

## OBSERVATIONS ON SOME AUSTRALIAN FOREST INSECTS.

8. THE BIOLOGY AND OCCURRENCE OF *GLYCASPIS BAILEYI* MOORE IN NEW SOUTH WALES.

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(Plate ix; seventeen Text-figures.)

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*Synopsis.*

The occurrence of large populations of *Glycaspis baileyi* Moore 1961 on *Eucalyptus saligna* Smith in coastal areas of New South Wales, and the severe debilitation and deaths of trees associated with these infestations, were investigated. The biology of this insect and its association with the affected trees were studied and parasites and predators recorded. Damage to *E. saligna* is described and reports of recent attack are reviewed. Results of trial rearings made on host-plants other than those on which *G. baileyi* normally occurs in the field, and of laboratory experiments to determine possible effects of temperature and relative humidity on embryonic development, are recorded. Some effects of weather, site-favourability of hosts, and other factors apparently influencing population fluctuations of this species, are discussed.

## INTRODUCTION.

Species of the Psyllidae feed on the sap of many species of plants and construct "lerps" or coverings on the surfaces of leaves and twigs, feed openly among the tender growth of new shoots, or form galls in the leaf-tissues. They are known by the common names of "jumping plant lice" or lerp insects. Dobson (1851) states that the word "lerp" was used by some Australian aboriginal tribes to denote the sweet coverings which some psyllid nymphs (probably those of the genus *Glycaspis*) construct over and around themselves from their body-excretions, and which were apparently utilized by the aboriginals as part of their food. The word "psyllid" will be used here to refer to the various stages of the insects of the family Psyllidae, and the word "lerp" used to denote the coverings made by certain species of these insects during their immature stages.

The psyllids previously reported as being of economic significance in New South Wales are *Aconopsylla sterculiae* (Froggatt) (the kurrajong psyllid) and *Protyora sterculiae* (Froggatt) (the kurrajong star psyllid), both of which occur in areas west of the Great Dividing Range; *Cardiaspina artifex* (Schwarz) (the brown lace-lerp) and *C. vittiformis* (Froggatt) (the lace-lerp), the latter severely affecting ironbarks on State Forests, and the former periodically attaining plague proportions on *Eucalyptus* spp. in many areas.

*Glycaspis* spp. have been recorded as breeding on certain species of the genus *Eucalyptus* only, some species of which are apparently unsuitable as hosts. They occur on coppice growth, epicormics, regeneration, or on crown-foliage, and exist under diverse climatic conditions, occurring as limited populations in the drier inland areas where rainfall may be only about 11 inches per annum; or at times as large populations in coastal areas, where an annual rainfall of 90 inches may occur. They are found from sea-level to an altitude of about 4,000 feet.

During 1953 a number of trees of *Eucalyptus* spp. on Ourimbah State Forest No. 290 (Newcastle Forestry District: Wyong Subdistrict) were reported to be dying, and during the years 1956-1960 the cause of these deaths was investigated. Mortalities at first appeared to be the result of persistent attack by *Glycaspis* spp. during a number of years, and although apparently not the direct cause of the deaths, the debilitation due to continual defoliation caused by them was a contributing factor. Weakened trees appeared to induce attack by *Xyleborus truncatus* Er. (Coleoptera: Scolytidae) which

was associated with brown staining in the timber, and deaths of trees (Moore, 1959). A complex of species of the genus *Glycaspis* was studied and many new species described (Moore, 1961).

*E. saligna*, *E. paniculata* J. E. Smith (grey ironbark), *E. triantha* Link. (white mahogany), *E. deanei* Maiden (Deane's gum) and *E. umbra* R. T. Baker (bastard white mahogany) grew intermingled on an attacked area on Ourimbah S.F., and most of the species of *Glycaspis* found there fed and bred only on their respective host-species. From an examination of *Glycaspis* spp. populations some 300 miles further north it was verified that considerable host-specificity occurred. Collections of adults, nymphs and lerps were made in many areas, as the tree-species collectively constituting some of the timber-stands differed considerably from the timber-stand composition on Ourimbah S.F.

The biology of *Glycaspis baileyi* Moore occurring from sea-level to over 3,000 feet in New South Wales was studied.

When investigations were commenced by the writer during 1956, current deaths of trees were apparently confined to *E. saligna*, but large populations of psyllids also persisted on the other tree-species. Variable degrees of attack, from very slight to heavy, with numerous trees apparently killed by constant infestation over many years in the one locality, were occurring in approximately 150 separate areas throughout the Gosford-Wyong district.

The most extensive single area of severe attack, on Ourimbah S.F., extended for about 1½ miles at a more or less constant width of about 9 chains, along the approximate centre of a slope with a general north-easterly aspect, the continuous area of attack crossing many small intersecting gullies and occasionally encroaching on the flats of the open valley where *E. saligna* grew. All of the *Eucalyptus* spp. were attacked by large, discrete populations of psyllids, principally of the genus *Glycaspis*.

The distribution of *E. saligna*, the principal host of *G. baileyi*, is from the south-east corner of Queensland, to Bateman's Bay on the south coast of New South Wales, and it occurs only within 100 miles of the coast, between sea-level and 1,000 feet altitude in the south to about 4,000 feet altitude at the northern extremity of its range (Anon., 1957).

#### DAMAGE.

During the early stages of an incipient large population of *Glycaspis* spp. damage is not readily discernible from the ground. The first indication of psyllid attack may be the presence of bell-birds. Damage is often characteristic of the particular psyllid species concerned.

Foliage of *E. saligna* heavily attacked by *G. baileyi* gradually becomes reddish-purple, and deepens in colour. This coloration is evident from a considerable distance when the attack has persisted for some months, and is most evident during the late winter. Foliage may remain in this condition for some months during the colder months of the year, and during early spring the trees shed most of the affected leaves. New crown foliage or epicormic growth on the trunks and branches may then appear and the trees seem to be recovering. This regrowth may be again heavily attacked, the trees thus being weakened further by recurring attempts to produce new foliage. Trees almost defoliated many times over a number of years are thus conditioned for attack by other insect pests.

A tree of approximately 12" diameter-at-breast-height, with about half of its normal crown-foliage, and attacked by a large population of *G. baileyi*, may carry approximately 15,000 last instar nymphs at the one time.

#### RECENT INFESTATIONS.

(a) Wauchope and Glen Innes Forestry Districts.

The first known official report of *G. baileyi* occurring in large numbers on *E. saligna* was made during 1944 by Mr. F. M. Bailey (Forestry Commission records). Attack occurred beside the Oxley Highway between Yarras and Yarrowitch, on Doyle's River State Forest No. 911 (Wauchope Forestry District) and Enfield S.F. No. 337 (Glen Innes

District). *E. saligna* had been severely attacked in the vicinity of Myrtle Scrub, Tobin's Camp and Stockyard Creek, where the infested areas were at an altitude of about 3,000 ft.

