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THE BIOLOGY OF *XYLOCOPA PUBESCENS* (SPINOLA) (HYMENOPTERA: ANTHOPHORIDAE) IN ISRAEL

Y. Ben Mordechai [1], R. Cohen [1], D. Gerling [1] and E. Moscovitz [2]

(1) The George S. Wise Faculty for Life Sciences, Department of Zoology, Tel Aviv University and (2) The Society for the Protection of Nature.

ABSTRACT

Xylocopa pubescens (Spinola) is distributed in Asia and Africa, but only little is known about its biology. In Israel, it occurs widely, forming extensive populations along the Rift Valley, from the Sea of Gallilee southwards, The ramified nests are constructed in soft wood in protected places. Nesting is gregarious and large colonies are often formed until the substrate is used up. The females and males overwinter together but mating takes place in the spring and summer. Hours of activity change according to the region and season. In the Rift Valley, there is adult foraging activity even during the warm hours of nice winter days, but elsewhere, the bees fly only from mid-February till October or November. In the months of May to October, in the Rift Valley, and May to September elsewhere, most flying is performed by the bees during the first 1—2 hours of light.

Nesting started in March when it was most intense and continued until October, resaulting in 3 overlapping generations.

Females stayed in their nests and guarded them except when on foraging trips. Progeny was sometimes allowed to nest in a tunnel near the mother, forming a nest complex.

Males perform territorial flights by hovering back and forth about prominent objects.

INTRODUCTION

Xylocopa pubescens (Spinola) belongs to the subgenus *Koptortosoma* which includes some 179 species of Ethiopian origin (Hurd & Moure, 1963).

In 1964 Lieftinck showed that this species had been confused with *X. aestuans* L., a species that probably occurs from Burma eastward. Hence, we consider all of the reports of *X. aestuans* from the Middle East as pertaining to *X. pubescens*.

A number of biological notes and reports have been published about *X. pubescens*. The most notable are those of El Borollosy and Ismail (1972) and Mellor (1926-1927), both from Egypt and that of Peerli (1973) from Israel.

In their publications, the authors mentioned different facets of bee behavior, including nesting materials and nest construction as well as the type of flowers visited by the bees. On the other hand, no studies of year-round biology, activity cycles, or peaks of activity have been reported.

These considerations prompted us to undertake an investigation on the year-round activity, the territorial behavior of the males, and the nesting and foraging of the females of *X. pubescens*.

For many of our studies we chose the area of En Gedi, in the Arava Valley, where our earlier investigations have shown a preponderance of *X. pubescens*. This oasis, on the shores of the Dead sea, is 400 meters below sea level. It abounds with water and tropical vegetation, and has a mild and short winter period and very hot summers. Comparative studies were conducted at the Ramat Aviv campus of Tel Aviv University.

MATERIALS AND METHODS

Distribution of *X pubescens* in Israel was determined through collecting records and observations. Biological studies and observations were conducted with bees that were marked either with spots of paint, or with numbered plastic plates. Developmental biology at Ein Gedi was followed by occasional opening of nests; at Tel Aviv, nests were X-rayed at different intervals. A "Softex" E-3 X-ray machine was used at 20-25 KVp and 3 mA. Two kinds of film were used: Kodirex (Kodak) at a 5 sec. exposure, and Curix (Agfa Gevaert) at 16 sec. exposure.

The regular observations in En Gedi were conducted from 1972 through 1974. In Tel Aviv, the observations were conducted mainly during 1975. Occasional observations have been carried out throughout the mentioned periods in both places to date.

RESULTS

Nest substrates and structure

Under natural conditions, most nests are found in dead, dry wood. *X. pubescens* prefers soft wood; consequently most nests in the Arava valley are located in *Calotropis procera* (Ait.) and *Moringa peregrina* (Forsk.) Fiori, whereas along the coastal plain they abound in species of *Populus, Morus* and in *Robinia pseudacacia.*

Additionally, nests were found in a variety of soft timber and dead trees, including *Tamarix,* eucalyptus and palms. Poles made out of old agave flowering stalks, and hollow reeds (*Arundo donax* L.) are among the natural substrates used. The bees also use other, unnatural, materials for nesting. These include walls and bottoms of styrofoam boxes, plates of fiberboard (an insulating material made out of fine wood shavings), and the center core of old wooden yarn rollers.

