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Dedicated to Mrs. W.S.S. van Benthem Jutting

The occurrence of *Xyleborus perforans* (Woll.) and *X. similis* in Java (Coleoptera, Scolytidae)[1]

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I. ZEHNTNER'S OBSERVATIONS OF *X. perforans* IN SUGAR-CANE, 1898—1900

In 1898 a shot-hole borer, identified as *X. perforans* (Woll.) appeared in an experimental plantation of sugar-cane varieties at Kagok, near Tegal, West Java. Zehntner, the Swiss entomologist on the staff of the Sugar-cane Experimental Station at Kagok, used the opportunity to study the borer extensively in the laboratory as well as in the field. The borer was already notorious at the time by its boring into the bung and staves of wine-casks in Madeira and beercasks in India, which caused leakages[2]).

Zehntner published the very important results of his investigations in an extensive paper written for the planters in the Dutch language, in 1900. A summary of this paper on "De riet-schorskever" (the cane bark-borer) was inserted in an annual report for 1900. An excerpt of the paper, quoting some parts verbatim but wanting several of the most interesting biological details, appeared in 1906 in VAN DEVENTER's volume on „De dierlijke vijanden van het suikerriet en hunne parasieten" (= The enemies of sugar-cane and their parasites).

As ZEHNTNER's paper has received very little attention abroad, the main contents are given here, together with a reproduction of his plate.

Cane attacked. The borer can only successfully breed in sugar-cane, which

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1) Provisions of the Uyttenboogaart-Eliasen Stichting have much facilitated the completion of the present study.

2) A shot-hole borer in sugar-cane in the West Indies, also called "*Xyleborus perforans*" in early papers, is apparently an allied species.

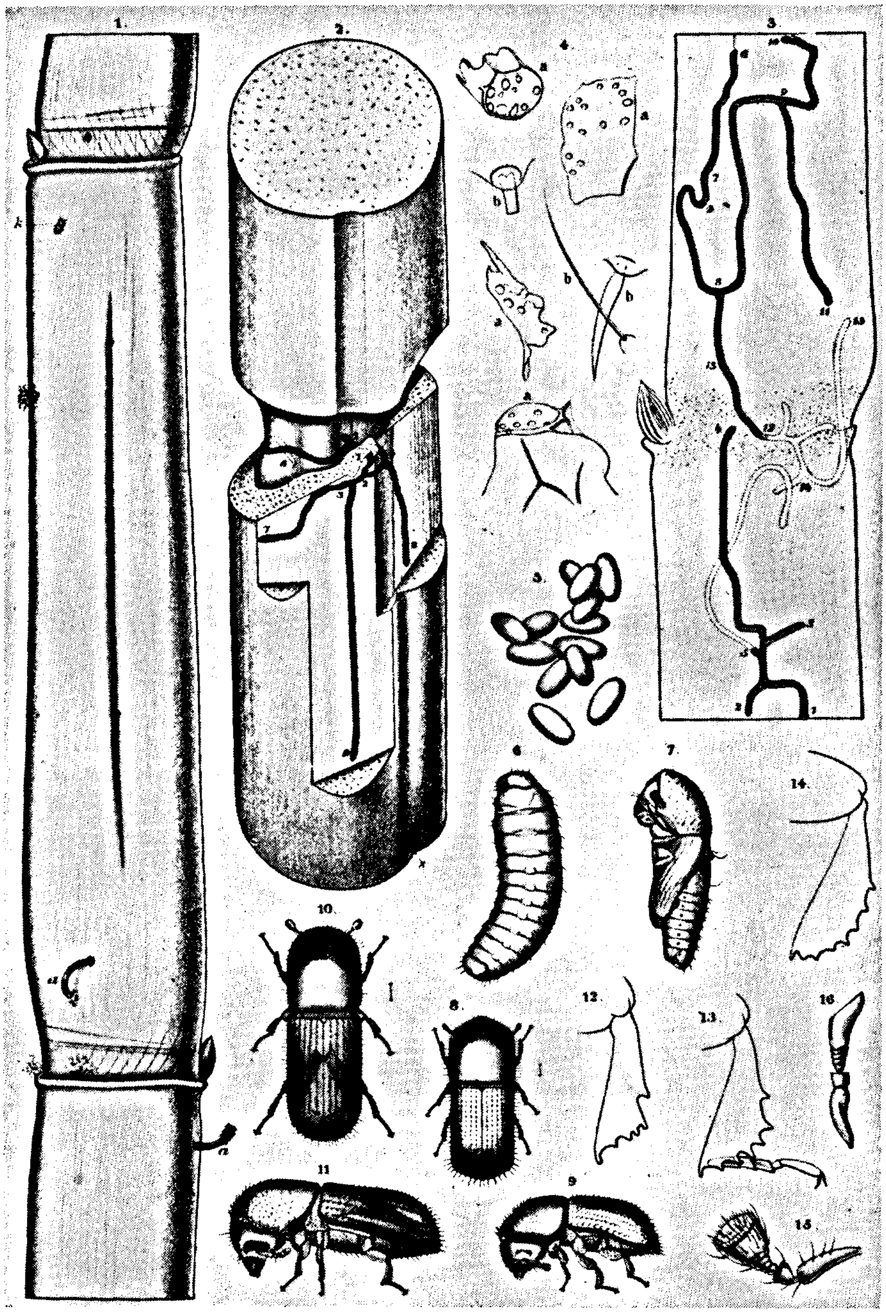
is affected by certain blights, notably *Schizophyllum* (sometimes accompanied by *Diplodia*) and a few others, their fungal hyphae having penetrated the tissues of the plants. Plants damaged by lepidopterous borers or by birds are also attacked. All these plants spread a typical odour of sourish fruits and are very rich in sap. Dead cane and plants attacked by top-rot or rotting from other causes are not attacked, no more than dry cane. Diseased cane is a breeding medium only as long as it contains sufficient moisture; when it dies and begins to dry the borer's development is stopped. The basal part of dying cane is longer inhabited by the borer as it remains moist for a longer time. The beetles then may enter the subterranean part of the stem ('dongkalan'). There is no preference for any variety of cane. Sound cane in the field is never infested by the borer.