During 1957 and 1958 attack by *G. baileyi* was reported on three small areas on Doyle's River S.F., causing severe defoliation and death of young *E. saligna* trees of 6" to 8" diameter-at-breast-height. *Xyleborus truncatus* was present in all stages of its life-cycle, in association with brown staining of the timber.

(b) Coff's Harbour Forestry District.

During 1949 and 1952 severe infestations of *G. baileyi* occurred on *E. saligna* on Cloud's Creek S.F. No. 111, and on Moonpar S.F. No. 489. The psyllids persisted for many years and the total area affected was assessed as more than 100 acres.

The areas of attack by large numbers of *Glycaspis* spp. were inspected by the writer during May, 1959, and heavy attack persisted on crowns and epicormics of *E. triantha* on Cloud's Creek S.F. *E. dunnii* Maiden (white-gum) was attacked in an area 10 miles north, and *E. saligna* in an area 1 mile north of Cloud's Ck.

(c) Taree Forestry District.

At Craven Plateau Mill Road in the Barrington area during 1952, severe attack by *G. baileyi* had occurred on young regeneration of *E. saligna* for more than three consecutive years.

During 1952, 1953 and 1957, 30 to 40 acres of *E. saligna* were severely attacked on Bulga S.F.

From the inspections of each of the above Districts it was determined that the severity and extent of attack were much less than that occurring in the Newcastle Forestry District at the same time.

(d) Newcastle Forestry District.

The first known report of *G. baileyi* on *E. saligna* in the Gosford-Wyong area was made during 1950 by Mr. P. C. Hely (N.S.W. Dept. of Agriculture records). Large trees and saplings were affected in a manner similar to those in the previously mentioned Forestry Districts, and attack had been apparent during the two previous seasons.

Large numbers of *Glycaspis* spp. were reported on *E. paniculata* on Ourimbah S.F. during 1952 and 1953 when a small percentage of the trees was dying. Beetles of the Scolytidae, particularly the species *Xyleborus pseudoangustatus* Schedl, were associated with the dying and dead trees. By 1954 numerous *E. saligna* and *E. deanei* had died and damage by the psyllids was reported to have been evident for some years. *E. triantha*, *E. umbra*, *E. paniculata*, *E. deanei* and *E. saligna* were all affected during October, 1956.

In all areas of infestation bell-birds occurred in variable numbers.

#### BIOLOGY.

So that biological observations could be made under conditions as near natural as possible, coppice growth and regeneration of *E. saligna* were enclosed in separate cages of mosquito netting (Plate ix, figs 1 and 2), the netting forming the base of each cage being tied around the plant stem. These cages, approximately 3 ft. x 3 ft. x 4 ft., were erected during 1957 in the heavily attacked area on Ourimbah S.F. All adults and nymphs of *G. baileyi* were removed from the cages, leaving only the eggs on the leaves. The netting excluded small parasitic wasps of the Chalcidoidea, and during these observations parasitism of nymphs on foliage of coppice near the cages varied from 23% to 50%. External shade-temperatures during these observations were: highest maximum 65° F., lowest maximum 53° F., and the lowest minimum 38° F.

#### Eggs (Plate ix, figs 3 and 4).

Length 0.41 mm.; width 0.15 mm. Eggs are firmly attached to the leaf-surface by a narrow, curved pedicle, the length of which is 0.10 mm., and their long axes form an angle of about 35° with the leaf-surface. The translucent eggs are at first cream to pale yellow, later deepening in colour, and with a reddish-orange proximal area; the chorion is hard, smooth, shiny and transparent. Oviposition occurs on either the upper or the

lower leaf-surface, the greatest number of eggs usually occurring on the former during the cooler months of the year. They may be found singly, or in groups of from two to about 100. The larger groups, usually oviposited when a female feeds beside the mid-vein of a leaf, are formed of eggs arranged side by side in a line describing an arc, or a complete circle composed of 80 to 100 eggs. This suggests a feeding-site favourability for this species of psyllid, and may be associated with a more copious supply of sap in the larger veins. It appears that the circles of eggs (i.e., up to about 100 eggs) are oviposited by the one female. Eclosion is effected from the distal end of the egg.

The number of eggs occurring on *E. saligna* leaves randomly collected from coppice, and epicormics at a height of 20 ft. and 50 ft. during June, 1958, is: Number of leaves examined, 225; average number of eggs per leaf, 36.8; greatest number on one leaf, 225; on seventeen leaves there were no eggs. There was a large population of psyllids in the area from which the foliage was collected.

The average number of fully formed eggs dissected from 10 females collected in the field on the same day was 37.1, the greatest number from one specimen being 53.

No parasitism, predation or disease of psyllid eggs was observed during these investigations.

#### *Nymphs.*

*G. baileyi* passes through five nymphal instars, each of which may be distinguished by the morphology of the antennae (Text-figs 1 to 5).

Within a few minutes after emergence, the first instar nymph commences to feed, and to construct its lerp. The proboscis is inserted adjacent to main veins, to approximately half of the thickness of a more mature leaf; thus the oil-glands of the leaf are always avoided. Prior to feeding, nymphs may move from the leaf where they have emerged to another leaf usually nearer the growing tip of the branchlet where the younger leaves appear to be preferred.

The dark coloration (Text-fig. 6) on nymphs of all instars is variable, and this, together with the orange coloration, is always more intense on those feeding on the upper leaf-surface.

During the third, fourth and fifth instars, a fine, filamentous excretion, waxy in appearance, issues from the edges of the three posterior abdominal segments. During ecdysis the nymph expands and contracts the abdomen, and arches the thorax so that the exoskeleton fractures longitudinally along the medio-dorsal line. The final instar nymph moves out from under the lerp before ecdysis.

Growth during each instar is more or less continuous and measurements are considered arbitrary. Antennal sensoria are shown in the figures.

First instar: Pale yellow to orange; dark grey marks absent; eyes red. Antennae 3-segmented (Text-fig. 1), pale or dark grey, darker distally; distal seta  $1\frac{1}{2}$  to 2 times length of distal segment.

Second instar: General colour as for first instar; dark marks may be absent, or present as in Text-fig. 6. Antennae 3-segmented (Text-fig. 2); distal seta one-half to two-thirds length of distal segment.

Third instar: General colour as for first instar, with eyes deeper red. Antennae 5-segmented (Text-fig. 3).

Fourth instar (Text-fig. 6): General colour as for the first instar, but eyes darker, sometimes purplish-red; antennae and legs darker. Abdominal segments sometimes suffused grey or red laterally. Antennae 7-segmented (Text-fig. 4).

