Behavioural characteristics of the Scale insect *Aspidoproctus* sp. near *glaber* (Homoptera: Margarodidae) in different instar stages in Miombo woodlands in Hurungwe, Zimbabwe

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Abstract
The behavioural characteristics of the different instar stages of Aspidoproctus sp. near glaber (Lindiger) were studied over a period of 10 months from December 1994 to October 1995 on Brachystegia boehimii and Julbernardia globiflora in the field in Hurungwe, Zimbabwe and on potted Afzelia quanzensis seedlings in the laboratory at the University of Zimbabwe. The behavioural aspects studied were egg-laying and hatching behaviour, crawler behaviour, settling behaviour, moulting behaviour, honey dew secretion, and over-wintering behaviour. Dissection of 20 randomly selected adult females daily for a period of 10 days during the oviposition period revealed that the scale insect produced eggs in batches and retained them inside the female body where incubation and eclosion took place. Dissection of 20 adult females when the insects were fully distended showed that the number of eggs produced per female ranged from 934 to 5673 (with a mean of 2403 ±1281 eggs). The newly emerged crawlers congregated around the fringes of the maternal scale before they started dispersing. Crawler emergence and congregation period were strongly affected by ambient temperature. The crawlers moved upwards until they reached the thinner twigs, petioles and leaves in the crown of the host plant where they wandered up and down before settling down to feed. The insect moulted three times and on each moult the insect actually escaped from the old exuvium leaving the latter attached to the host plant. After each moult the insect moved down to a thicker portion of the host plant. Throughout its development, the insect produced copious amounts of honeydew.

Key Words:
Aspidoproctus, behaviour, Miombo woodlands

1. Introduction

The scale insect *Aspidoproctus* sp. near *glaber* (Lindiger)(*Aspidoproctus sp.*) has a wide host range, but it has developed localized host-plant preferences in the Hurungwe area in north west Zimbabwe, where it has become a serious pest of *Brachystegia spiciformis*, *B. boehmii* and *Julbernardia globiflora.* It also attacks other indigenous trees including *B. allenii*, *Burkea africana*, *Vangueria infausta*, *Acacia negrescence*, *Albizia amara*, *Pericorpsis angolensis*, *Afzelia quanzensis*, *Bauhinia petesiana* and *Xerodendris stulhmanaii.*

Reports of serious field infestation in the Hurungwe were made in 1987, when the infested area was then estimated at about

100 hectares (Forest Research Centre Reports, 1992). In Zimbabwe, no control measures have been attempted and this has resulted in the total infested area, with dead and dying trees, increasing to about 215 000 ha by 1994 (Mazodze, pers.com). Since the host trees are the dominant species in the area these infestations, if unchecked, may result in extensive deforestation and cause a major ecological disturbance.

Literature on the biology, ecology and behaviour of *Aspidoproctus* sp., on which control strategies are supposed to be based, is very scarce except for the early descriptions of the adult female of *Aspidoproctus giganteus* (Newstead,1913-1914) and of the adult females of *Aspidoproctus cinerea* and *A. Euphorbia* (Green, 1922).

Control strategies for other scale insect pests include dormant pruning of infested wood (in deciduous fruit trees), dormant oil sprays or applications of organophosphate insecticides to control crawlers (Jorgensen, Rice, Hoyt. and Westgard, 1981). Studies on the biology and population dynamics of the scale insect may provide a basis for more judicious use of preventative sprays and for alternative control measures to such sprays. The aim of this research was therefore to study the behavioural characteristics of *Aspidoproctus sp*. near *glaber* as a basis for an integrated management approach for the scale insect.

2. Materials and Methods

2.1. Study sites

The two study sites were in the Chidamoyo area of the Hurungwe district (16^{0}12'E, 29^{0}37'S) about 300 km north west of Harare. The first study site was at the foot of Chidamoyo hill and measured about 100m x 45m. Its vegetation consisted mainly of 2-3 m high *B. boehmii* and *B. spiciformis* trees interspersed with a few but very tall *B. spiciformis* trees. The second site measured about 40m x 50m and its vegetation consisted mainly of 2-5m high *J. globiflora* trees, with fresh and heavy scale insect infestations, interspersed with some very tall trees. Using a table of random numbers, 25 *B. boehmii* trees (2-3m in height) were randomly selected and marked at the first site and 25 *J. globiflora* trees (2-5 m high) were randomly selected and marked at the second site.