Tunneling. The female beetle — 2.15 to 2.60 mm in length — drills its entrance hole mostly in the nodes of the cane, entering behind buds and remaining parts of the leafsheaths, or, in basal nodes, at the spot where adventitious roots have grown, occasionally also near exit holes of lepidopterous borers, near wounds made by woodpeckers and in longitudinal clefts in the bast of the joints. The entrance hole, only 0.7 to 1.0 mm wide, can be detected by small piles of yellowish frass or sometimes by curved cylinders of frass, up to 8 to 10 mm long, which are pushed out by the beetle while excavating its initial tunnel. These tunnels mainly run in the nodes but are extended afterwards into the tissues of the internodes, running most irregularly, here quite near the bast, there in the core of the cane. The tunnels bifurcate repeatedly. Where they happen to reach the periphery the bast may be pierced, apparently on purpose, and the frass is expelled to the outside through these additional holes. Sometimes a part of the tunnel-system itself is filled with frass. In severely infested cane the amount of frass expelled may be so large as to soil the cane and spread over the soil.

The female beetles always make individual tunnels. Still it is very difficult, as a rule, to trace the course of a single gallery-system, because usually several beetles live in the same portion of a cane-stalk and the numerous furcating galleries form a labyrinth that is scarcely to be disentangled. However, breeding experiments have allowed the method of tunneling to be studied rather accurately (see the two examples in fig. 1).

Oviposition. Development. The beetles often penetrate 8 to 10 mm into the cane during the first 2 or 3 days, and lay the first eggs in a gallery of the same length extending to the periphery. The eggs are ovaloid, 0.6 × 0.3 mm.