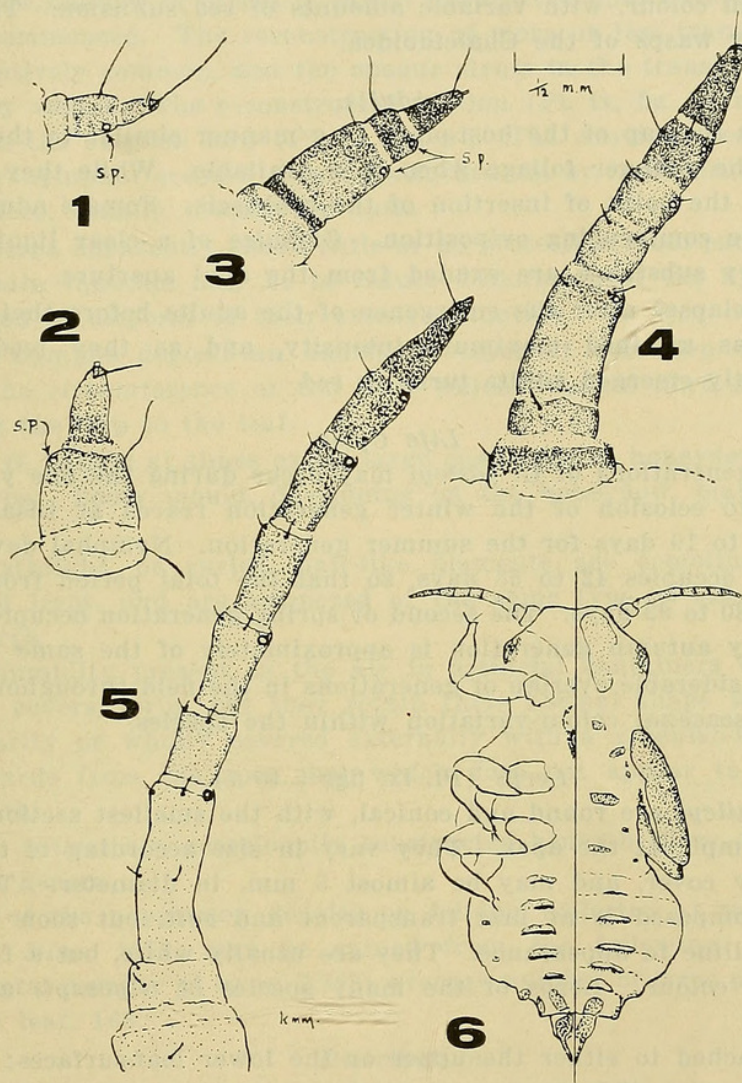
Fifth instar: The colouring of nymphs is variable, denoting an early stage and a late stage in this instar. Antennae 9-segmented (Text-fig. 5); grey to black, darker distally.

#### (a) Early stage: 5th instar.

Head: Yellow to orange with variable amounts of red suffusion; eyes pale violet, pale grey or pale green. Dark, longitudinal marks on head sometimes present, and the head may be suffused red. Some nymphs have a dark grey crescentic mark which may

be suffused red, on each side of median area on posterior border; marks may be joined by a dark line. Wing-pads grey to black.

Thorax and abdomen with dark markings as described for previous instars, but generally indistinct because of surrounding grey to black suffusion. Broad, longitudinal median stripe on thorax, yellowish. Abdominal segments suffused grey to black laterally; yellow to orange median area, narrowing on each segment posteriorly to distal extremity of abdomen.



Text-figures 1-6. 1, Antenna of first instar nymph of *Glycaspis baileyi*. 2, Antenna of second instar nymph of *Glycaspis baileyi*. 3, Antenna of third instar nymph of *Glycaspis baileyi*. 4, Antenna of fourth instar nymph of *Glycaspis baileyi*. 5, Antenna of fifth instar nymph of *Glycaspis baileyi* (sp., sensory pit). 6, Penultimate instar nymph of *G. baileyi*: left, ventral aspect; right, dorsal aspect.

Ventral: Head pale yellow or cream, with anterior border darker; thorax and wing-pads pale grey; abdomen pale grey or suffused pale turquoise-blue; abdominal segments with a series of dark lines and lateral spots; lateral areas may be suffused grey; legs grey, darker distally.

(b) Late stage: 5th instar.

Colouring of head as for early stage, but dark longitudinal marks may be absent; eyes grey, green, violet or suffused with red.

Dark markings on thorax and abdomen paler, and thorax suffused with pale to deep greenish-yellow; red area each side of broad, yellow to green, median longitudinal stripe.

Abdomen: First segment yellow, orange, greenish-yellow or green, with variable amounts of red suffusion; median area, yellow or orange, sometimes turquoise or green laterally, with contiguous longitudinal areas red suffused grey, and with yellow or orange median area of variable widths, narrowing posteriorly, on abdominal segments 2 to 6; dark lines on posterior edges of segments.

Ventral: Pale to bright turquoise; dark markings as for second instar, with lateral greyish suffusion.

Some specimens show little or no darkening during this or earlier instars, remaining yellow to orange in colour, with variable amounts of red suffusion. This is associated with parasitism by wasps of the Chalcidoidea.

#### *Adults.*

Adults feed on the sap of the host-plant in a manner similar to the nymphs. They appear to prefer the younger foliage when it is available. While they feed, they move in a circle around the point of insertion of the proboscis. Female adults may feed for several days before commencing oviposition. Globules of a clear liquid coated with a fine, white powdery substance are exuded from the anal aperture.

A short time elapses after the emergence of the adults before their complement of dark colouring has attained maximum intensity, and as they feed, the turquoise colouring of recently emerged adults turns to red.

#### *Life Cycle.*

Six or seven generations of *G. baileyi* may occur during the one year. The period from oviposition to eclosion of the winter generation reared at Lisarow is 32 to 40 days, and about 8 to 10 days for the summer generation. Nymphal development of the winter generation occupies 42 to 53 days, so that the total period from oviposition to the adult stage is 80 to 93 days. The second or spring generation occupies about 53 to 63 days and the early autumn generation is approximately of the same duration.

There is a considerable overlap of generations in the field throughout the year, with no evidence of a seasonal colour-variation within the species.

#### *Lerps* (Pl. ix, figs 5 to 7).

Lerps of *G. baileyi* are round and conical, with the smallest section constructed by the first instar nymph, at the apex. They vary in size according to the instar of the nymph which they cover, and may be almost 5 mm. in diameter. The exudation of which they are composed is at first transparent and soft, but soon becomes opaque, harder, and crystalline in appearance. They are usually white, but a few may be grey, brown or pink in colour. Lerps of the many species of *Glycaspis* are known to be sweet to the taste.

Lerps are attached to either the upper or the lower leaf-surfaces; they are rarely contiguous, usually more than 1 mm. apart when nymphs are in the last instar. When rearing *G. baileyi* on *E. camaldulensis* some third instar nymphs constructed their lerps on young stems of the plant. This does not occur on *E. saligna*.

The method of construction of a lerp is variable. A nymph, with its proboscis inserted for feeding, exudes from the posterior abdominal segment a colourless, transparent, sticky fluid which adheres to the leaf-surface. On contact with the atmosphere the exudation appears to solidify partially, thus allowing the nymph to construct narrow ribs upward and over itself as the abdomen is raised with short, quick rubbing movements, backward and forward along and beyond these ribs. The number of supports may vary from five to fifteen, and when the lerps are partly constructed with the supports joined more or less at the apex, the sides are filled in as the nymph attaches an almost continuous stream of exudation from one rib to the other, and to the base of the lerp.