2.2. Field study

The two study sites were visited twice a month, with each visit lasting for a week. On each visit, behavioural aspects such as egg-laying and hatching, crawler settling, feeding, moulting and honey dew secretion were studied. The stages of development of the insects were noted. On each day, 20 randomly selected females were weighed with a pocket digital balance (Tanita Model 1479V) and had their length and width measured using a veneer calipus before being dissected out in search of eggs. The number of eggs, if any, found in each insect, their stage of development, colour and shape were noted. When the insects were fully distended, 20 insects were randomly selected, weighed with a pocket digital balance (Tanita Model 1479V) and had their lengths and widths measured with a veneer calipus before being dissected out to expose the eggs. The eggs in each dissected female scale insect emptied into a glass petri dish and then counted. The mean number of eggs per female scale insect was calculated. The exact positions of the insects on the host plant were studied.

2.3. Laboratory study

2.3.1. Insects

Infested branches collected from the field were taken to the greenhouse (where average minimum and maximum temperatures 16.5^{o}C and 38.5^{o}C, respectively, and the relative humidity range was 37 – 65%) and placed in water-filled glass tanks to slow down the drying process and to allow the attached insects to continue with development. The branches could survive for two to three weeks, which was long enough for the crawlers to emerge. Portions of the branches with adult scale insects were covered with muslin cloth to prevent the escape of crawlers upon emergence.

2.3.2. Host plant

Two-year old, potted *Afzelia quanzensis* seedlings were maintained in the greenhouse before the introduction of the insects. By the time of the introduction of the insects onto the seedlings, the latter were, on average, 28cm in height.

2.3.2.1. Inoculation of the host plant

Upon emergence the crawlers were picked up from the *B. boehmii* tree branches (brought in from the field and maintained alive in water-filled glass tanks in the greenhouse) and from the muslin cloth using a camel – hair brush and placed on the butt region of the potted *A. quanzensis* seedlings. At least 25 crawlers were introduced onto each seedling. The seedlings were subsequently covered with wire-framed muslin cloth cages whose open ends were tightly fitted into the plastic pots.

2.3.3. Behavioural studies

2.3.3.1. Laying and hatching behaviour

Twenty adult female scale insects were randomly selected daily from infected branches brought in from the field (and maintained in water-filled glass tanks in the green house) and dissected in search of eggs. This procedure was done for a period of 10 days. This was commenced just prior to the onset of the expansion of the female body and continued until the 10th day. Eggs in different stages of development were observed under the dissecting microscope.

When the insects were fully distended, 25 adult female scale insects were randomly selected and dissected. The number of eggs in each of the 25 adult female scale insects was recorded and the average number of eggs per female was calculated.

The adult female scale insects were also examined daily to check whether they had started releasing the crawlers. When the crawlers started emerging, 10 adult female scale insects were randomly selected and dissected per day. This procedure was continued for a period of 5 days. Eggs in different stages of the hatching process were observed.

2.3.3.2. Crawler behaviour

Crawler behaviour was studied in the greenhouse, where average minimum and maximum temperatures were 16.5^{0}C and 38.5^{0}C, respectively, and the relative humidity range was 37 - 65%. The study was carried out on infested branches just after crawler emergency and on the *A. quanzensis* seedlings just after the introduction of the crawlers, as well as on potted *Ficus bakea* cuttings. Ambient temperatures were taken during the period of the study.

On infested branches the time the crawlers spent congregated around the maternal scale was recorded. The direction of movement of the crawlers was also noted. When the crawlers were placed on the butt region of *A. quanzensis* seedlings, the direction of crawler movement was noted. The duration of the wandering period and the settling sites were studied. Similar observations were also made on crawlers introduced onto potted *F. bakea* cuttings.

2.3.3.3. Moulting behaviour

When the crawlers settled down to feed, 14 infested seedlings were randomly selected and transferred to the 30^{0}C constant temperature room which served as the insectary. Particular attention was paid to how the insect escaped from the exuvium, length of the moulting process and the duration of the after-moult wandering phase.

2.4. Data analysis

To determine whether the number of eggs produced per female was dependent on the size of the insect, the data were subjected to correlation analysis.