FIG. 1. Reproduction of ZEHNTNER's plate, 1900. 1, internode of infested sugar-cane, grooved by shrinking as a result of fungus action, and showing holes of *Xyleborus perforans*; at *a* cylinders of expelled frass; 2, piece of cane with tunnels made by a single mother beetle; 3, tunnels made in confinement by two beetles; somewhat schematic (so far natural size). 4, some particles from the larval intestines; at *a* cell wall fragments, and *b* hairs from larval exuvia (× 610); 5, 6, 7, eggs, fullgrown larva, and female pupa (× 15); 8, 9 male beetle; 10, 11 female beetle, the folded wings shining through the transparent elytra (× 15); 12, first femur; 13, second femur and tarsus; 14, third femur (× 70); 15, 16, female antenna from above and in profile (× 70).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Another tunnel leads to the core and sends off branches. As soon as the ramification has reached a sufficient extent, more eggs are deposited in batches up to 50 pieces in tunnel-branches that come to a dead end.

The duration of the egg stage is 4 days, that of the larval stage 7 to 9 days and of the pupal stage again 4 days, so the development from egg to young beetle takes only 16 to 18 days. All the various stages of development of the borer may be found in one and the same tunnel. The pupae and the immature beetles are arranged neatly in a row.

In a tunnel-system of 14 cm total length, completed within two weeks, 13 eggs, 1 young larva and two mature larvae were found. In a gallery of 30 cm a batch of 35 eggs was counted, besides 15 larvae of different ages, 6 pupae and 7 beetles (one of which the mother beetle) (ZEHNTNER, 1900 : 3).

In another case, closely observed, the following notes were made (l.c.: 4):

on the 10th day, since boring started: 0 eggs, 2 young larvae and one half-grown larva counted and removed.
on the 16th day: 27 eggs, 4 young larvae, two larvae of 1.15 mm removed. Beetle moved to fresh piece of cane.
on the 22nd day: only a short gallery; beetle again moved to another piece.
on the 35th day: 12 eggs, 9 larvae.
on the 37th day: 3 eggs.
on the 39th day: 8 eggs.
on the 40th day: 2 eggs.
on the 43th day: 6 eggs.
on the 57th day: mother beetle dead after having produced 58 eggs and 18 larvae.

From these and other observations ZEHNTNER concludes that a beetle when left undisturbed may produce 80 to 100 eggs and that its longevity may be at least three months during most of which period oviposition continues (l.c.: 5).

When the first female beetles which are raised in a gallery become mature, they do not leave the cane but extend the gallery-system and begin to lay eggs before the mother beetle has stopped its activities. Therefore, the same cane-stalk may serve as breeding place of several generations of the borer, which generations, however, cannot be separated. The number of beetles which develop in a single cane is sometimes very large. In a portion of infested cane of only 6 cm length no fewer than 77 eggs, 31 larvae, 10 pupae and 16 beetles (one of them a male) were found (l.c.: 7). (Something similar has been observed in the breeding of *X. destruens* in living teak trees, cf. KALSHOVEN, 1962).

No swarming season has been observed but small numbers of female beetles are seen at lamplight the whole year through.

Food of the larvae. The larvae move freely in the tunnels by loop-like movements, alternatively stretching the body while pressing the tip of the abdomen against the substrate and curving the body while lifting the abdomen.

The larval mouth-parts are not adapted to sucking but to pressing and chewing. Under the lens it can be seen that the larvae constantly open and shut the toothed mandibles while actively moving along the tunnel wall (the same has been seen in *X. destruens*, cf. KALSHOVEN, 1962). In the excrements some fragments of cell walls can be detected but no fungal hyphae, not even in tunnels blackened by the growth produced in the 'ananas disease'. In drying cane where some fungi grow rapidly the larvae stop feeding. However, in living cane the fungi appear to increase the exudation of sap in the tunnels (and in other wounds). This sap has the sourish smell already mentioned and corrodes metals. Taking into account this method of larval feeding and seeing that cell fragments form such a small part of the contents of the intestine, while further the larvae complete their growth in as little as 6—7 days, ZEHNTNER concludes that there is a probability that the larval food mainly consists of the sap of the plant which has been more or less changed by the fungal action.

Males. Sex-ratio. The wingless males, 1.7 to 2.0 mm long, are to be found in unbranched tunnels of 2 to 3 cm, opening onto the surface of the cane. As was customary at the time ZEHNTNER gave a minute description of the insect in all its stages, including the male pupa and beetle. Only 62 specimens of the typical wingless male, were collected from various infested canes investigated against some 1000 female beetles. The male pupa is 1.5 to 1.8 mm, against 2.0 to 2.5 mm for the female pupa.