After each nymphal ecdysis additions are made to the wall of the lerp, increasing its height and diameter. The additional excretion is first attached to the internal surface of the existing lerp, close to the base. A ledge, represented by the previous area of attachment to the leaf-surface, projects beyond the new portion until this is eventually

produced to a greater diameter than the ledge, as it is forced upward. The relevant portions constructed by the various nymphal instars are distinguished by ridges around the outer surface of the lerp.

Loosening of the lerp may be caused by humid or showery weather, heavy dews, birds, the rubbing together of the leaves, larvae of syrphid predators, or when there is copious excretion by the nymph. Large numbers of lerp covering late-instar nymphs, when detached from the foliage, almost cover the ground beneath trees carrying a large population. After a lerp is displaced, and another is being constructed by a late-instar nymph, a variable number of struts is raised toward the apex before the circumference of the base is commenced. The reconstruction of more or less transparent, thin-walled lerp is comparatively common, and the opaque struts in the translucent or transparent walls are readily visible. The reconstructed portion (Pl. ix, fig. 7) is dome-shaped, and not conical as is the original lerp (Pl. ix, fig. 6). The exuviae shed at the completion of the first four nymphal ecdyses may be attached to, or incorporated in, the internal surface of the lerp, usually toward the apex.

When dry, lerp apparently afford little or no protection from parasites or predators, so that their main function may be to reduce desiccation of the nymphs, or act as a fortuitous method of disposal of their excess exudation.

Parasitized nymphs deposit an additional layer of excretion on the leaf-surface, inwards from the circumference of the lerp, which becomes hard and dry, thus more firmly attaching the lerp to the leaf.

Nymphs of *G. baileyi* at times exude large quantities of honeydew which flows from beneath the lerp. Sooty mould, developing on the honeydew, may cover the surface of the foliage.

Numerous straight, or curled, hair-like filaments are sometimes present on the outer surface of lerp, and are composed of the same type of exudation as that constituting the lerp.

Excessive humidity present in the air in artificial containers or in the field condenses on, and covers, lerp, but they retain their normal shape when drying. They may become partly or wholly covered externally with a greenish-black fungus which spreads downwards from the apex, but which does not appear to affect the nymphs adversely beneath.

Lerp of *G. baileyi* are occasionally constructed beneath those of species belonging to other psyllid genera.

Some idea of the population density on foliage, collected at random from various heights during June, 1958, may be gained from the following: Number of leaves inspected, 50; total number of lerp, 2,807; average number of lerp per leaf, 56; greatest number on one leaf, 166.

#### *Distribution.*

The known distribution of *G. baileyi* in New South Wales is: Cloud's Creek State Forest; Moonpar S.F.; Doyle's River S.F.; Bulga S.F.; Wyong S.F.; Ourimbah S.F.; and in more than 150 separate localities in the Gosford-Wyong area generally.

*G. baileyi* probably occurs wherever its host-plants are distributed naturally.

#### *Dispersal.*

Populations of *G. baileyi* generally showed a relatively sudden increase in numbers during March-April, increasing to plague proportions during the winter months and persisting in large numbers to September, October or even to January, depending on the weather conditions. The population then usually decreased and remained in low numbers until the following March or April, although, again, weather conditions influenced variations in this generalized pattern of fluctuations in numbers.

Adults of the genus *Glycaspis* are capable only of limited flight. After the initial jump from a leaf they have not been observed to fly beyond about 10 feet in still air.

During five years of observations on one valley at Lisarow where *G. baileyi* periodically occurred in plague numbers, the rate of movement was recorded. The centre of infestation proceeded about 1,000 yards in an easterly direction along the slope, thus

representing an average annual lineal dispersal of 200 yards during that time. The original area of infestation was then apparently free from attack, numerous trees of *E. saligna* had died, and regeneration appeared to be vigorous and healthy. During the fifth year (1958-1959) the extension of attack equalled that of the previous four years. Such movement did not occur in all areas, for some populations observed during those same years remained static.

Dispersal of large numbers of some small insects over great distances by air-currents occurs, and adults of this species may be carried from one locality to another by this means, although they are not readily detached from the leaves when feeding.

#### *Parasites and Hyperparasites.*

In the nymphal stages *Glycaspis baileyi* is attacked by a complex of species of the Chalcidoidea during all months of the year.

After consuming the contents of the nymphal skins the larvae of the parasites and hyperparasites pupate within them, the adults later emerging by cutting a round hole with their mandibles through the skin and the lerp, close to the leaf-surface.

The early stage of parasitism of psyllid nymphs by chalcidoid wasps may be determined from the swelling of the thoracic region, and later by distension of the abdomen. Oviposition by parasites and hyperparasites occurs through the lerp, and penetration by the ovipositor of a single wasp may occur several times, and in different places, through the one lerp.

Adult wasps of most species reared usually emerged in about 6 to 10 days after pupation during summer, or about 15 to 20 days during winter. Lerp covering nymphs showing a late stage of parasitism are more firmly attached to the leaf-surface than lerp covering unparasitized nymphs. Parasitism of first instar nymphs was not observed.

Small, black chalcid eggs were often found in nymphs. The black eggs, from which an attached "stalk" protrudes through the integument of the nymph, were found inserted in the ventral area of the abdominal segments, in and beneath the wing-pads, below the thorax, in the legs, eyes or other parts of the head, ventrally or laterally. As many as four black eggs were found in the one nymph, and psyllids of other genera occurring with *G. baileyi* were also attacked. Larvae of wasp-parasites in the skins of psyllid nymphs also contained these black eggs and it was assumed that they had been attacked by hyperparasites. Black eggs have been found in nymphs of instars 3 to 5. When parasitized, a psyllid nymph is gradually immobilized, becomes swollen by the parasite larva within, and is ventrally attached firmly to the leaf-surface.

For assessments of parasitism and hyperparasitism, nymphs of penultimate and last instars only were utilized. They were collected each month from the same area of heavy attack at Lisarow. After selection of a tree of *E. saligna* with a diameter-at-breast-height of no more than 15", it was felled, and large twigs with foliage attached were removed from different areas of the crown, and epicormics when present, from the branches and varying areas of the stem.

As much material as possible was carried to the laboratory where leaves bearing the largest lerp were randomly taken and placed in a large container. From this container leaves were taken at random and all nymphs of instars 4 and 5 assessed as being parasitized or not parasitized. No more than 200 nymphs were examined at any one assessment and, when possible, at least 100 nymphs were examined at each assessment. When the population in the field was low, as many as five trees were felled to obtain a sufficient number of nymphs for an assessment. Results are expressed as percentage parasitism in the graph showing the association of high parasitism with drier weather conditions (Text-fig. 17).

In the attacked area on Ourimbah S.F., certain chalcid species were found to attack *G. baileyi* consistently, but not the species of *Glycaspis* which occurred on *E. triantha*, although these host-tree species grew intermingled. Some of the Chalcidoidea reared from *G. baileyi* from Cloud's Creek, Moonpar and Bulga S.F.s appear to be other species than those reared from *G. baileyi* collected in the Gosford-Wyong area.