3. Results

3.1. Laying and hatching behaviour

The mature females collected from the field did not lay eggs into the external environment. Instead, the eggs were produced and retained inside the female body, where incubation and eclosion took place. The egg was spindle shaped, 0.5mm long and 0.3mm wide, initially creamish white and then yellowish amber in colour, and covered with a sprinkling of white powdery wax.

Dissection of the randomly selected mature females showed that the eggs were produced in batches under the scale and hatched in the order in which they were produced. The crawlers emerged head first from the egg. Among the 20 randomly selected mature adult females, the number of eggs produced per female ranged from 934 to 5673 (with a mean of 2403 ± 1281eggs).

Table 1: Relationship between the number of eggs produced per female and the length, width, height and weight of the female

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Insect	Number of eggs/female	SIZE OF THE INSECT			
		Length (mm)	Width (mm)	Height (mm)	Weight (g)
1	934	15	11.5	6.5	0.2019
2	977	13	11.5	8	0.2149
3	991	10	8	7	0.2185
4	1001	13.5	11.5	9	0.2334
5	1213	12	11	8	0.2818
6	1095	15.5	13.5	8.5	0.2944
7	1708	14	12	9.5	0.3420
8	2108	15.5	13	9.5	0.3448
9	1925	15.5	12	9	0.3582
10	2274	16	14	9	0.3772
11	2393	16	14	9.5	0.3923
12	2586	18	15	9.5	0.4214
13	2417	15.5	12	9.5	0.4306
14	2477	17	14	9.5	0.4352
15	2992	18	15.5	10	0.4511
16	3219	15.5	13	10	0.4629
17	3615	19	14	10	0.6010
18	3585	18.5	15	9.5	0.6273
19	4873	19	16.5	10	0.6914
20	5673	19	17.5	11.5	0.7290

Table 1 above shows that among the 20 adult females dissected during the egg counts, the number of eggs produced per female (eggs/female) was strongly correlated to the size of the insect. The correlation coefficients of eggs/female and weight, eggs/female and length, eggs/female and width, and eggs/female and height were 0.975, 0.811, 0.841, and 0.828, respectively.

3.2. Crawler behaviour

The newly hatched crawlers remained for some time beneath the maternal scale. The crawlers escaped from the mother scale through an operculate pore on the ventral surface. It was observed that the crawlers seldom emerged at night and tended to emerge earlier on warmer days (temperature > 25^0C) than on cooler ones (temperature < 20^0C). Upon emergence the crawlers congregated around the fringes of the maternal scale before they started dispersing. The congregation period was seemed to be affected by abiotic factors, especially ambient temperature. Delayed dispersal (or longer congregation periods) was observed during cold periods (temperatures < 22^oC). On warmer days (temperature 28-35^0C) in the green house *Aspidoproctus* sp. crawlers began to migrate from about two minutes after emergence from the maternal scale.

In the field and in the greenhouse the crawlers moved up the tree trunk until they reached the thinner twigs, petioles and leaves in the crown. On the trunk and the major branches the orientation of the crawlers was always upwards. In the crown the crawlers wandered up and down the twigs and petioles or up and down the midrib on the underside of the leaves until they found suitable attachment sites.

On cooler days (temperatures < 20^0C) the crawlers spent more than two hours congregated around the fringes of the maternal scale and on average took 10 minutes to reach the crown of *A. quanzensis* seedlings. On warmer days (temperatures > 25^0C) the crawlers started dispersing soon after emerging from the maternal scale and took, on average 4 minutes to reach the crown of *A. quanzensis* seedlings. In the field large numbers of crawlers crawling on the topside of the leaves were dislodged by wind.

When placed on potted *Ficus bakea* trunkeons (measuring, on average, 55 cm in length and 6,6 cm in diameter) almost at ground level, the crawlers moved up the cutting and then crawled down after reaching the cut-end of the trunkeon. The crawlers tended to congregate on the rough cut-end of the *F. bakea* trunkeon.

The duration of the wandering period of the crawlers ranged from one to two days. Although no attempt was made to measure the distance travelled by the crawlers, it was observed in the field that the crawlers could travel distances of up to 5 metres from a maternal scale on the trunk of the host plant to the leaves higher up in the crown of the tree. Both the first and second instars of *Aspidoproctus* sp. were able to move from one feeding site to another at various times during their respective stadia. The second instars however, were also able to change orientation whilst on the same attachment site.