Parthenogenesis. Copulation has not been observed and appears even to be unnecessary. Female beetles bred from pupae which have never had any contact with male beetles, also produce eggs and these normally develop into larvae. From these, apparently accurate observations, ZEHNTNER (1900 : 7) concludes that there is a possibility that *X. perforans* can reproduce through parthenogenesis.

II. OBSERVATIONS ON THE OCCURRENCE OF *X. perforans* IN TREES

Distribution, frequency. Xyleborus perforans is the most common shot-hole borer in damaged, diseased and dying trunks and branches in various habitats — even in towns — all over Indonesia and neighbouring countries. (For its world distribution see BEESON, 1929; WOOD, 1960; BROWNE, 1961). In Java it occurs from the low-lying plains up to at least 1500 m altitude. As the female beetle is very generally attracted by lamp-light in the evening, the species is often very numerous in collections of coleopterologists and museums. The beetles are also attracted by alcohol. So it was found in bell-glasses set out to catch necrophagous insects, Bogor 1932. The borer is easily transported to other countries in logs which still contain sufficient moisture. These features are only met with in a limited number of *Xyleborus* species.

Hosts. X. perforans is very unselective and occurs in woods with very different properties and botanical affinities, as well as in palm trunks and in stems with little lignification. In 1930, BEESON enumerated 75 species of trees found infested occasionally by this borer (mentioned under its synonym *X. kraatzi*) in India and neighbouring countries; but in his handbook BEESON refrains from listing all the host-plants once more. BROWNE in his recent monograph (1961) enumerates some 30 hosts for Malaya. Many of these species have been found to harbour the borer also in the Indonesian archipelago, including fruit-trees, forest trees, trees in parks or planted along the wayside etc. For an extremely polyphagous and common species like *X. perforans* there is little sense anymore in drawing up another lengthy list of regular and occasional host-plants in an oriental region. It would, indeed, be more interesting to collect observations on plants which have proved to be non-susceptible to the attack.

As BROWNE (1961) specifies, *X. perforans* is also rather unselective as to the size of the host, occurring as it does in branches and stems of 5 cm and even less, but also in big trunks and logs. It never occurs as a truly primary borer, but only breeds in diseased and dying parts of the host plants. However, it very often bores in an otherwise sound tree in places where a wound occurs and the trunk is deprived of its bark. In these cases the galleries may extend into wood which still looks sound, and here the beetle acts as a wound-parasite. The species particularly attacks trees immediately after they have been struck by lightning and killed 'in full sap', as has been noticed repeatedly in rubber (*Hevea*)-plantations and in *Cocos*-groves.

Tunnel-system (figs. 2, 3). In tracing the course of individual tunnel-systems in infested timber in order to take measurements and collect the brood, the difficulties encountered have been even greater than those met with by ZEHNTNER in his studies of shot-holed sugar-cane. The reasons are that the borer commonly attacks a trunk or branch simultaneously in numbers and often it does so together with populations of other secondary ambrosia beetles. Therefore, the tunnels mostly become very crowded and intertwined. The method used in Bogor, 1924, was to saw an infested portion of the timber into disks and exposing the tunnels on cross cuts with chisels. In this manner a good many initial and young tunnels could be laid open (see table) but not a single example of a well advanced tunnel-system in its full length. Still, it was possible to draw some general conclusions.

