THE HORNETS OF SINGAPORE: THEIR IDENTIFICATION, BIOLOGY AND CONTROL

By K. L. Chan

SYNOPSIS

This is the first report on the identification, biology and control of hornets in Singapore.

There are 3 hornet species in Singapore — *Vespa affinis indosinensis* Perez, *Vespa tropica leefmansi* van der Vecht, and *Vespa analis analis* Fabricius. Their identification is presented for the first time by a pictorial key and a simplified dichotomous key.

The stinging apparatus of hornets is presented in detail for the first time and those aspects of hornet biology related to stinging and association with man are briefly mentioned. These include the relative prevalence and aggressiveness of the 3 species, their distribution, location of nests, types of nest supports, the chemical composition of the sting venom, and the stinging incidence in Singapore in recent years.

The technique of hornet control and precautionary measures taken during control are given.

INTRODUCTION

Wasp and bee stings occur in Singapore with sufficient frequency as to constitute a medical problem (Wong, 1970). Records show many cases of stinging with several deaths in recent years. Although 3 recent fatal cases reported in Singapore were due to systemic toxic reactions (Tan *et al*, 1966; Wong, 1970), fatality from hymenoptera stings appears to result mainly from anaphylactic shock and rarely from systemic toxic effects based on the study of 50 fatal cases by Barnard (1967) in America. Death from anaphylaxis can occur from a few stings, even one if the victim is hypersensitive, but death from systemic toxic effects normally results after multiple stings are received coincidentally. No mention of the reaction to stings and the treatment of stings is made here as these have been treated in detail by Wong (1970).

Wasps are easily distinguished from bees by their simple, unmodified legs. The highly developed (swollen) legs of bees are so modified for the collection of pollen. Wasps also differ morphologically from bees in their stings. The bee sting, because it is barbed at the end like a fish hook, is invariably left behind in the wound, and results in the subsequent death of the bee. Bees thus can sting only once. Wasps, on the other hand, have unbarbed stings. They are thus able to sting their victims repeatedly without having to lose their stings and die. Wasps are thus generally more deadly killers than bees. Because of this difference in the anatomy of the stings, it is possible to differentiate between the wound made by a hornet sting and that by a bee sting. The bee sting always includes the sting and poison gland in the wound unless brushed off, while the hornet sting leaves only a wound mark, which is usually larger than that made by the bee sting.

The word "hornet" is interchangeable with the word "wasp" but in its proper usage it refers to "large wasps" (Encyclopaedia Britannica, 1970 edition). Wasps thus include hornets and many other smaller stinging species of the same order, Hymenoptera.

Only the hornets of Singapore are presented here.

IDENTIFICATION OF SINGAPORE HORNETS

There are only three hornet species in Singapore. All belong to the genus *Vespa* of the family Vespidae in the order Hymenoptera which include ants and bees.

The identification of the 3 hornet species are presented pictorially in Fig. 1. Female hornets have 12 segments in the antenna and 6 visible segments in the abdomen. Males have 13 segments in the antenna and 7 visible segments in the abdomen.