The nests are located in protected places, such as the underside of logs, the shade of vegetation, or man-made structures. The bees usually dig a short entrance tunnel perpendicular to the grain of the wood, then turn and proceed to follow the grain in short (5-10 cm) tunnels. Occasional exceptions occur when the entrance hole is at the distal end of the single or biforked tunnel, in direct continuation with it. Such tunnels were found when nesting was done in cane, broken wood boards, or dry, cut agave flowering stalks.

Space permitting, a nest of *X . pubescens* is ramified. This is due to the manner of nesting in which each female digs several short tunnels containing 2-3 cells each (Fig 1). Except when nesting in cane, a number of nests may have a common exit hole which may be reached directly, or through a common tunnel (Fig 2A). In the latter case, more than one exit hole may exist. The number of cells does not change when nesting in unramified nests such as those in cane or in styrofoam. However, in that case there seems to be no definite pattern of digging and direction (Fig. 2B),possibly because no grain direction is present. The tunnels in the finished nests do not seem to differ in length (nest in dry wood - 60 cm.; 2 nest in styrofoam 67 and 68 cm.).

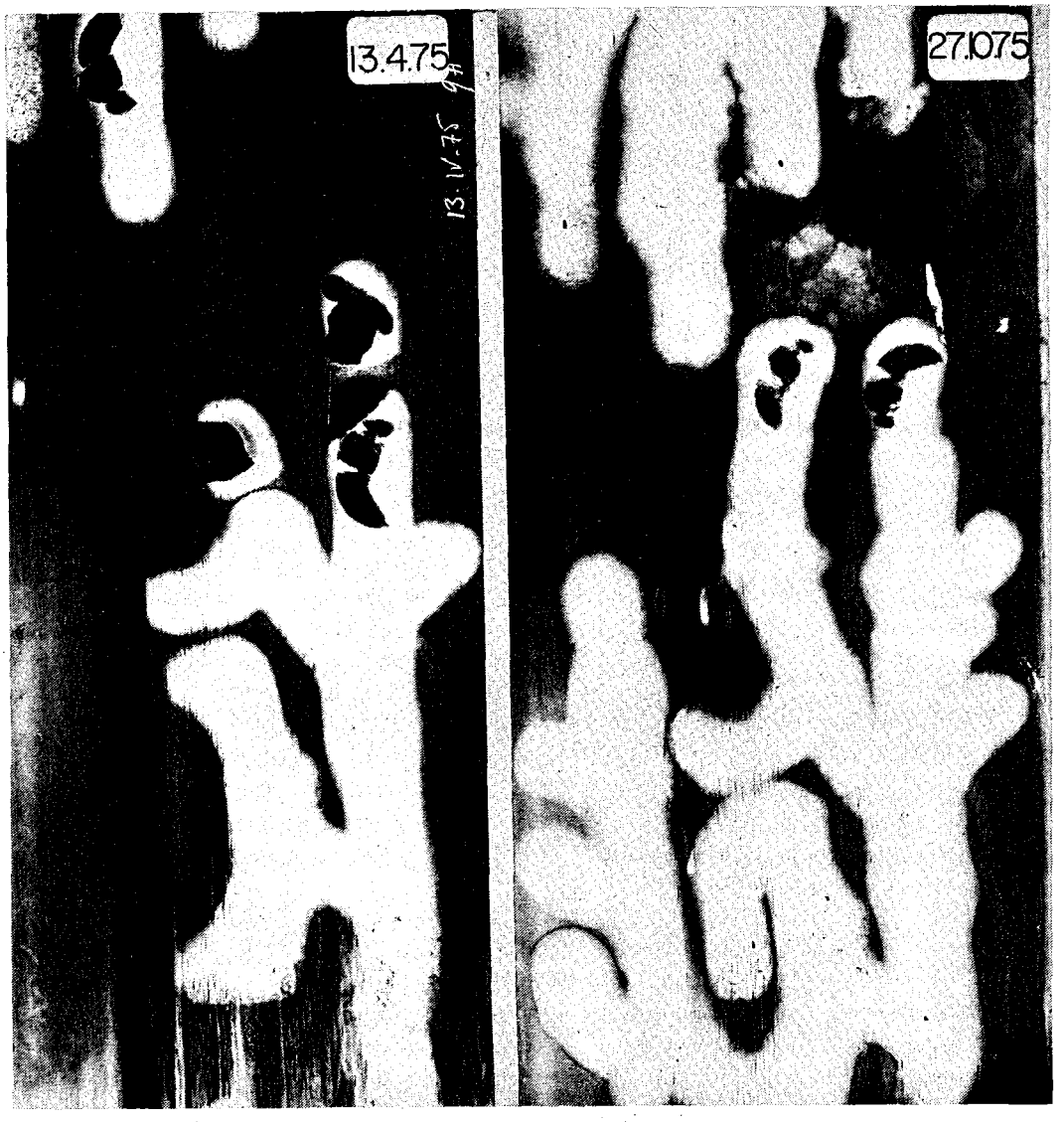

Fig. 1. X-ray radiogram of nest of *Xylocopa pubescens*, A- in April, beginning of season, B- in October, end of season.