The development of the tunnel-system may be very different in different hosts which may probably be attributed to differences in woodstructure, dimensions and sap-content and to the vaiiable competition of other ambrosia-beetles. Even the initial tunnels are different in shape and general pattern; they enter the wood mostly in a curved or slanting course and may penetrate for some 2 to 3 cm before side-branches are started. These branches are thrown out left and right in the horizontal level and extend over various lengths and at various distances from the entrance.Further irregular extensions and ramifications follow. The first eggs and larvae appear when the total tunnel length is about 6 to 8 cm, sometimes not more than 3 cm (see table). Advanced tunnels have two features which make the matter still more intricate. First horizontal ramifications may be laid out on several levels, which are interconnected by one or two vertical shafts (as found in *Xyleborus tectonae* in teak, KALSHOVEN 1920, 1962). Secondly some of the side branches are directed right outwards to the periphery and form additional openings ('exits' or 'outlets'). The additional connections with the open air take off

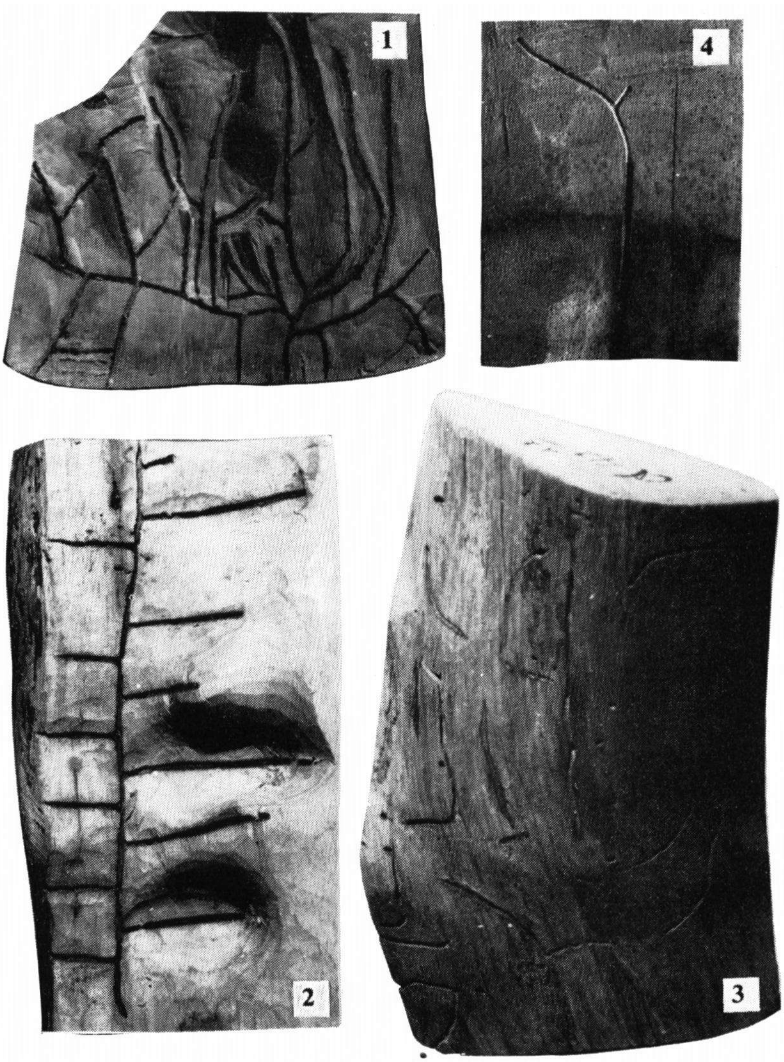

FIG. 2. *Xyleborus perforans*. 1, crowded horizontal tunnel-system exposed on cross-section of *Kopsia* wood; six 'outlets' to the periphery (bottom); 2, 'ladder' exposed on vertical section of *Kopsia* wood; six 'outlets' (to the left), seven tunnels directed inwards (to the right); 3, tunnels under the bark of shot-holed branch of *Mangifera foetida*; 4, cross-section of part of *Canangium* trunk showing tunnel of *X. perforans* started from an old, empty tunnel of *X. funereus*, the latter in discoloured sapwood (bottom of the picture).

from the vertical shafts as well as from the outer concentrical branches of horizontal ramifications. In the vertical shafts it has been found that the side branches directed inwards — which often form the beginning of a new horizontal ramification — alternate rather regularly with opposite branches leading outwards. They even form a distinct kind of ladder (see fig. 2). The pattern in horizontal levels of old tunnel-systems reminds one of a Ficus benjamina ('waringin') tree with the huge crown supported by numerous additional trunks (the 'outlets') (figs. 2, 3). In some timber species (those belonging to the soft kind with large pores?) the tunnels are wide-spread, in other species (those with a rather hard, compact structure?) the systems are narrowly built and very compact. Often the tunnels are slightly widened at the junctions and furcations, forming small triangles.