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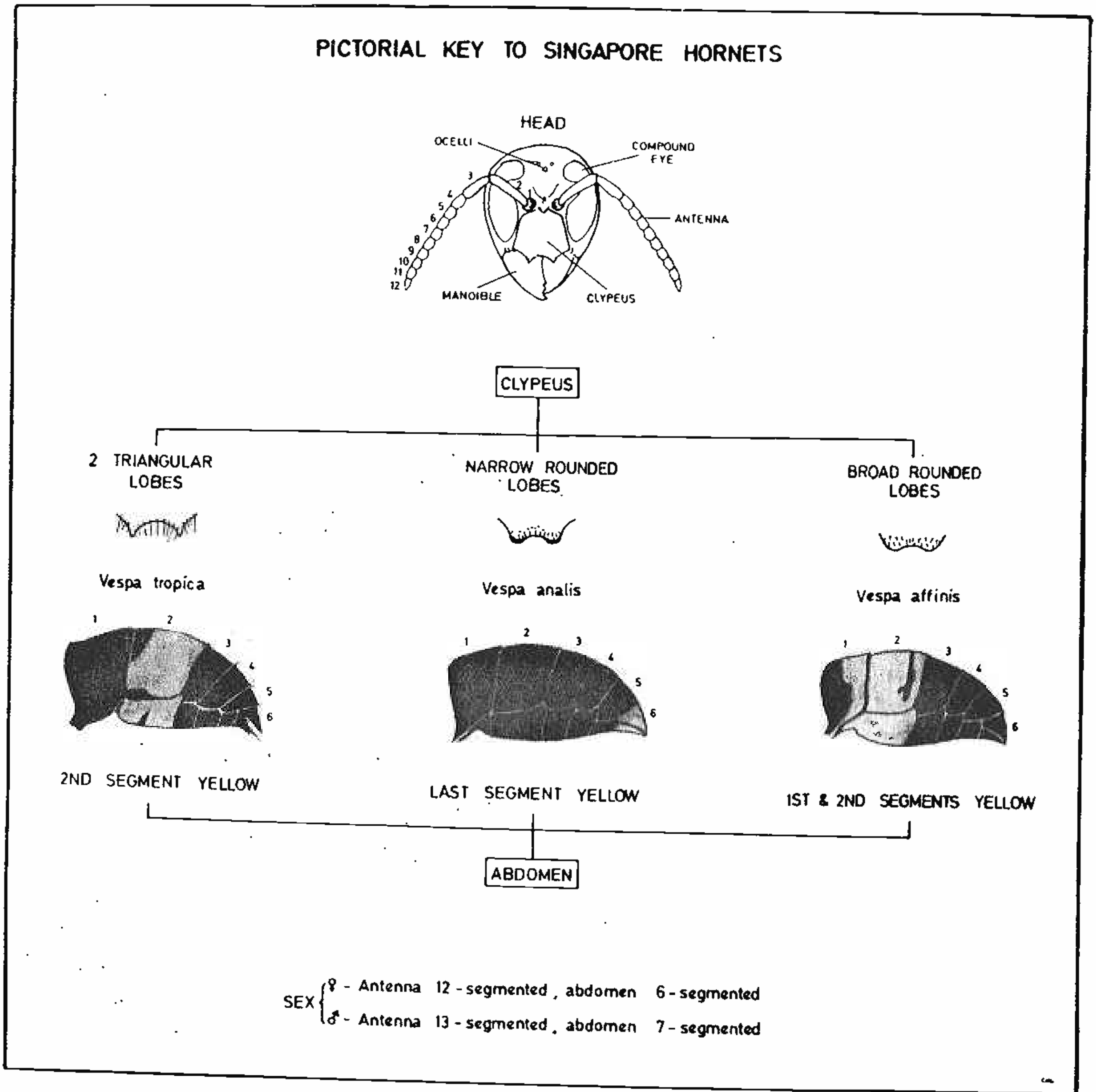

Fig. 1. Simplified pictorial key for the identification of Singapore hornets.

A simplified identification key to the 3 hornet species is as follows:

Key to Hornets of Singapore

1. Clypeus with narrow rounded lobes. 6th abdominal segment yellow -	*Vespa analis analis* Fabricius
Not so - - - - - -	2
2. Clypeus with blunt triangular lobes. 2nd abdominal segment yellow -	*Vespa tropica* L. *leefmansi* van der Vecht
Clypeus with short broadly rounded lobes. 1st and 2nd abdominal segments yellow - - - - -	*Vespa affinis* L. *indosinensis* Perez

One other species of *Vespa* must be mentioned. Vecht (1957) records *V. analis tyrannica* Smith as present in Singapore and Johore, Malaysia, from a few specimens taken in Singapore, the most recent being in 1911. According to Roche (1970), this sub-species had not been taken in Singapore since then, having been replaced by the typical and commoner form, *V. analis analis*. Roche (1970) collected a worker *tyrannica* near Lombang, some 8 miles north of Kota Tinggi in Johore on November 19, 1967. The records listed in van der Vecht (1957, 1959) must now be amended. Alfred's (1970) record of *V. analis tyrannica* as the sub-species in Singapore must also be corrected.

BIOLOGY OF HORNETS

Hornets are social insects which display a high degree of social organization. They have a complex system of communication by which individuals of the same colony recognize one another. This is achieved by social hormones (pheromones) and by the mutual exchange of food exudates (trophallaxis), as well as by other stimuli.

Social polymorphism (polyphasy) or the presence of different castes (queens, workers, males) exists for the efficient functioning of the colony through division of labour and functional specialization. In each nest there is normally one queen. She is the most important digit as she is the originator and reproducer of the entire colony. Her main function is the laying of eggs. The workers (all females) tend the young and build the nest. The males exist only for fertilization of the females.

Species Prevalence

The relative prevalence of the 3 hornet species in Singapore is based on the number of nests destroyed from complaints received by the Vector Control & Research Branch since this Branch took over this function in November 1969 from other Departments (National Museum, Fire Brigade, Parks & Trees Unit of the Public Works Department, and Works & Buildings Department of the Public Works Department).

Table I shows 196 nests destroyed in 1970 and 439 in 1971. The number of nests destroyed in both years appears to show the same monthly distribution, with more nests destroyed in the latter half of the year (Fig. 2). This distribution is probably related to a proportionate increase in hornet food (nectar and other smaller insects) during the latter period of the year.

Table I also shows that the commonest species is *V. affinis* followed closely by *V. analis* while *V. tropica* is much less common.