3.3. Settling behaviour

In the field *Aspidoproctus* sp. crawlers settled only on the very thin twigs, petioles and the midribs on the under-surface of the leaves and nowhere else, whilst in the laboratory they settled virtually on all parts of *A. quanzensis* seedlings. These included leaves, petioles, very thin twigs and the main stem. The crawlers however, were more concentrated in the crown on petioles, leaves and on very thin twigs. On leaves the crawlers settled only on the midrib on the under-surface of the leaf whilst on the twigs they did not show any side preferences. In the field the crawlers tended to settle on the twig surface shielded from the wind.

In the laboratory, whilst the first instars were more concentrated on the leaves, petioles and very thin twigs, the second instars occupied slightly thicker twigs ranging in diameter from 5 mm to 15 mm and were never found on leaves and petioles. The third instars and adults settled on the main stem of the seedling that ranged from 8mm to 15mm in diameter.

In the field the second instars settled on slightly thicker twigs ranging from about 3.5 mm to 10 mm in diameter and were never found on leaves and petioles. The third instars tended to move further down the tree and settled on portions ranging from 15 mm to 40 mm in diameter. The adults occupied portions of the host plant ranging from about 15 mm to even more than 30 cm in diameter. On thicker trunk portions (i.e. portions at least 25 cm in diameter) in the field most of the scales were found on freshly growing bark under the old dry bark flakes that were in the process of peeling off.

In the field, the scale insects settled onto the host plant on the side opposite the windward side. In cases where scale insects were located under dry bark flakes no side preferences were evident. With only two exceptions, in the field, the adult scale insects were always found oriented with the anterior end upwards. In the laboratory heavy infestations on individual twigs tended to cause leaf abscision but no seedling mortality was caused by the infestations.

3.4. Moulting behaviour

During the first moult, the second instar escaped from the first instar exuvium by breaking through the anterior end of its dorsal surface, leaving a large irregularly shaped hole. Initially, a dorsal hole occurred at the anterior end of the insect. The hole was progressively enlarged probably due to pressure exerted by the insect. The insect appeared to push its way out, while at the same time withdrawing its mouthparts, antennae and legs from their old cuticle. Once these were out, the scale insect pulled the rest of its body out of the old skin. The later was left firmly attached to the substratum throughout development. The first moult lasted about 24 hours.

The second moult, which also lasted about 24 hours, closely resembled the first one. A dorsal split occurred in the anterior region of the insect probably due to the internal pressure exerted by the insect. The third instar appeared to push out its anterior end causing the split to enlarge while at the same time withdrawing its mouthparts, antennae and legs from their old casings. Once these were out, the insect crawled out pulling the rest of its body out of the second instar exuvium. This remained loosely attached to the substratum. The only point of attachment of the exuvium was the insertion of the stylets into the substratum.

The exuvium came to lie at an angle with the substratum as the posterior end of the exuvium was levered up by the pulling effect of the third instar as the later withdrew its posterior end from the former. The third moult did not differ in any respect from the second moult and it also lasted about 24 hours. Each of the three moults which occurred in the life cycle of *Aspidoproctus* sp. were subsequently followed by a wandering phase before the insects settled down to feed.

The wandering phase after the first moult lasted less than 12 hours whilst the wandering phases which followed the second and third moults lasted at most 2 days and 7 days, respectively. However, the wandering phase following the third moult could be shortened to two days by dark conditions induced by covering the cages with a black cloth.

3.5. Honeydew secretion

In the laboratory the settled first instars started producing honeydew droplets about 24 hours after settling down to feed. The honeydew droplets were seen hanging from the setae or erect hairs on the dorsal surface on the insects.

Honeydew was not continuously produced during the first instar stadium. Large amounts of honeydew were secreted before the appearance of the waxy secretions on the dorsal surface of the insects. With the appearance of waxy secretions honey dew production stopped until about 3 days before the first moult when smaller amounts of honey dew were observed dripping down the host plant from the insects. Those first instars that failed to moult into the second instar never produced honeydew after the appearance of the waxy secretion on their dorsal surface.