The figures about the size of the brood (see table) are generally only approximate for three main reasons: 1, when we use a chisel in exposing the tunnels which often deviate more or less from a strict horizontal level, it is almost inevitable that part of the eggs or youngest stages get lost; 2, in well-advanced tunnels part of the beetles may already have left the nests; 3, one cannot make allowance for any losses by predators. Particularly no exact data can be given about the size of the brood in fully mature tunnel-systems with several levels of ramifications and many 'outlets'. However, the data in table 1 may give some idea about the matter.

Very intricate, narrow tunnel-systems of *X. perforans* have been exposed in a portion of a dying *Kopsia* trunk, 15 cm in diameter, which was attacked additionally by *X. andrewesi*, *Platypus solidus* and *Crossotarsus saundersi*. One horizontal ramification measured 64.4 cm, it had 26 terminals (dead ends) and 12 'outlets' of 3 to 4 cm in length. It contained 3 larvae, 8 pupae and 46 female beetles. Still the collection of the brood was far from complete as a vertical shaft could not be followed.

In a portion of a dead *Toona sinensis* trunk, 20 cm in diameter, attacked by *X. perforans* and *X. similis*, some adjacent horizontal ramifications of the former species, together with portions of vertical shafts, the whole probably belonging to 2 or 3 complete tunnel-systems, were exposed. The combined length of the horizontal ramifications was 164.9 cm, showing 69 dead ends or terminals; the total length of the vertical shafts was 38.1 cm; there were 11 short outward leading branches ('outlets') measuring 18.1 cm in total. The brood gathered from all the galeries comprised 3 eggs, 22 larvae, 10 female pupae, 64 female beetles and 1 male beetle (its sum total being 100 specimens).

These few figures show, at least, that *X. perforans* can be nearly as prolific in timber as in diseased sugar-cane, where the living conditions appear to be optimal. It is evident in any case, that very large numbers of beetles may breed and eventually swarm from shot-holed trunks of some size.

If a *perforans* borer enters a portion of a trunk with an open wound, deprived of its bark, it will bore straight through the blackened, fungus-infested portion before beginning to make side branches.

In a very exceptional case it has been observed that *perforans* mother beetles had made use of an empty entrance tunnel of another species (*X. funereus*) to penetrate into the wood (fig. 2, no. 4).

TABLE I. Development of tunnel-system and brood

Host-species, size of the host	Tunnel-system			Composition of the brood						
	total length in cm	number of branches	number of 'outlets'	mother beetle	eggs	larvae	pupae	adults ♀	young ♂	size of the brood
				Initial and half-grown tunnels of X. perforans						
Albizzia falcata, branch, 15 cm diam.	6.3	2		1	4					
Albizzia falcata, branch, 15 cm diam.	6.5	2		1	3	8				
Durio zibethinus, 9 cm diam.	2.9	?		1	2	8				
Canangium odoratum, 29 cm diam.	4.7	2		1	6	4				
Canangium odoratum, 29 cm diam.	5.5	3		1	11					
Theobroma cacao, 5—7 cm diam.	4.0	1		1	1	6	2	2	1	12
Theobroma cacao, 5—7 cm diam.	6.4	3		1		14	5	3	1	23
Hevea brasiliensis, young tree	9.8	3		1	25	5	1			31
Mangifera foetida, 6—7 cm diam.	10.2	7		1		9	1	12	1	23
Canarium commune, young tree	11.3	7		1		4	2	4	1	11
Aegle marmelos, 19 cm diam.	14.5	8		1		4	1	6		11
				Advanced tunnels of X. perforans						
Toona sinensis, 20 cm diam.	56.0	14	1	1	3	9	4	4	1	21*)
Hevea brasiliensis, young tree	26.0	11	3	1	59	33	10	10		112*)
Saccharum officinarum	?	?	?	1	35	15	6	6		62**)
Kopsia arborea	62.2	18	8	1				36		
Kopsia arborea	64.4	26	12	1		3	8	45		56*)
				Tunnels of X. similis						
Canangium odoratum, 29 cm diam.	4,5	2		1	8					
Durio zibethinus, 9 cm diam.	3,4	2		1		7	2			
Manihot glaziovii, 20 cm diam.	6.6	4		1		3	1	4		
Ficus ribes, 11 cm diam.	8.3	4		1	4	5	2	2		13
Manihot glaziovii, 20 cm	19.9	7	1	1		2		8		10
Durio zibethinus	19.8	7	1	1		6	3	5		14
Ficus ribes, 11 cm diam.	15.3	9	1	1	5	13	3	4		25
Ficus ribes, 11 cm diam.	21.0	10	1	1	3	7	4	6	1	21
Manihot glaziovii, 20 cm diam.	48.0	12	2	1		20	8	8	1	37
Manihot glaziovii, 20 cm diam.	47.0	12	4					10		