Species Distribution

Fig. 3 shows the distribution of the 3 hornets based on nests destroyed in Singapore. No clear pattern of distribution is seen, but from observations made on all nests destroyed, *V. tropica* appears to be associated most closely with man, showing a distribution more or less related to that of houses. The other two species have their nests built mostly away from human habitations, often on plantation trees like coconut, mango, rambutan and rubber and on roadside trees like acacia and madras thorn.

Nest Supports

Table II shows the kinds of supports or structures on which the 3 hornets build their nests.

V. tropica builds its nests mostly on undisturbed portions of buildings e.g. under roofs (Fig. 4) and inside other artificial structures like unused sheds, boxes, planks, tiles, drums, inside or near human habitations. It rarely builds its nests on trees.

V. analis has a distinct preference for trees. About 86% of its nests are built on trees. The

TABLE I

NUMBER OF NESTS DESTROYED IN 1970 AND 1971

Month	1970			1971		
	V. tropica	V. analis	V. affinis	V. tropica	V. analis	V. affinis
January	2	0	0	0	16	7
February	0	1	0	3	6	4
March	2	3	2	3	4	3
April	0	2	0	2	11	8
May	2	1	0	5	22	14
June	0	1	1	3	17	18
July	4	8	17	0	16	23
August	2	13	23	0	12	38
September	4	8	24	0	13	50
October	3	12	14	4	19	25
November	6	4	13	2	21	26
December	5	12	7	3	19	22
TOTAL	30	65	101	25	176	238
GRAND TOTAL	196			439		

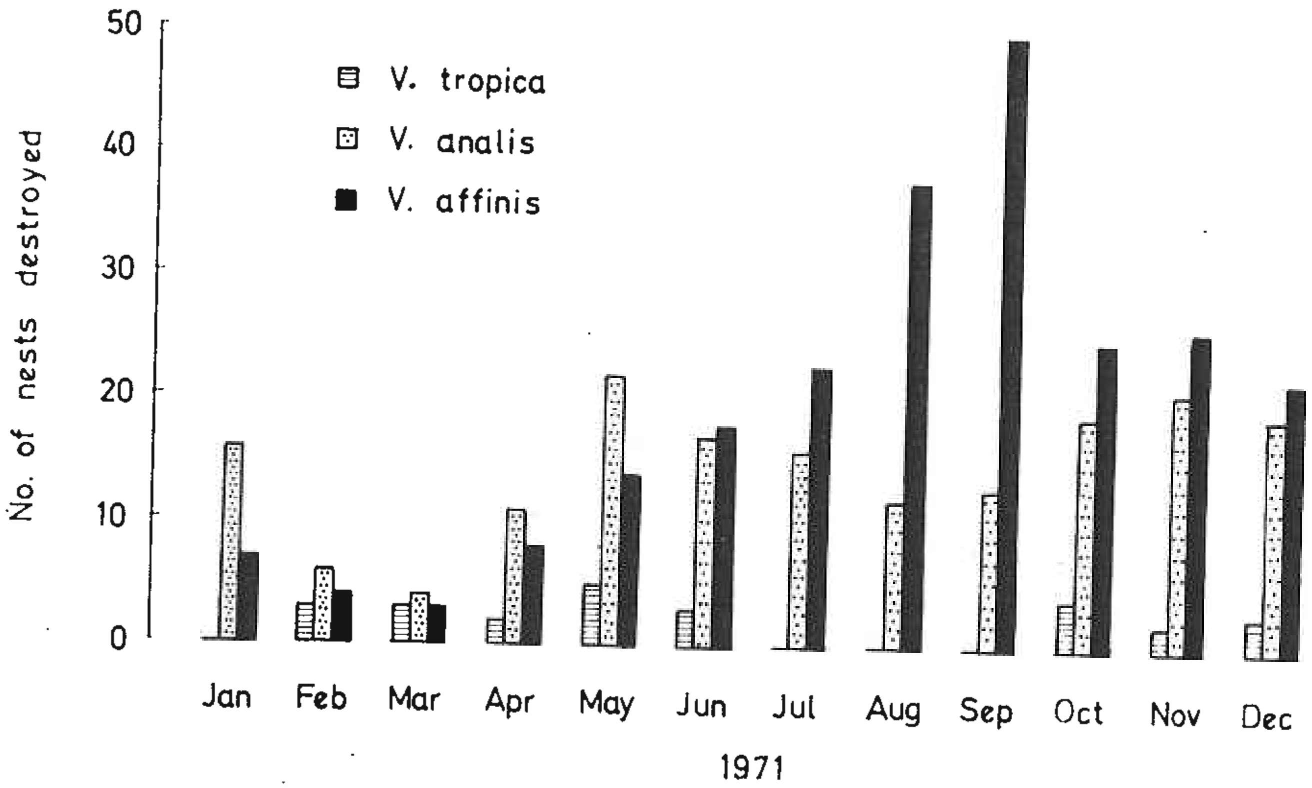

Fig. 2. Monthly incidence of hornet nests destroyed by the Vector Control & Research Branch in 1971.