In the laboratory, the second and third instars secreted honeydew at irregular intervals throughout their respective stadia whilst all the adults died before they started producing honeydew. In the second instar the honeydew was dripping down the host plant from the insects whilst in the third instar it was in the form of small droplets coming out through the anal orifice and dropping directly to the ground.

In the field, the settled first instars were observed producing honey dew in droplet form before the appearance of the waxy secretions on their dorsal surfaces and were not seen secreting any honey dew after being completely covered by a waxy secretion.

In the field, the settled first instars were more frequently visited by ants before the appearance of the waxy secretion than after its appearance. The second instars secreted honey dew at irregular intervals and were always associated with ants whenever they produced the honey dew which could be seen dripping down the substratum from the insects. The third instars secreted honeydew droplets through their anal orifices at irregular intervals and were frequently visited by ants.

Within 14 days after settling down to feed, the adults intermittently secreted honey dew droplets through their anal orifices. Although the amount of honey dew secreted by the insects could not be measured, the adults were observed producing relatively larger amounts of honey dew from 14 days of settling and thereafter. At this stage the adults were almost continuously secreting honeydew that dropped to the ground and gave the soil and rocks underneath the infested trees an oily and shiny appearance.

3.6. Over-wintering Behaviour

In Hurungwe, the insects overwintered as adults in the preoviposition phase that took about five months, from April through winter to August.

4. Discussion

In *Aspidoproctus* sp. near *glaber* the eggs were retained inside the female body until they hatched into crawlers. All the nourishment for the embryo was present in the egg as evidenced by the absence of special nutritional structures between the eggs and the adult female. Consequently, the type of reproduction in *Aspidoproctus* sp. can be better described as ovoviviparous. Unlike in diaspidids such as *Aspidiotus destructor,* there is no space between the female body and the external scale - covering in *Aspidoproctus* sp. A mature female of *Aspidoprotus* sp. near *glaber* is just like a container of eggs attached to the host plant.

Aspidoproctus sp. exhibited crawler behaviour typical of the majority of the members of the superfamily Coccoidea. Upon hatching the crawlers remained for some time under the maternal scale and only emerged when ambient conditions were suitable. The crawlers were especially very responsive to temperature. The crawlers seldom emerged at night, when temperatures were very low, and tended to emerge earlier on warmer days than on cooler ones. Bliss, Cressman and Broadbent (1935) reported similar results for the Camphor scale (*Pseudaonida duplex*).

Temperature strongly affected the time the crawlers spent congregating around the fringe of the maternal scale after emergence. Beardsley and Gonzalez (1975) also made reference to San Jose scale (*Quadraspidiotus perniciosus*) crawlers beginning to migrate between two minutes and 24 hours after emergence, depending on temperature.

At temperatures around 35^{0}C in the greenhouse, most *Aspidoproctus* sp. crawlers died soon after emergence. According to Young (1982) very high temperatures such as those associated with the mid day period in the tropics promote lethargy and general inactivity in many insects. The cold, however, cannot be tolerated by the physiological mechanisms of most insects even those in temperate regions (Young, 1982). This to a lesser or greater extent explains why the crawlers seldom emerged at night when the lowest temperatures were recorded.

Aspidoproctus sp. exhibited orientation-behaviour that varied with location on the host plant and stage of development of the insect. The nature of the stimulus to which the insects responded could not be established because on the trunk of the host plant the crawlers appeared to be negatively geotactic whilst in crown they wandered up and down. After each moult the insects appeared to be positively geotactic as they moved down to thicker portions of the host plant. However, whether all these directed movements were due to gravity or a chemical stimulant from the plant food source could not be established.

Beardsley and Gonzalez (1975) reported that in some scale insect species settling behaviour may be initiated as soon as a suitable settling site is encountered, while in others a definite period of wandering is necessary before settling can be induced. In *Aspidoproctus* sp., it appeared as though settling behaviour was not initiated as soon as a suitable settling site was encountered but that a definite period of wandering was necessary before settling could be induced. The duration of the wandering period of the crawlers ranged from one to two days both in the field (on 2-5m high trees) and in the laboratory (on seedlings 28cm height). Therefore, if settling was induced by encountering a suitable settling site, the crawlers would have settled much earlier on seedlings in the greenhouse than on the larger trees in the field.

Aspidoproctus sp. was also severely affected by other environmental factors such as wind. In the field the crawlers tended to settle on the twig surface shielded from the wind, whilst in the laboratory where there were no strong winds, the crawlers did not show any side preferences.