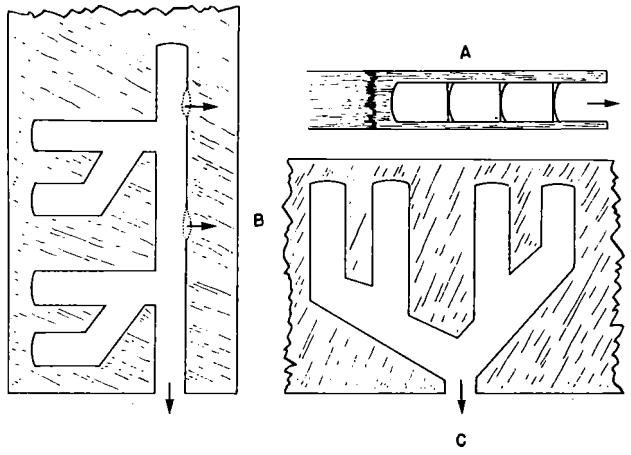

Fig. 2A. Ramifications (diagramatic) of nests of *Xylocopa pubescens*, A- in cane, B- in a log, into which auxilliary openings (dotted) have been dug following ramification of the nests, C- in a wooden log or board.

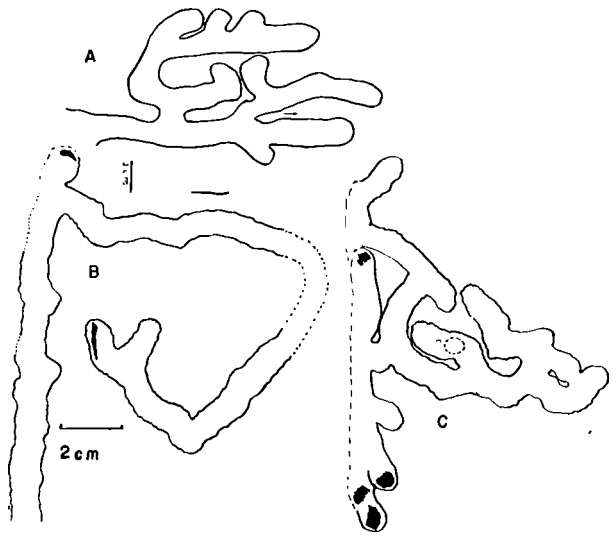

Fig. 2B. Extent of boring by *Xylocopa pubescens*, A- in poplar, B- and C- in styrofoam.

Tunnels in wood are reused, but not more than twice, or - in harder wood - three times. Elongation of the tunnel continues for a short while, but in no case reaches more than 90 cm. in length. The same substrate is often permeated by numerous nests, until it is structurally unsuitable for additional digging (Fig. 1B).

DISTRIBUTION

X. pubescens were found in the Sinai (A-Tor, Tarfat El Kadarin, Wadi Nasb) and throughout Israel. It ranges from Southeast Asia (Burma and Thailand) through Northeast and West Africa (Morocco and Cameroon) (Lieftinck, 1964).

NESTING AND DEVELOPMENT

The yearly cycle of *X. pubescens* varies somewhat from one place to another according to climate. However, the general pattern is as follows: mostly, unmated females pass the winter in old nests together with other bees that may or may not consist of sibs, of one or both sexes. Mating occurs in March and nest building, provisioning and egg laying proceed in March and April. First adult generation emerges 1½ - 2 months after oviposition. Following emergence, the progeny stay in the nest for a few days. Then they may leave and establish nests of their own, usually close to their mother's nest. Three overlapping generations are usually formed in this way (Fig. 3). Female longevity may reach 8