It was not possible to obtain identifications of these parasites and hyperparasites, and as a basis for reference, figures of the antennae of those occurring on *E. saligna* are given. The reference-letters are attached to specimens in the collection of the Forestry Commission.

From nymphs on *E. saligna*: From Cloud's Creek and Moonpar S.Fs. (highlands): C, D<sup>1</sup>, G, J<sup>1</sup>. From Gosford-Wyong area (coastal): A, B, C, D<sup>1</sup>, F<sup>2</sup>, G, H, J<sup>1</sup>, J<sup>2</sup>, M<sup>1</sup>, P, R, T, W.

From nymphs on *E. triantha*: From Cloud's Ck. S.F.: D, E, F<sup>1</sup>, F<sup>2</sup>, H, J, J<sup>1</sup>, K, M, M<sup>1</sup>. From Gosford-Wyong area: D, E, F<sup>1</sup>, F<sup>2</sup>, H, M, M<sup>1</sup>.

Those bred from a common host-plant association in both areas may thus be summarized as: From *E. saligna*: C, D<sup>1</sup>, G, J<sup>1</sup>. From *E. triantha*: D, E, F<sup>1</sup>, F<sup>2</sup>, H, M, M<sup>1</sup>; and those bred from both hosts in a common area as: Cloud's Ck. S.F.: J<sup>1</sup>. Gosford-Wyong area: F<sup>2</sup>, H, M<sup>1</sup>.

Specific host-association is thus indicated by the following chalcids occurring only on: *E. saligna*: A, B, C, D<sup>1</sup>, G, P, R, T, W; *E. triantha*: D, E, F<sup>1</sup>, J, K, M.

#### *Some Details of Parasites and Hyperparasites.*

Species (A). Hyperparasite (?). These adults are the smallest of the species reared from *G. baileyi*, and are approximately 0.88 mm. to 1.07 mm. in length, the female being slightly larger than the male. They are black, indistinctly suffused dull green or purplish, with the frons metallic-green. The scape of the antenna of the male is mainly yellowish-brown and that of the female is black. Antennae are creamy-brown, moderately hairy on the male, but less so on the female (Text-fig. 7).

Species (B). Parasite (?). Adults suffused metallic-green or -blue. They have been bred from last instar psyllid nymphs. The broad antennal scape is cream, the small proximal segment with a black mark (Text-fig. 8), and remaining segments suffused pale brown. It has been reared only from the Gosford-Wyong area.

Species (C). Parasite (?). This species is suffused purplish-black with frons metallic-green. Antennal scape mainly yellow, grey distally; proximal antennal segment marked with black, other segments suffused pale brown (Text-fig. 9).

Species (D<sup>1</sup>). Parasite (?). Metallic-green. Antennae similar to (C).

Species (G). Parasite (?). Dull purplish-black, with frons metallic-green. Scape of antenna yellow; other antennal segments pale brown (Text-fig. 10).

Species (H). Hyperparasite. Metallic-green with antennal scape bordered black ventrally (Text-fig. 11).

Species (J<sup>1</sup>). Hyperparasite. Adults black, with frons and ventral area dull purple or green. Antennal scape and antennae shiny black (Text-fig. 12). This species appears to be the female of J<sup>2</sup>. They have also been reared from the species of *Glycaspis* occurring on *E. cameroni* Blakely & McKie (diehard stringybark).

Species (J<sup>2</sup>). Hyperparasite. Adults as J<sup>1</sup>, but with antennae hairy.

Species (M<sup>1</sup>). Hyperparasite (?). Adults black, with scutellum faintly suffused green. Antennae similar to J<sup>1</sup>, but less hairy. Antennal scape black; proximal segment black, remainder dark brown.

Species (P). Dull bronze-green with frons bright metallic-green. Antennal scape black at distal two-thirds on internal face and on posterior edge, yellow on external face (Text-fig. 13).

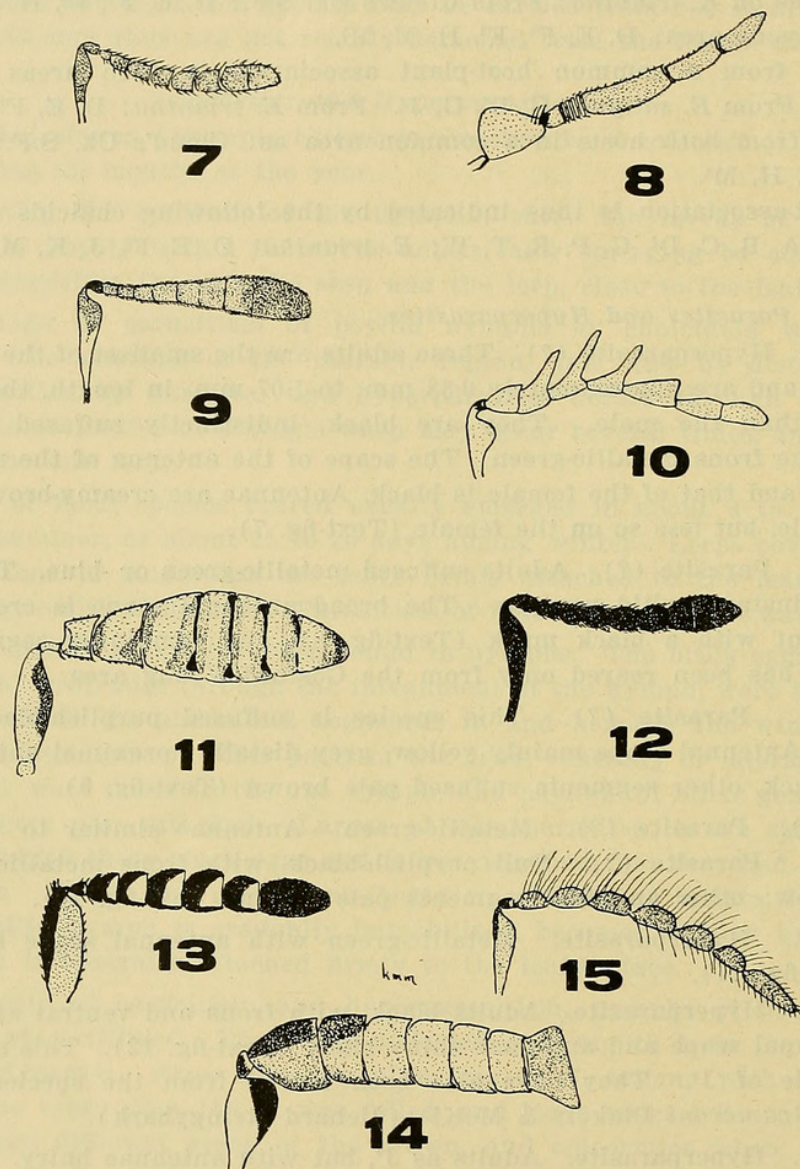
Species (R). Parasite. Bright metallic-green, bronze-green or metallic-blue-green. Antennal scape black, sometimes suffused brown or cream distally; shape similar to (C); segments grey-brown, with the club darkest.