The second and third instars as well as the adult scale insects also settled on the host plant on the side opposite the windward side in the field. That wind played a vital role in the settling behaviour of the scale insects is further supported by the fact that in cases where scale insects were settled under dry bark flakes no side preferences were evident.

When introduced onto *Ficus bakea* cuttings, the crawlers tended to congregate on the rough cut-end of the cuttings. It seems that *Aspidoproctus* sp. crawlers did not actively seek out the rough cut-end of the *F. bakea* cutting, but simply moved faster elsewhere on the cutting than on the rough cut-end. When they encountered the rough cut-end their rate of movement was adversely affected by the roughness of the surface resulting in their congregation on the cut-end of the cutting. It has been often noted that heavy scale insect infestations frequently occur in the presence of deposits of dust or other particulate matter on host foliage (Beardsley and Gonzalez, 1975). Dust particles or any particulate matter affect crawler behaviour and, therefore, distribution and density. Hulley (1962) reported that the average wandering time of purple scale (*Lepidosaphes beckii*) crawlers on dusty orange leaves was 63.8 min at 28^{0}C, and 91.0 min on clean leaves.

Different developmental stages in the life cycle of *Aspidoproctus* sp. settled on different parts of the host plant with only a few overlaps between the third instar and the adult in the field. In the laboratory, however, limitations imposed by the small size of the seedlings forced the first, second and third instars as well as the adults to settle on trunks ranging from about 8 mm to 15 mm in diameter although the first instars were more concentrated on the leaves, petioles and the very thin twigs.

In some eurymerous species the location of the insect on the host plant may affect its morphological characteristics (Beardsley and Gonzalez 1975). Such effects sometimes are so pronounced that individual scales from different parts of the same host are considered to be distinct species and sometimes placed in different genera (Beardsley and Gonzalez, 1975). Takahashi (1953) in Beardsley and Gonzalez (1975) stated that certain Japanese species that had been placed in the genera *Phenacaspis* and *Chionaspis* were, in fact, site-determined morphological forms of the same species.

In the field, *Aspidoproctus* sp. exhibited temporal overlaps between the second and third instars and between the third instar and the adult but with little spatial overlap. Observation of the third instars and the adults on different locations on the same host at the same time would appear to suggest that *Aspidoproctus* sp. exhibits site-determined morphological forms, yet the species does not display this phenomenon.

There is no literature on the moulting behaviour of Margarodidae. However, the findings of this study differ from those of Beardsley and Gonzalez (1975) and Taylor (1935) for the Diaspididae. In *Aspidoproctus* sp. there were three moults and during each moult, the insect actually escaped from the old exuvium. This was left attached to the substratum as the insect wandered in search for a new attachment site. In diaspidids, with a few exceptions, the insect undergoes two moults. The insect does not escape from the exuvium and the first and second exuviae are incorporated into the scale-covering (Beardsley and Gonzalez, 1975; Taylor, 1935).

During ecdysis in *Aspidoproctus* sp., a dorsal hole (in the first moult) or a dorsal split (in the second and third moults) (probably due to an increase in turgor pressure inside the scale insect body) first appeared at the anterior end of the insect. The insect then pushed its way out while at the same time withdrawing its legs and antennae from their old coverings. Once these were out, the insect crawled out pulling the rest of its body out of the exuvium. Unlike in insects such as *Locusta,* gravity seems to be unimportant in the moulting of *Aspidoproctus* sp. since the orientation of the insects was commonly with the anterior end upwards and not vice versa.

Honeydew secretion by the insect served to confirm it as a member of the family Margarodidae. According to Beardsley and Gonzalez (1975) armoured scale insects (diaspidids) do not excrete honeydew and lack the filter-chamber type of digestive system found in most other Coccoidea.

In the greenhouse, where ambient conditions closely resembled those in the Hurungwe district, the first instars started producing honeydew within 24 hours of settling. In the first instar, the largest amounts of honeydew were secreted before the appearance of waxy secretions on the dorsal surface. In the field, the settled first instars were also observed producing honeydew before the appearance of the waxy secretion. Consequently, in the field the "settled first instars" were more frequently visited by ants before the appearance of the waxy secretion (when they were more vulnerable to predation and parasitism) than after its appearance (when they were relatively secure).

