of healthy tissues.

The effect of rainfall on the production of sandarac resin by fire-injured *Callitris* spp. was again observed on Euglo State Forest. The rainfall for the period December-

* Commercial sandarac resin is also obtained from the North African species *Tetraclinis articulata* (Vahl) Masters. Mantel *et al.* (1942) give the main constituents as sandaracolic acid and callitrolic acid. Howes (1949) states that there are only minor differences between Australian and North African sandarac. The essential oil of African sandarac contains a diterpene and α pinene, whereas Australian sandarac contains only α pinene.

February was 481 points, during which time there appeared to be little recovery. In March, 421 points were recorded, and this was followed by resin and foliage production. In May, 1958, the sandarac resin was observed to affect the larvae in a similar manner to that previously described.

Sandarac resin has been recorded by Baker and Smith (1910) to exude from the bark of *Callitris* spp. in response to injury.

Bamber (1959—personal communication), during a study of the bark of *C. hugelii*, found that the resin canals were formed within one to four cells of the cambium by proliferation of the parenchyma cells. He determined that the resin of the resin canals was liquid in the phloem and solid in the rhytidome. *D. erythrurus* larvae rupture the cambium, preventing future production of resin canals in the area of damage. Normally the resin canals immediately adjacent to the damaged tissue produce a liquid resin which flows into the larval channels. This flow appears to be greater after substantial rain and is sufficient to exclude the larvae.

In considering the relative susceptibility of *Callitris hugelii*, *C. endlicheri* and *Cupressus macrocarpa* var. *lambertiana* to *D. erythrurus* the alcohol solubles in the bark were estimated after exhaustive extraction with boiling water.* The percentage alcohol soluble content of *C. hugelii* was 8·89, *C. endlicheri* 9·58 and *C. macrocarpa* var. *lambertiana* 5·07. These figures therefore include all the alcohol soluble resin in the barks. In the case of the *Callitris* spp. this resin is sandarac resin, but *Cupressus* sp. do not contain sandarac resin.

Discussion.

D. erythrurus usually requires an injury for the initiation of attack, but unless this injury is accompanied by other conditions such as damage to the crown of the tree or periods of low rainfall the infestation does not necessarily progress. Forest fires frequently damage the crowns of trees as well as injuring the bark, thus producing conditions favourable to the development of *D. erythrurus*. Trees affected in this way are not only suspectible to attack, but are likely to be completely girdled by the jewel beetle larvae particularly if periods of low rainfall occur.

When substantial rains (approximately three inches or more within a month) occur after a fire the tree produces sandarac resin freely and numerous tears are formed on the surface of the outer bark. No quantitative estimations of the alcohol soluble content of the bark prior to and after rain have been made. This information would establish correlation between the activity of the tree and the production of sandarac resin, but entails a prior knowledge of the occurrence of a major forest fire.

When freshly produced, this resin is clear and sticky, and the young larvae may avoid coming into contact with it. It appears that larvae are not able to encroach on the cells actively producing resin.

The introduced species *C. macrocarpa* var. *lambertiana* does not require to be injured before *D. erythrurus* can initiate its attack. Brimblecombe (1956), in referring to the introduced *Cupressus* spp., states that attack four or more years after planting is a common occurrence. Unlike the *Callitris* spp., the introduced species does not appear able to resist the ingress of *D. erythrurus* by the production of resin. The bark of *Cupressus* spp. is not known to contain sandarac resin, although a resin is exuded from the bark after injury. In addition, the alcohol-soluble content of the bark of *C. macrocarpa* var. *lambertiana* is significantly less than that of *C. hugelii* or *C. endlicheri*. Bamber,† when comparing the bark structure of *C. macrocarpa* var. *lambertiana* with that of *C. hugelii* and *C. endlicheri*, found that the resin canal formation was less frequent in *C. macrocarpa* var. *lambertiana*. The fibre layers which are a bark characteristic of the family Cupressaceae are much less abundant in *Cupressus*

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* Bark samples of *C. hugelii* and *C. endlicheri* from six trees of each species from Warraderry State Forest near Forbes on 28th May, 1958. *C. macrocarpa* var. *lambertiana* samples were collected at Sydney during May, 1958. Analyses by F. R. Humphreys, Forestry Commission of N.S.W.

† Personal communication.

macrocarpa var. *lambertiana* than in *Callitris* spp. The walls of the fibres of *Callitris* spp. were also thicker. He also records that the tannin content of the living phloem cells is higher in the two *Callitris* spp. The significance of these various differences is not known, but they should not be overlooked when considering the relative susceptibilities of these species to *D. erythrurus*.

Parasites and predators were abundant immediately after the high rainfall was recorded, but later examinations showed that their numbers had fallen markedly, probably because the *D. erythrurus* larvae had been affected by the resin production. Prior to the channels being invaded by the resin, these biotic factors had reduced the numbers of *D. erythrurus* considerably, and in their absence the progress of attack would have been accelerated. Therefore, parasites and predators would have their greatest effect on the population of *D. erythrurus* during prolonged dry weather and before resin flowed into the channels.