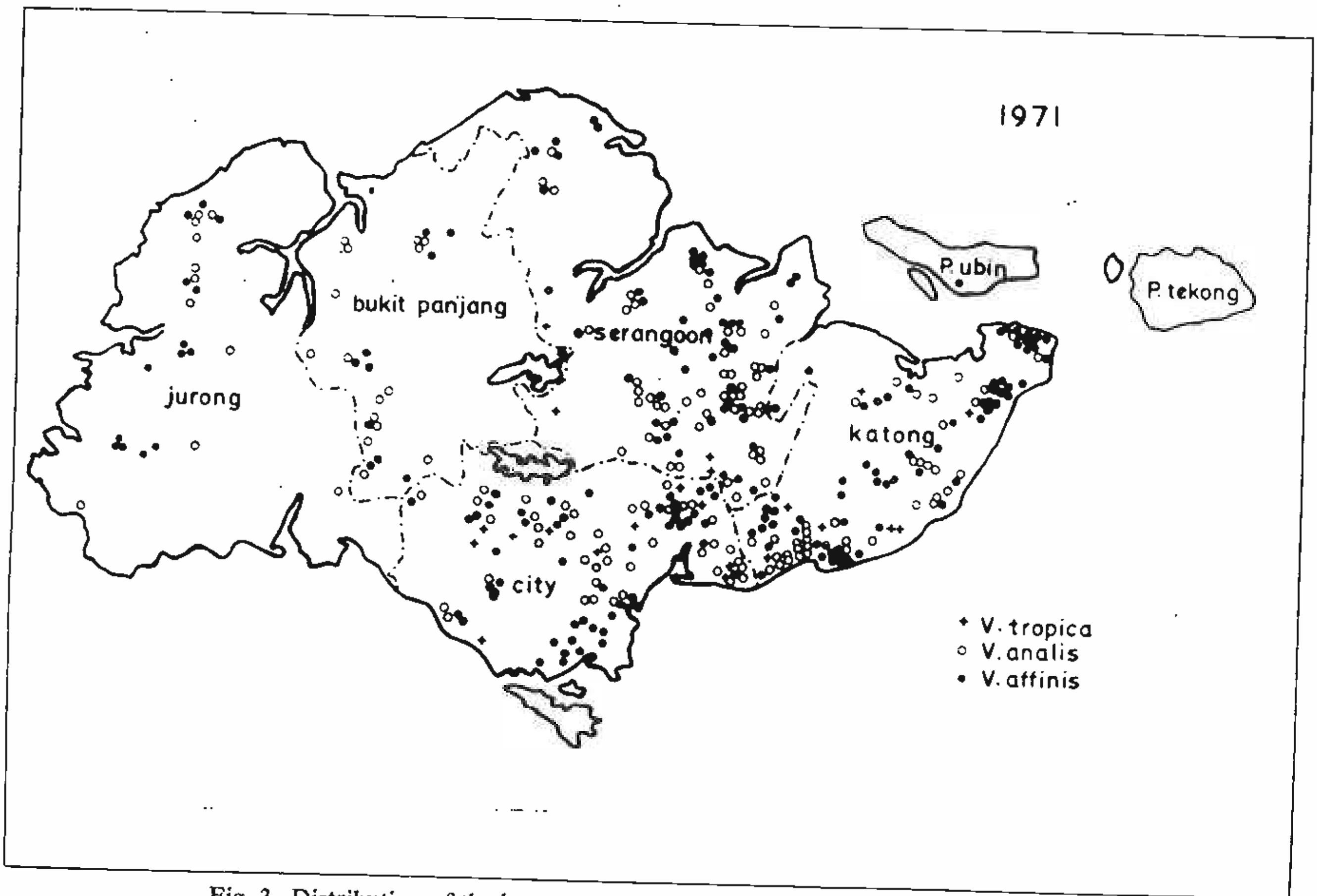

Fig. 3. Distribution of the hornets of Singapore based on nests destroyed in 1971.

TABLE II

NUMBER AND PERCENTAGE OF DIFFERENT TYPES OF NEST SUPPORTING STRUCTURES OF SINGAPORE HORNETS

Type of Nest Support	V. tropica		V. analis		V. affinis	
	No.	% of Total	No.	% of Total	No.	% of Total
I. GROUND	3	5·9	4	1·8	13	4·1
II. SHRUBS AND BUSHES*	0	0·0	9	3·9	22	7·0
III. TREES						
1. Acacia *(Acacia auriculiformis)*	0		4		28	
2. Coconut *(Cocos nucifera)*	0		15		9	
3. Mango *(Mangifera indica)*	0		12		8	
4. Rambutan *(Nephelium lappaceum)*	1		26		11	
5. Rubber *(Hevea brasiliensis)*	1		16		29	
6. Others (24 species of trees)	9		121		136	
		21.6		85.5		69.9
IV. ARTIFICIAL BUILDINGS AND STRUCTURES						
1. **Building Proper**						
(a) Basement, staircase, storeroom	4		0		2	
(b) Wall, window	3		0		4	
(c) Roof, ceiling	16		7		33	
(d) Chimney, clock tower	7		0		1	
2. **Peripheral Structures**						
(a) Fence (with plants)	0		11		13	
(b) Huts, sheds, planks and tiles box, drum, rain-guage, swing	7		2		3	
3. **Communal Structures**						
(a) Telegraph, wiring and lamp posts	0		0		4	
		72·5		8·8		19·0
TOTAL NO. OF NESTS STUDIED	51	100·0	227	100·0	316	100·0