Species (T). Hyperparasite. Metallic-green. Broad antennal scape yellow, marked with black ventrally; antennal segments brownish-yellow to grey, small basal segment and following two or more segments marked with black dorsally; apical segment truncate (Text-fig. 14).

Species (W). Bright metallic-green. Antennal scape cream, tipped black distally; antennal joints hairy (Text-fig. 15).

*Predators.**Syrphidae.*

Many larvae of *Syrphus viridiceps* Macq. (Diptera: Syrphidae), predatory on nymphs of *G. baileyi*, were reared to the adult stage. Their life cycle occupies about 11 weeks during winter, 5 weeks during spring and 4 weeks during summer. The opaque, white eggs, approximately 0.88 mm. in length, and with flattened tubercles on the chorion, are laid on the leaf-surfaces, usually near large groups of lerps.



Text-figures 7-15. Antennae of parasites (Chalcidoidea): 7, Species A. 8, Species B. 9, Species C. 10, Species G. 11, Species H. 12, Species J<sup>1</sup>. 13, Species P. 14, Species T. 15, Species W.

Fully grown larvae may be 8 mm. to 10 mm. in length and are variable in colour from pale yellow in the early instars to yellow, yellow and orange, orange, orange and green, green, green and grey or black, and various combinations of some or all of these colours. Larvae are mottled with variable amounts of grey or black.

The puparia, about 6 mm. in length, are at first light brown with wavy, light grey lateral markings and medio-dorsal spots, which darken to almost black.

During 1957 a larva of *S. viridiceps* destroyed 67 penultimate and last instar nymphs of *G. baileyi* during its larval life of about 15 days. The adult syrphid emerged ten days after pupation.

Occurrence of the various stages of *S. viridiceps* during these investigations were: Eggs: April to July, September, November to January; Larvae: April to January, and most numerous during June and July.

*S. viridiceps* was abundant during most of the year when psyllid nymphs were plentiful, and usually absent from about January to March when psyllids were few in number.

#### *Hemerobiidae.*

A larva of the brown lace-wing, *Drepanacra* sp., attacking nymphs during July, 1957, pupated by 23 August, the adult insect emerging on 1 September, 1957.

#### *Chrysopidae.*

Larvae of the green lace-wing, *Notochrysa ramburi* Schneider, are predatory on nymphs of *G. baileyi*. Larvae place pieces of lerp, sooty mould, skins of destroyed psyllid nymphs and other debris on their backs. When about to pupate, they spin thin, silken cocoons to which they attach externally the debris and cast skins. Two larvae pupated during November, and adults emerged two weeks later.

#### *Coccinellidae.*

Larvae of *Rhizobius evansi* Mulsant were reared during November and April. Adults emerged about six weeks after pupation during autumn.

Adults of the black, yellow-banded larvae of *Leis conformis* (Boisd.), predatory on *Glycaspis* spp., were also reared.

#### *Acarina.*

The red mites, *Erythraeus urbrae* Womersley (Erythraeidae), were numerous during the winter and spring of 1958, principally on adults of *G. baileyi*, but they did not appear to affect either adults or nymphs adversely. They were usually found attached to the abdominal intersegmental membranes, or sutures of the head and thorax. Nymphs beneath lerp were also attacked.

#### *Arachnida.*

Numerous spiders, in leaves which they had curled and spun together with their webs, were predatory on the psyllids. Their webs covered groups of lerp, so that when psyllid adults emerged, some became entangled in the web. Species were identified as *Theridion pyramidale* L. Koch (Theridiidae), *Deliochus zelivira* (Keyserling) and *Arcys clavatus* Keys. *Diaea* sp. is predatory on *D. zelivira*.

During April and May, 1958, practically the entire crowns of trees showing severe damage by *G. baileyi* were shiny with the webbing of *T. pyramidale*.

#### *Birds.*

*Manorina melanophrys* Latham (the bell-bird) was present wherever *Glycaspis* spp. were most numerous throughout the coastal and highland areas of N.S.W. This bird belongs to the family of honey-eaters, and appears to prefer lerp of *Glycaspis* spp. although it is also insectivorous (Campbell and Moore, 1956).

From general observations covering the period of investigations, the population of bell-birds in each area studied did not noticeably fluctuate, irrespective of the considerable fluctuations in psyllid population.

### EXPERIMENTAL WORK.

#### *Effects of Various Temperatures and Humidities on Emergences of Nymphs.*

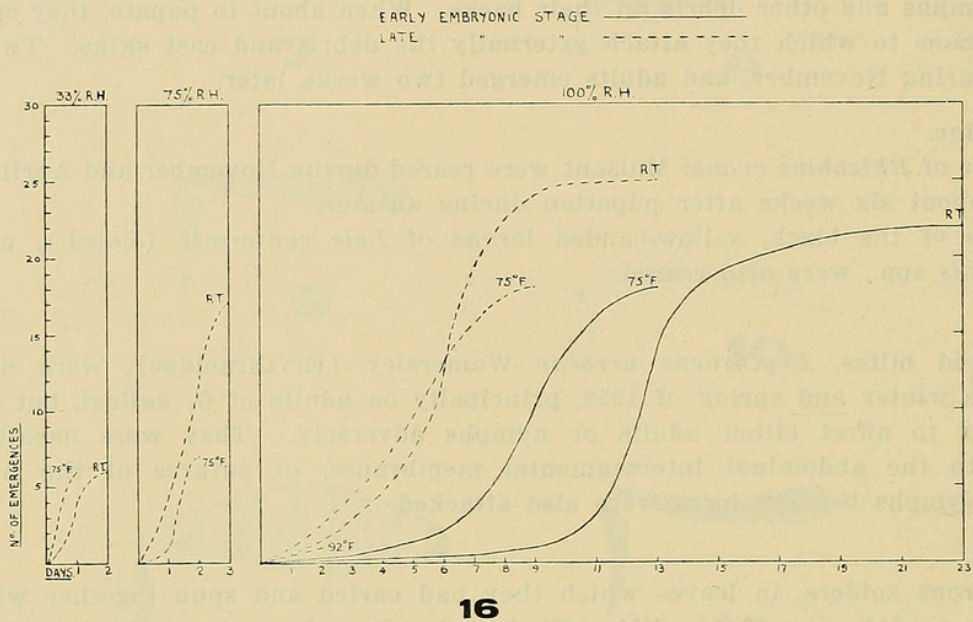
The embryonic development in eggs was regarded as of two stages, the early stage considered as terminating when the eyes of the future nymph occurred near the distal end of the egg, approximately 15 to 20 days after oviposition in the winter generation, or 5 days in the late spring generation. The late stage was considered to occupy the remainder of the time to eclosion of the nymph and was represented by a period of from 17 to 20 days during winter, or about 3 days during November-December.