*) single horizontal ramification of multilevel tunnel-system **) data of ZEHNTNER, 1900

III. Observations on *Xyleborus similis* Ferr.

Xyleborus similis Ferr., 1867 (syn.: *X. submarginatus* Bldf., 1895) has much in common with *X. perforans*. It has the same general habitus but for a slightly larger size — the ♀ ♀ mostly measuring 2.3 to 2.5 mm — and a prominent pair of spines on the elytral declivity. Populations of a slightly smaller form, viz. 2.2 to 2.4 mm, formerly separated as *X. parvulus* Eichh., 1868 may be considered to come within the range of variation of *similis*. The male of this very common species was described as late as 1942 by Schedl, from material collected by the present author in West Java. It has similar morphological characters as that of *perforans* and is (1.6) 1.7 to 1.9 (2.05) mm in size. The species has a very large distribution in the oriental regions (from India to the Philippines, Indonesia, Papua, Queensland and the Solomon Islands), but does not occur in the neotropics. In Java it is found in the West with its rainy climate, as well as in the East with its pronounced dry season, from the plain up to at least 800 m altitude. It is somewhat less abundant in Indonesia than *X. perforans*.

Breeding places, hosts. X. similis is also a typical secondary species. It is seldom the only species attacking a sickly or wounded tree, but, as a rule, it occurs as one of the species of a mixed ambrosia beetle fauna often including *X. perforans*. The species is rather polyphagous though somewhat less unselective than *perforans*. So it has not been found in Java in sugar-cane, nor in the Cocos palm or any other monocotyl. Beeson (1930) has listed no less than 42 host-species for India and the surrounding countries. Browne (1961) mentions some 22 species for Malaya belonging to 14 plant families, for *X. similis* and *X. parvulus*. In Java it has been observed in the following plants:

Anacardiaceae: *Mangifera caesia, M. odorata*
Annonaceae: *Canangium odoratum*
Apocynaceae: *Kopsia arborea*
Bombacaceae: *Ceiba pentandra, Durio zibethinus, Gossampinus heterophylla*
Compositae: *Eupatorium pallescens, Vernonia*
Euphorbiaceae: *Hevea brasiliensis, Manihot glaziovii*
Fagaceae: *Castanopsis* sp.
Leguminosae: *Butea monosperma, Cassia multijuga, Erythrina fusca, E. lithosperma*
Meliaceae: *Lansium domesticum, Toona sinensis*
Rutaceae: *Aegle marmelos*
Sterculiaceae: *Sterculia* sp., *Theobroma cacao*
Theaceae: *Thea sinensis*
Tiliaceae: *Actinophora fragrans*
Urticaceae: *Artocarpus elastica, A. integra, Ficus benjamina, F. ribes*
Verbenaceae: *Tectona grandis*

This enumeration of 28 species belonging to 15 families includes the rubber tree, several fruit-trees, cultivated and wild forest trees, woody crops like tea, and a shrub *Eupatorium*. There are several divergencies from Browne's list, which again confirms the marked unselectivity of *X. similis*.