*Include: *Baphia nitida*, *Bougainvillea* sp., *Hibiscus sinensis*, *Jasminum* sp. *(sambac?)*, Lallang *(Imperata cylindrica)*.

rambutan tree is most preferred with rubber, coconut and mango trees (Figs. 5(*a*) and 5(*b*)) a close second. It rarely builds its nests in shrubs and bushes. When associated with buildings, it almost always builds its nests between roofs and ceilings and on fences.

V. affinis also has a distinct predilection (about 70%) for trees (Figs. 6(*a*) and 6(*b*)). Of the 20* odd species of trees on which it builds its nests, rubber and acacia trees appear most preferred with the rambutan tree a close second. It also builds its nests in shrubs and bushes. It often uses buildings (Fig. 7); roofs and ceilings, and, to a lesser extent, fences, are the most preferred.

Location of Nests

Table III shows the location of nests at various heights.

V. tropica clearly builds its nests on the ground or near to the ground. More than 50% of its nests are located within 10 ft. from the ground. Alfred (1970) reports that it also builds its nests under-

*These include durian *(Durio zibethinus)*, guava *(Psidium guava)*, jack fruit *(Artocarpus heterophyllus)*, rambai *(Baccaurea motleyana)*, star fruit *(Averrhoa carambola)*, sukun *(Artocarpus incissus)*, casuarina *(Casuarina equisetifolia)*, flame of the forest *(Delonix regia)*, frangipani *(Plumeria* spp.*)*, madras thorn *(Pithecellobium dulce)*, pinang *(Areca catechu)*.

TABLE III

LOCATION OF NESTS AT VARIOUS HEIGHTS (1970-1971)

Approx. Height (Feet)	No. of Nests		
	V. tropica*	V. analis**	V. affinis†
0 (ground level)	5	3	20
1 - 10	8	56	62
11 - 20	4	67	51
21 - 30	3	50	69
31 - 40	4	22	35
41 - 50	—	8	26
51 - 60	1	10	7
61 - 70	—	—	5
71 - 80	—	—	3
81 - 90	—	—	—
TOTAL NESTS STUDIED	25	216	278

*52·0% between 0 and 10 ft.

**90·2% between 1 and 40 ft.

†94·6% between 0 and 50 ft.

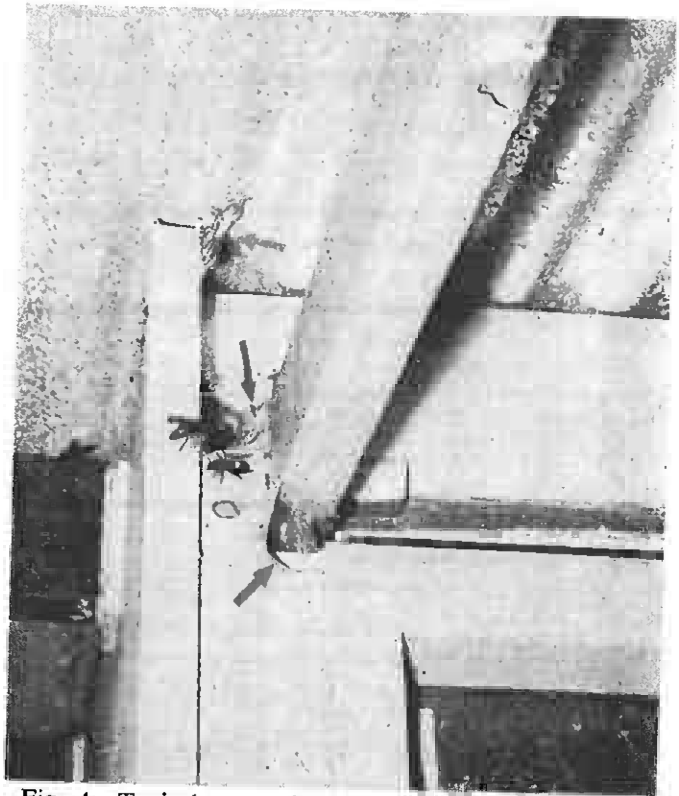

Fig. 4. Typical nest of *Vespa tropica leefmansi* built inside crevices at ends of wooden beams under roof of house. Arrows show small portions of nest protruding from wall crevices. Two adult hornets are guarding the hole of the nest.