Honeydew secretion has a protective value in scale insects. If the scale insects produced copious quantities of honeydew, the attendant ants, which use the honey dew as a source of food, may defend them from attack by predators. Although the amount of honeydew secreted could not be quantified, the number of the attendant ants increased with the amount of honeydew secreted on most of the marked trees in the field.

Second and third instars produced small amounts of honeydew in varied patterns, both in the laboratory and in the field. However, in the field, the adults continuously secreted copious quantities of honeydew from 14 days of settling. Judging from the oily appearance of the soil underneath the infested trees, the largest amounts of honeydew were secreted just before the insects entered the oviposition period. The significance of this pattern of honeydew secretion is difficult to interpret. Its quite possible, however, that this could be protective in function. As the adult female entered the oviposition phase its dorsal scale became much softer and distended in such a way that most of the waxy processes (or spines), except for those on the marginal series, levelled off. This might have rendered the insects vulnerable again to attack by predators. Secretion of large amounts of honeydew just before and during the oviposition period would have, therefore, attracted more ants and these would have defended the scale insects from predators. Most of the ants that visited the scale insects in the field belonged to *Anoplolepis* spp.

Observations showed that, in the Hurungwe area, *Aspidoproctus* sp. has one generation per year and it overwintered as adults in the preoviposition phase that took about five months, from April through winter to August. However, whether *Aspidoproctus* sp. overwinters exclusively as adults in the preoviposition phase could not be established. In the diaspidids, in areas that are subject to severe winters, only scale insects of a particular age-class may be able to overwinter while in areas characterised by mild winter all stages of the insects may overwinter (Beardsley and Gonzalez, 1975).

Beardsley and Gonzalez (1975) also noted that in areas experiencing mild winters, as in southern Europe, true hibernation does not occur, and although development may be retarded by cool weather, it does not cease. In Hurungwe it appeared that the overwintering adult females of *Aspidoproctus* sp. did not go into diapause but had their development retarded by the cold weather (with temperatures below 18^{o}C). Through the winter *Aspidoproctus* sp. produced copious quantities of honeydew and this showed that development did not completely cease during overwintering period.

The results of this study showed that *Aspidoproctus* sp near *glaber* is probably most vulnerable to attack, especially by its predators, and contact insecticides in the crawler stage before the nymphs settle down to feed. The insect also moulted three times and each moult was followed by a wandering phase before the insects settled down to feed. The wandering phases after the first, second and third moults lasted, at most, 12 hours, 2 days, and 7 days, respectively. The insects did not feed or produce any honey dew during the wandering phases and probably they were also vulnerable to attack by their natural enemies and contact insecticides at these phases. Control strategies for this pest should therefore target the crawlers, second instars, third instars, and fourth instars during their wandering stage before they settle down to feed. At these stages, the insects are not protected from their natural enemies by the ants because they only begin to secrete the honey dew which they use to attract their ant protective partners after settling down to feed. However, if chemical control methods are to be used there will be need to study the phenology of the pest in order to determine the time of crawler emergence, as well as the onset of the wandering phases of second, third and fourth instars in the field. This may require the use of degree-days phenology models which can give an estimate of the time of occurance of a particular stage within the life cycle of a pokilothermous organism.

The feasibility of using systemic insecticides requires further study with regards to the cost implications of spraying chemicals over such vast infested areas, the pesticide backlash, and the ability of the infested trees to absorb the pesticide into its transport system.

The biological control approach also requires further study. The adult stage of *Aspidoproctus* sp appears to be protected from natural enemies by the hard external scale covering. Furthermore, all the honey dew – producing stages of the pest are provided with some degree of protection from their natural enemies by the ants that feed on their honey dew.

The biological control of diaspidids, such as *Aonidiella aurantii*, which do not produce honey dew to attract protective ants, has worked well on the highveld in Southern Africa but has not been successful in the lowveld (Samways, 1985). The reasons given include a high rate of scale insect population increase at high summer temperatures as well as the sensitivity of parasitoids to these high summer temperatures (Samways, 1985). The Hurungwe area of Zimbabwe lies in the midleveld where summer temperatures are usually very high (>28^{o}C) and the nature of the relationship between *Asidoproctus* sp. and its natural enemies needs to be investigated.

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