It is doubtful if drought alone causes major changes in the stand composition of the cypress pine forests by predisposing *Callitris* spp. to the attack of the jewel beetle. The changes recorded by von Lendenfeld may have occurred, but the more gradual effect of settlement on stand composition in these areas has not been investigated. There has been a tendency to produce tree-stands composed largely of cypress pine at the expense of the eucalypt species which grow naturally in association with it. This trend is more likely to accentuate attack by insects.

Von Lendenfeld's observations suggest that the trees had been weakened, predisposing them to the attack of *D. erythrurus*. If his rainfall data from Sydney were parallel to that of the interior it is likely that the periods of high rainfall favoured an increase of *N. juniperi*. Attack by this aphid would not be followed by *D. erythrurus* infestation as long as the rainfall remained high and resin was produced abundantly. When the drier periods were experienced *D. erythrurus* possibly became established in the weakened trees, producing the high mortality observed by von Lendenfeld in 1885. The trees weakend by *N. juniperi* would be unlikely to produce resin in sufficient amounts to terminate the infestation of *D. erythrurus*.

Fire damaged trees which have been attacked and subsequently recovered, and have retained an area of functional bark and cambium sufficient for the tree to continue to re-foliage, present problems in the conversion of the log to sawn timber. That section of the bole which has had the conductive tissue destroyed does not produce new wood or bark, and as a result a malformed log results. The main value in leaving such trees is for seed production, as these are often needed after a forest fire, particularly if the tree mortality is high.

After forest fires, or attack by foliage feeding insects, reference to rainfall data should lead to a better understanding of the capacity of cypress pine to recover in particular areas and so assist in the marketing problems which follow.

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References.

Baker, R. T., and Smith, H. G., 1910.—*A Research on the Pines of Australia*. Govt. Printer, Sydney. P. 75.

Brimblecombe, A. R., 1956.—Destructive Wood Borers and their Damage. *Dept. Agric. and Stock, Queensland*, Pam. No. 165. P. 19.

FRENCH, C., 1911.—*Handbook of Destructive Insects of Victoria.* Govt. Printer, Melbourne. Pp. 45-50.
FROGGATT, W. W., 1923.—*Forest Insects of Australia.* Govt. Printer, Sydney. Pp. 159-160.
FROGGATT, W. W., 1927.—*Forest Insects and Timber Borers.* Govt. Printer, Sydney. Pp. 33-36.
HADLINGTON, P., 1951.—The jewel beetles or flat-headed borers. *Tech. Notes N.S.W. For. Comm. Div. Wood Techn.*, 5 (4) : 7.
HOWES, F. N., 1949.—*Vegetable Gums and Resins.* Chronica Botanica Co., Waltham, Mass., U.S.A. P. 137.
LENDENFELD, Baron VON, 1885.—Recent changes in the forest flora of the interior of N.S.W. PROC. LINN. SOC. N.S.W., 10 (4) : 721-722.
MANTEL, C. L., *et al.*, 1942.—*Technology of Natural Resins.* John Wiley & Co., New York, U.S.A. P. 82.
NIXON, G. E. J., 1954.—Two new Braconid parasites of wood-boring Coleoptera (Hymenoptera). *Ann. Mag. Nat. History*, 7 (Ser. 12) : 380-384.
PESCOTT, R. T. M., 1932.—The cypress pine girdler. *Jour. Dept. Agric., Vic.*, 30 (8) : 396-397.
RODD, N. W., 1951.—Some observations on the biology of Stephanidae and Megalyridae (Hymenoptera). *Aust. Zool.*, Vol. II, 11 (4) : 343-346.
SAUNDERS, E., 1868.—A revision of the Australian Buprestidae. *Trans. Ent. Soc. Lond.* (Ser. 4), Pt. 1 : 4, Pl. 1, f. 5.
THOMPSON, W. R., 1953.—*A Catalogue of the Parasites and Predators of Insect Pests*, Section 2, Pt. 2.
THOMPSON, W. R., 1954.—*A Catalogue of the Parasites and Predators of Insect Pests*, Section 2, Pt. 3.
ZECK, E. H., 1955.—Cypress pine Buprestid beetles. *Agric. Gaz. N.S.W.*, 66 (6) : 296.

EXPLANATION OF PLATE XVI.

1.—A stand of fire damaged cypress pine.

2.—An accumulation of sandarac resin at a point of injury.

3.—Channels of *D. erythrurus*. Since the tree from which this bark was removed had been previously ringbarked no resin is to be noticed invading the material in the channels.

4.—A tree which has recovered from attack by *D. erythrurus*. An accumulation of resin may be seen along the front of attack.