Fig. 5(*a*).

Fig. 5(*b*).

Figs. 5(*a*) and 5(*b*). *Left:* Nest of *Vespa analis analis* built on mango tree. Note hole on the side of the nest and the semicircular "tiger" striped markings on the outside of the envelope. *Right:* A typical *analis* nest with the bottom part of the envelope removed to show the tiers of combs interconnected by a central stalk. Note the encapsulated pupal cells.

Fig. 6(*a*).

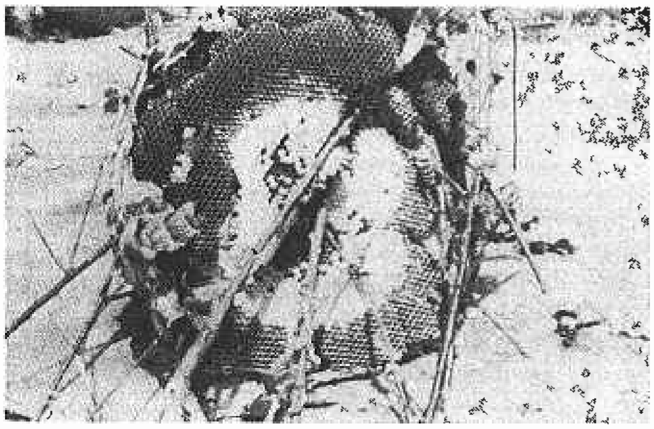

Fig. 6(*b*).

Figs. 6(*a*) and 6(*b*). A typical nest of *Vespa affinis indosinensis. Top,* lateral or side view of intact nest showing scalloped surface of envelope without "tiger" striped markings. *Bottom,* ventral or bottom view of same exposed nest showing hexagonal cells of comb and white encapsulated pupal cells in the centre.

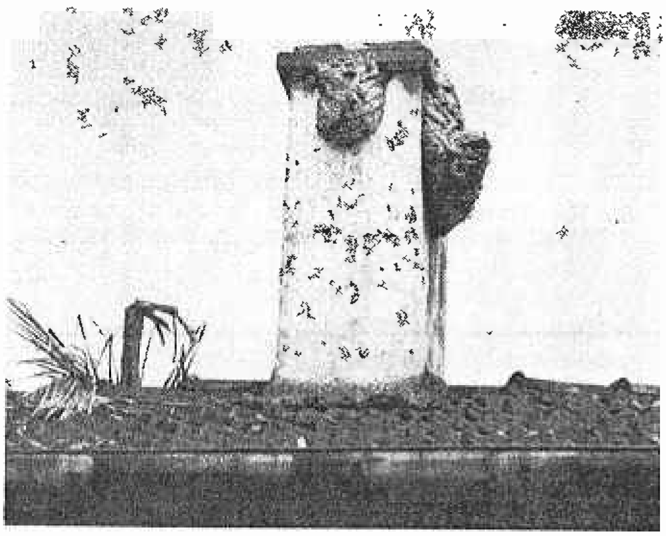

Fig. 7. Nest of *V. affinis* built inside the top portion of a house chimney and extending to the outside through the smoke holes.

ground in addition to building nests on the tops of trees.

V. analis, on the other hand, builds its nests mostly well above ground level, rarely on the ground. 90·2% of its nests are several to 40 ft. above ground. It does not appear to build its nests above 60 ft.

V. affinis is the most versatile. It builds its nests from ground level to as high as 80 ft. However, 94·6% of its nests are within 50 ft. from the ground.

Aggressiveness

All 3 species will sting when their nests are disturbed accidentally or deliberately. Observations show that *V. affinis* is the most vicious and aggressive and *V. analis* the least so. Slight provocations would cause *V. affinis* females to walk in a frenzy all over the nest and fly around it. On seeing a moving object they would make a beeline chase and sting it, often more than once. Death is almost certain when a person accidentally steps on an *affinis* nest on the ground.

Stinging Incidence

Alfred (1970) reports 38 cases of stinging by *V. affinis* with 2 fatalities based on observations conducted by the National Museum, and respectively 3 cases and 1 case of stinging by *V. tropica* and *V. analis*, both without fatality.

Tan *et al* (1966) reported two local fatal cases of stinging by hornets but these were not well-documented as the species were not identified.

Wong (1970) reported 45 cases due to stings of wasps and bees in children under 10 years admitted to the Department of Paediatrics, University of Singapore, from July 1967 to June 1970, and 149 cases between 0 and 80 years from admissions to Outram Road General Hospital obtained for the period 1958-1968. It is not known how many of these were due to hornets.

Between 1970 and 1971 the Vector Control & Research Branch recorded 4, 2 and 1 cases of stinging by *V. affinis*, *V. tropica* and *V. analis* respectively. Of these, one in 1970 received 4 stings, and another in 1971 received 5 stings, both from *V. affinis*. Both recovered after several days of hospitalization.