A total of 360 eggs of the winter generation, in half of which the embryos were in the early stage, were selected at random from the one tree of *E. saligna* in the severely attacked area on Ourimbah S.F. The two stages of embryonic development were separated, and portions of leaves with 30 eggs attached were placed in open Petri dishes. Six dishes each containing eggs in the early stage, and six in the late stage were used

in various combinations of temperature and relative humidity. Eggs were examined on the fifth day. A longitudinal indentation in the ventral surface of the chorion was interpreted as indicating desiccation of the egg-contents.

Because of the large number of eggs desiccated by the fifth day, a further experiment was carried out, with the same procedure and treatment as previously, with additional treatments at 100% r.h. for each temperature. Desiccation accounted for 99% of the mortalities.

Results indicate that the most favourable conditions for embryonic development and emergence of the nymphs were obtained with a combination of the higher r.h. and lower temperatures.



16

Text-figure 16. Emergences of nymphs of *G. baileyi* from eggs held at various temperatures and humidities.

#### Rearing of Nymphs.

In an attempt to determine whether *G. baileyi* could survive on alternative host-species, cages were erected at Lisarow, over coppice about 3 feet in height, of *E. triantha*, *Angophora floribunda* (Sm.) Sweet (rough-barked apple) and young trees of *E. camaldulensis* Dehn. (Murray River red-gum). Five hundred eggs of *G. baileyi* were placed on the foliage of each of two bushes of each of these species. The nymphs apparently could not survive on the two former species, although they attempted to feed on their foliage. This experiment was repeated three times on *E. triantha*, with the same results.

Twenty early instar nymphs covered by their lerps were observed on the *E. camaldulensis*, and six were reared to the adult stage. A further attempt to rear *G. baileyi* on this host-plant was made, and although numerous first instar nymphs were observed to construct lerps, only 40 specimens survived to the adult stage from approximately 800 eggs placed on the plant. Again, about 500 eggs were placed on the same plant, and 48 adults and 11 last instar nymphs were reared.

Blakely (1955) places *E. camaldulensis* in Series 15 (Exsertae) and, as far as is known, the natural ranges of *E. saligna* and *E. camaldulensis* are not contiguous, nor do they overlap at any point.

Some hundreds of nymphs of the species occurring on *E. paniculata* in the attacked area on Ourimbah S.F. were placed on *E. saligna*, but no adults were reared, although most nymphs had transferred to the *E. saligna* coppice as the branches and leaves of *E. paniculata* became desiccated. Large populations of *G. baileyi* were present in all infested areas during these rearing experiments.

Results of these experimental rearings assisted in determining a degree of host-specificity (Moore, 1961).

## DISCUSSION.

Information was sought from property-owners, timber cutters, bush-workers and the older residents able to assist with details of the occurrence and movements of bell-birds, or other relevant observations on the areas examined. Such information concerning felling and logging operations, with the consequent opening up of the undergrowth and thinning of the timber-stand, and occurrence of fires, etc., could not be correlated consistently with the increases or decreases in large psyllid populations.

Apparently reliable verbal reports by residents of some of the areas for 30 to 40 years indicated that populations of psyllids and bell-birds have persisted in certain localities on the poor-quality *E. saligna* along the creeks and watercourses of the more open valleys in the Matcham and Holgate areas for more than 50 years.

*Possible Causes of Incidence of Attack.*

Many areas where no plague population had been observed over a period of eight years previously, and where bell-birds were not then occurring, carried a large psyllid population during the years 1948 to 1959. Thus trees previously not carrying a large population of psyllids had apparently become suitable hosts during these years.

Plagues occurred on slopes of all aspects and with variable degrees of timber- or undergrowth-cover, in very sheltered situations, or in those open to strong, cold south-westerly winds or hot north-westerly winds, typical of winter or summer conditions respectively, occurring on the central coast of New South Wales. In some gullies, *E. saligna* on one of the slopes was sometimes attacked, while little or no attack occurred on the opposite slope. *E. saligna* of diverse ages and heights was plentiful in many gullies where no attack occurred. No consistent correlation of incidence of attack with age, aspect, or apparent general health of trees could be made.

Because of the general increases and decreases over many years in the populations of all the different species of *Glycaspis* found in the same locality at the one time and occurring on various host-tree species, it appears that some local influence common to all these psyllid species has acted as one of the predominating factors affecting their population numbers.

At times, but not consistently, incidence of new foliage on *E. saligna* appeared to be associated with an increase in population, and when available, new foliage appeared to be favoured for oviposition.

Should there be a feeding-site favourability on the leaves for adults to oviposit a maximum number of eggs, and an association with a stronger sap-flow, then a reduced flow of sap during drier years may be expected to influence the occurrence of large populations.

The regrowth of *E. saligna* on all of the areas investigated may be classed as relatively immature in comparison with that which occurred in those areas when undisturbed for long periods, as was probably the case prior to settlement by white people. Timber on these areas has been cut over many times, so that virgin stands are found only in the less accessible areas. Because of the intensified disturbances to the general equilibrium of the *Eucalyptus* spp. and other flora, which was presumably more or less stabilized over the preceding centuries, it appears that certain of these tree-species have regenerated in unfavourable situations for which previously they could not compete. Their present distribution may thus tend to induce attack on the species in less favourable situations, and so exert an important influence on the persistent large populations of *Glycaspis* spp. This appears to be paralleled in many localities in the Gosford-Wyong area where attack by longicorns (Coleoptera: Cerambycidae) is often more concentrated in *E. saligna* now occurring on or near the tops of ridges, where this species does not appear to flourish, but where the slower-growing and naturally occurring species such as *E. triantha* have been suppressed.

The only constant factor correlated with the large populations of the various *Glycaspis* spp. throughout the Gosford-Wyong area was that they were not in large numbers on the tops of ridges, even though their host-trees, occurring as a mixed stand, persisted to the ridges above the areas of attack. In many instances there was a

definite demarcation of the upper limit or lateral dispersal of heavy attack, which did not extend to the limits of host-distribution. This was sometimes denoted by the presence of a road, an abrupt rock-face, or a steep incline, beyond which the psyllids did not persist in large numbers. This suggests a definite local condition affecting the incidence of plagues, such as a soil-drainage effect unfavourable to the trees during seasons of high rainfall. To investigate this aspect, a 2½" soil-auger was used to a depth of 6' 4" to examine occurrence and distribution of the various soil-types in attacked and adjoining areas. Although information from these investigations was inconclusive, it was found that the attacked areas examined were situated in areas of shallow top-soil (11" to 18") over deep, heavy clay, the consistency of the various clay layers varying considerably.

An association of the fungus *Armillaria mellea* (Vahl.) Quel. with *E. saligna* was noticed during November, 1959. Although the tree had recently died and the dead leaves were retained on the crown, no apparent cause of mortality apart from the fungal attack could be found. This fungus, also recorded from several other *Eucalyptus* spp., may be involved in the deaths of *E. saligna* in areas of large psyllid populations.