Tunnel-system (fig. 3). The initial tunnels of similis show no difference in their lay-out from those of *perforans*. The advanced tunnels have only one of

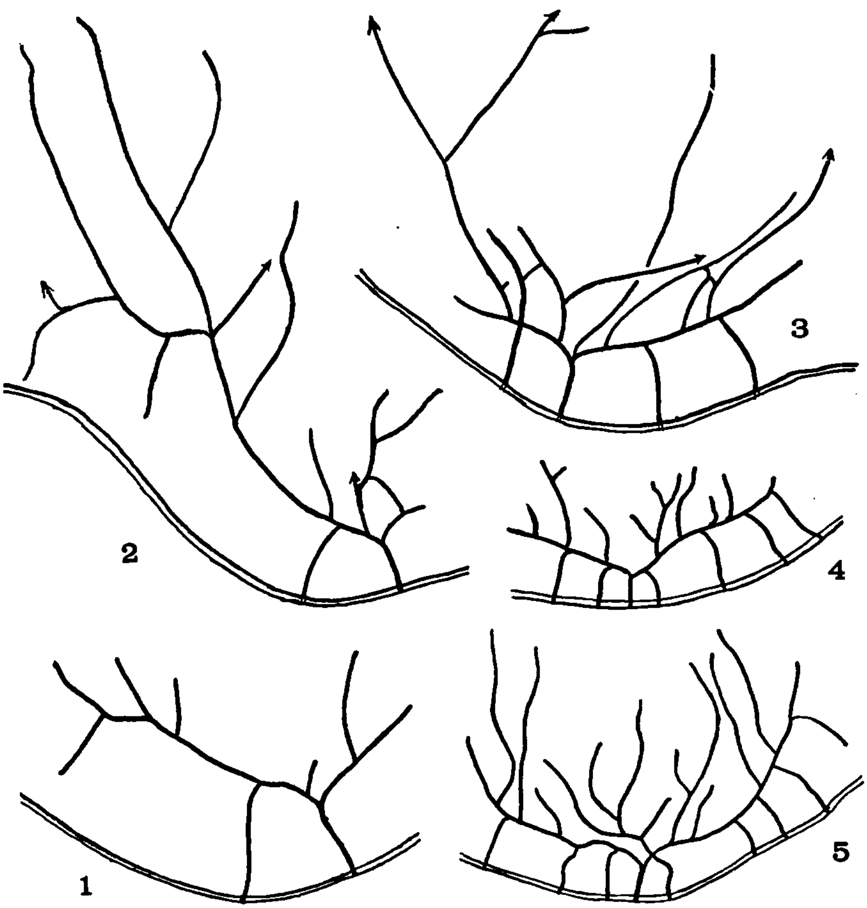

FIG. 3. 1—3, patterns of horizontal tunnel-systems of *Xyleborus similis* with one to three 'outlets', in wood of *Manihot glaziovii;* 4—5, patterns of horizontal levels in tunnel-systems of *Xyleborus perforans,* with six and seven 'outlets' in *Kopsia* wood (× ¾).

the particular features of the latter species, viz. the exit-holes or 'outlets' which, however, are not as numerous as those in some *perforans* tunnels. Though the course of the ramifications may deviate from a strictly horizontal level, there is no example in my collection of a tunnel-system showing vertical shafts leading to additional ramifications at several levels, as found in *perforans.*

Development of the brood. The limited number of data on this matter collected during the investigations in Java in 1924 are included in table 1. They point to a moderate prolificity of the species. BEESON (1930) mentions the faculty of this borer to continue the development of a 'community' (nest) for a prolonged period when a heavy pure infestation of *similis* occurs, the emergence period of young beetles then being short and sharply defined; but when the infestation is light or when there is competition with other borers, the period of emergence is much prolonged.

Other habits. The *X. similis* females have a nocturnal flight and are attracted then to lamp-light as in *perforans.* Most probably the species is also a sapfeeder and not an ambrosia feeder. As the males are scarce — in one case one ♂ to eight ♀ and in another case a score of ♀♀ without a single male — it would be worth while to investigate whether there is the same tendency to reproduction by parthenogenesis as is met with in *perforans.*

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