The incidence of stinging must however be properly interpreted. It should be attributed not only to aggressiveness of the hornet species but also to their nesting habits which determine the frequency of encounters between man and the respective hornet species either through accidental or wilful disturbance of their nests. Thus, *V. tropica*, though uncommon, is frequently encountered by man through its nesting habits near or on human habitations. The incidence of stinging by this species is thus observed by Alfred (1970) and the writer to be higher than that by *V. analis* although the latter is more common but which builds its nests almost always away from human habitations and outside the reach of man, on trees.

Stinging Apparatus

Only the queen and the workers (females) sting. Male hornets do not sting as they do not possess stings.

The sting or terebra of hornets is a modified ovipositor formed from 2 pairs of gonapophyses of the last two abdominal segments (8th and 9th), one pair on the 8th and one pair on the 9th (Fig. 8). Those of the 8th segment form the stylets or sting lancets which enclose the poison canal. They are the 1st valvulae. Those of the 9th segment fuse together immovably to form the sting or stylet sheath which makes the wound and encloses and holds the stylets in position. They are the 2nd valvulae. These fused 2nd valvulae have along most of their length a pair of ridges projecting into corresponding grooves in the 1st valvulae, thus enabling the 1st valvulae (stylets) to move in and out without being detached from their sheath. The stylet sheath expands at its base to form the sting bulb. The tip of the stylet sheath is pointed and does not bear barbs as in bees. Hornets thus can sting over and over again without losing their stings.

The sting bulb continues anteriorly as two diverging slender arms which join into the oblong plates (2nd valvifers) or parts of the 9th

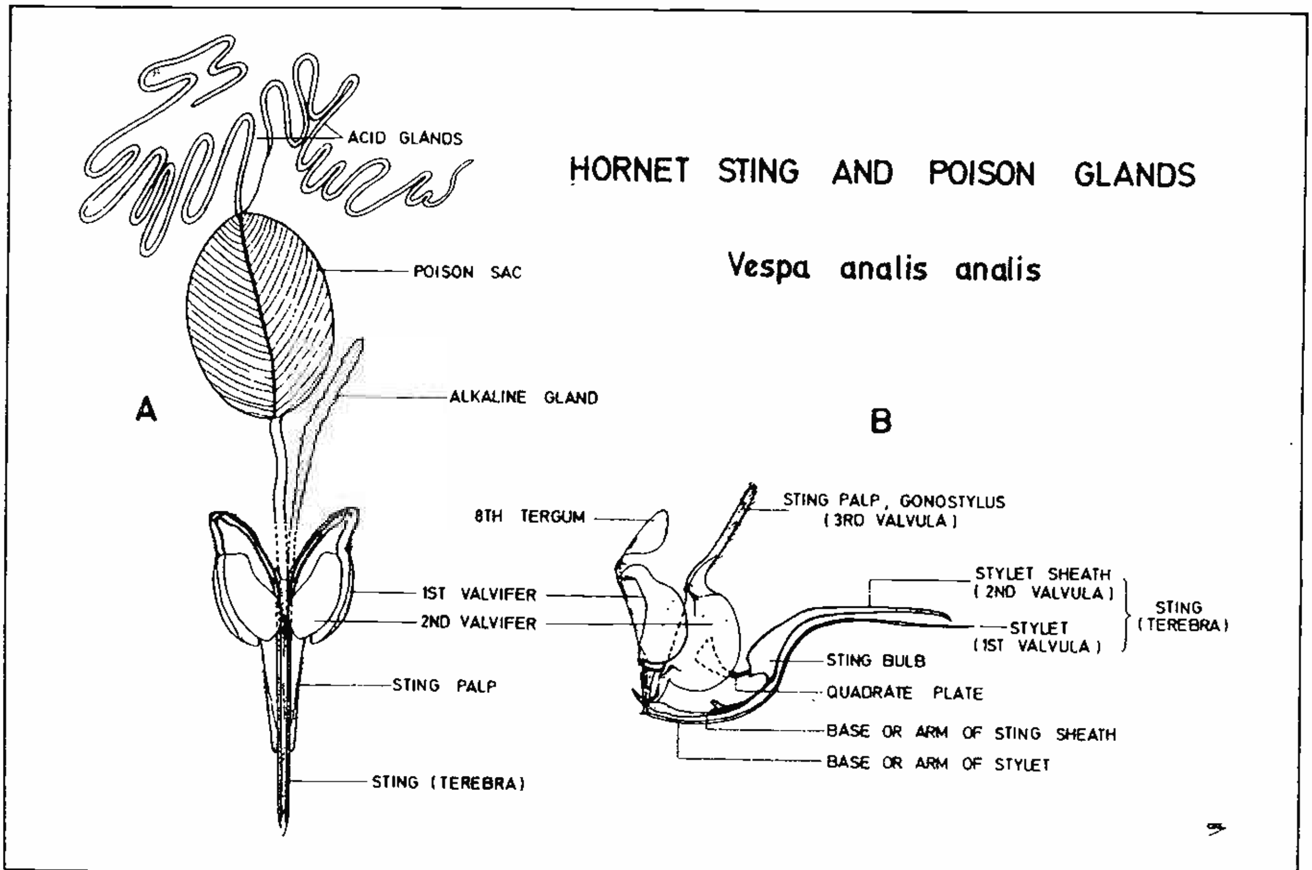

Fig. 8. Stinging apparatus of *Vespa analis analis* presented for the first time in literature. *A*, ventral view; *B*, lateral view showing parts separated by dissection.