The discrete populations of *Glycaspis* spp. which occurred on *E. triantha*, *E. umbra*, *E. deanei*, *E. saligna* and *E. paniculata* on the one area at the same time, fluctuated considerably in relation to each other.

#### *Some Influences Exerted by Weather.*

De Bach (1958) presents evidence of the natural control of insect populations by weather-influences, and it appears that the general weather conditions have exerted considerable influence on the *Glycaspis* spp. populations in the areas studied. During seasons approaching the normal in New South Wales, the paths of anti-cyclones bringing drier air with consequent heavy frosts in winter, and higher temperatures with lower relative humidities in summer, is from west to east across the approximate centre of the State.

For about 15 years prior to 1957 the cyclonic centres had gradually moved in a southerly direction, and conditions of moist air with above-average rainfall and relative humidity had increased to a maximum during 1949-1950, when more than 86 inches of rain was recorded for each of these years. From 1942 a cycle of 15 years of comparatively higher rainfall occurred.

During the 6-year period 1917 to 1923 the yearly average rainfall exceeded the mean average for all recorded years on only one occasion, the same situation recurring during the 6-year period 1935 to 1941. These years may be considered as comparatively dry.

During the ten-year period 1924 to 1934 the mean was exceeded on all but two of these years, and for the 15-year period 1942 to 1957 the mean was exceeded on all but three occasions. The average annual precipitation for the latter period exceeded that of any of the other periods. These periods may be considered as years of comparatively high rainfall.

Records of the occurrence of *G. baileyi* prior to 1944 on the north coast, or prior to 1948 in the Gosford area, are not available. Lack of records thus limits the possibility of an accurate estimate of previous plagues. The earliest reports coincide with the cycle of years of higher rainfall, and the future influence of weather on the incidence of psyllid plagues will continue to be investigated in the latter district.

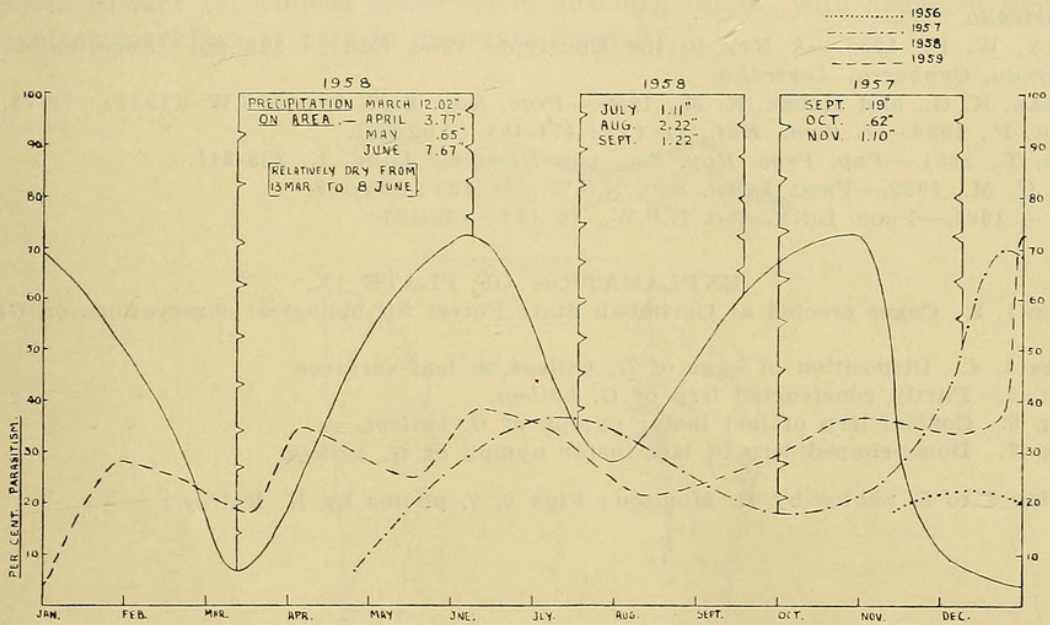
During the spring and summer of 1959-1960 general weather conditions remained comparatively humid until 24 January, 1960. In all of the areas examined large psyllid populations persisted from the previous winter until that time. Parasitism had risen to 72.2% by 21 January, the increase coinciding with a fine, dry period during the previous six weeks.

From 25 January to 29 January, 1960, the daily maximum shade-temperatures recorded near the area utilized for assessments of parasitism were 99°, 104°, 104°, 104° and 97° F.

These temperatures apparently exerted sufficient influence on the psyllid population to reduce it to such an extent that great difficulty was experienced in obtaining sufficient material (i.e., about 100 penultimate and last instar nymphs) for parasitism assessments during the following three months. Many other areas previously carrying large populations of *Glycaspis* spp. were then examined, and it was determined that they were almost, if not entirely, absent from each area.

#### *Influence of Weather on Parasitism.*

Lerps become covered with moisture during wet or humid weather, and after considering the method of oviposition by the chalcidoid wasps, it appears that they are able to operate at a high level of efficiency only when the lerps are more or less dry, and this is associated with periods of relatively dry weather conditions. Such conditions, occurring from September to December, 1957, March to June, 1958, August to October, 1958, and November, 1959, to February, 1960, were in each instance associated with significant increases in the incidence of parasitism by the chalcidoid wasps, which increased on each occasion until parasites reached the maximum numbers within the period of these investigations. This association of increase in parasitism with drier weather conditions is expressed in Text-figure 17.



### 17

Text-figure 17. Percentage parasitism of nymphs of *G. baileyi* associated with periods of dry weather.

Influences exerted by dry weather conditions on the ability of the parasites to operate effectively and the apparent favourability of moist conditions with moderate temperatures for the increases of *G. baileyi* thus may have been the most important factors in the incidence of plague numbers of *Glycaspis* spp. in the areas studied.

#### *Influence of Predators.*

Bell-birds did not apparently diminish in numbers in the areas studied. Limited reductions in the psyllid populations at times coincided with various factors such as an increase in the population of *Syrphus viridiceps*, of chalcidoid wasps, or the various species of spiders. Parasites and predators were capable of exerting only temporary and limited control during the investigations. No reducing factor from which the psyllid population was unable to recover rapidly during the autumn and winter generations was observed.

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#### EXPLANATION OF PLATE IX.

Figs 1, 2. Cages erected at Ourimbah State Forest for biological observations on *Glycaspis baileyi*.

Figs 3, 4. Disposition of eggs of *G. baileyi* on leaf-surfaces.

Fig. 5. Partly constructed lerp of *G. baileyi*.

Fig. 6. Conical lerp of last instar nymph of *G. baileyi*.

Fig. 7. Dome-shaped lerp of last instar nymph of *G. baileyi*.

(Figs 3 to 5, photos by R. Moulton; Figs 6, 7, photos by K. Fairey.)



Moore, K M. 1961. "The biology and occurrence of *Glycaspis baileyi* Moore in New South Wales." *Proceedings of the Linnean Society of New South Wales* v.86=no.395-397 (1961), 185–200. <https://doi.org/10.5962/bhl.part.12155>.

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