abdominal sternum; these plates bear on their dorsal aspect two sting palps or gonostyli (3rd valvulae) bearing bristles. The bases or arms of the stylets also diverge to join into the fulcral or triangular plates (1st valvifers) to the dorsal aspect of which are attached the 8th tergite bearing bristles. Just anterior to the sting bulb and attached to it are the quadrate plates formed from the 9th tergum. They are fused together at their anterior edges.

The poison sac or gland is a fairly large oval muscular sac. Four sets of muscles encircle the sac. Their contraction squeezes the poison into the poison canal. Into the poison gland opens two long filiform acid glands. In *V. analis*, one of these is connected to the poison sac by a slender stalk. An alkaline gland opens separately into the sting.

The stinging mechanism is operated by many muscles attached to the valvifers and basal portions of the valvulae.

Venom

The venom is the secretion of the poison gland, acid glands and alkaline gland. It is a complex mixture. The most important constituents are certain proteins and enzymes. The latter act on the tissues of the victim to release histamine which, depending on the amount and host sensitiveness, may cause death through anaphylactic shock.

Jacques and Schachter (1954) found that wasp venom contains hyaluronidase in addition to 3 active muscle stimulants—histamine, 5-hydroxytryptamine, and a substance resembling bradykinin. The high concentration of histamine and 5-hydroxytryptamine accounts for some of the features of skin reaction following a wasp sting. The large amounts of hyaluronidase in the venom would enhance the diffusion of toxic substances in the skin (Tan *et al*, 1966).

The venom of bees, on the other hand, contains 3 toxic factors: (*1*) a haemolytic enzyme, phosphatidase, (*2*) a neurotoxic factor which paralyses adjacent nerve endings to cause localized oedema and (*3*) histamine (Schenken *et al*, 1953).

Many of the deaths from wasp or bee stings appear to be due to anaphylaxis from foreign protein injected with the venom (Tan *et al*, 1966). In the case of bees, the implanted barb and the pollen carried have been indicated as anaphylactic agents.

CONTROL OF HORNETS

Technique

Because of the aggressiveness of hornets and the serious consequences of being stung, hornet nests are most safely destroyed at night when all the individuals are inside the nest. The Vector Control & Research Branch, however, has developed an effective insecticide spray mixture which, when used singly or in combination with a fire flame, can be used safely for destroying hornet nests in the day time.

The technique employed involves throwing a ball of fire onto the nest by spraying a continuous jet of the spray mixture from a pressurized knapsack sprayer across a flame ignited at the end of an extensible aluminium pole by soaking kerosene in a ball of combustible material (Fig. 9). In this way, no time is allowed for the hornets to escape and disperse, and an average-sized hornet nest can be destroyed in about 10-15 minutes, the time required for the nest to be completely burnt up. When used alone i.e. without fire, as is often necessary when dealing with nests located on buildings, the jet is directed at the hole of the nest as the hornets emerge (they invariably will) in order to prevent them from escaping, and maintained until all have died.

Fig. 9. Hornet control outfit, showing hornet sting-proof suits and insecticide-proof respirators. Note knapsack pressurized sprayer for throwing jet of insecticide mixture, ball of combustible material at the end of an aluminium pole, and a long ladder folded on rack at the top of landrover.

The spray mixture consists of two insecticides in an oil base. A quick knockdown insecticide (synergized pybuthrin) is the frontline weapon. It knocks the hornets down on immediate contact. A residual insecticide (Dieldrex 15) then continues the killing action by autointoxication or by other mechanisms of poisoning. All hornets coming in contact with the spray would thus eventually die even if they escaped a direct dose of the spray mixture. The oil base (anti-malarial oil) acts as a carrier for the two insecticides and also as a heavy wetting agent for wetting the wings and body of the hornet so as to bring it straight down onto the floor before it could fly some distance and sting an innocent victim. The oil also serves as a fuel for the fire flame.

Precautions

During nest destruction, the operators wear sting-proof suits and insecticide-proof respirators (filters) for preventing insecticide poisoning (Fig. 9). Other precautionary measures against fire and insecticide poisoning are also taken. Buckets of water and sand are brought to the site of operation. The operators are also checked periodically for signs of insecticide poisoning. Cholinesterase tests are carried out on the operators every six months.

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