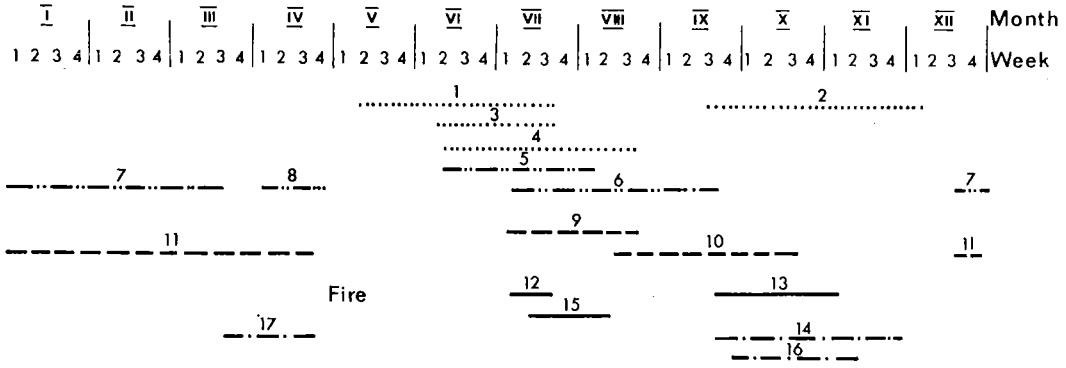

Fig. 3. Occurrence of marked bees, En Gedi 1972-1973, showing three overlapping generations. Each number signifies one bee.

months or more in overwintering females, but is shorter in the summer generation. If the founding mother of a nest dies before the Fall, one of her daughters probably occupies her nest. There are also cases in which more than one female occupies the same nest, particularly close to the end of the summer.

The bees do not undergo a diapause; they fly even in the winter during warm days, probably in order to feed. Cessation of the winter rest is probably related to temperature. We have no exact measurements to back this up, but in 1977, when a warm spell that lasted for approximately 2 weeks occurred in the Arava Valley during February, *X. pubescens* started nesting some 2-4 weeks earlier than their normal nesting time.

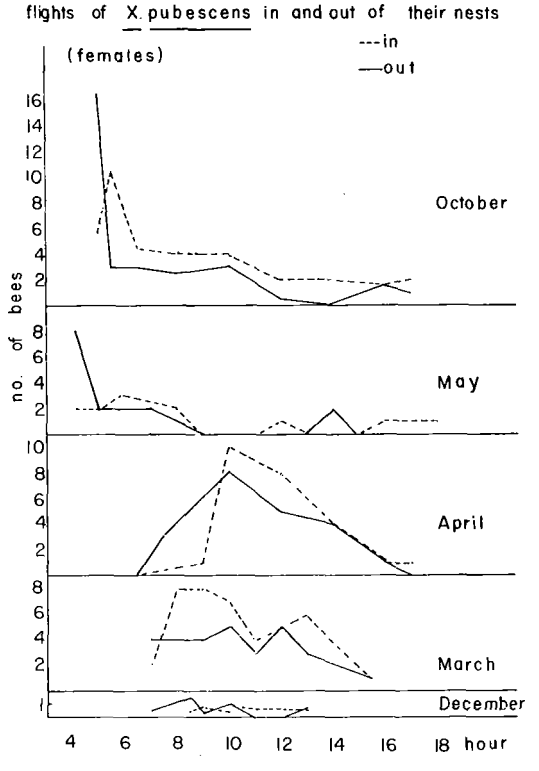

Fig. 4. Flights of *X. pubescens* in and out of nests; each monthly record is an average of 3 whole-day observations, En Gedi, 1972-1973.

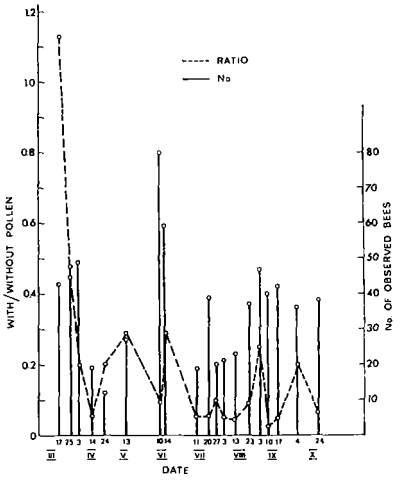

Fig. 5. Numbers of and ratio between pollen carrying and pollenless flights of *Xylocopa pubescens*, at En Gedi, 1972; whole-day observations on 10 bees or more.

Hours of flight changed throughout the season. In the winter, when only occasional feeding flights occurred, they seemed to be geared to the presence of the sun and took place during the morning and early afternoons (7:00 - 16:00 in November and 8:00 - 14:00 from December to February). The average number of bees was low and no preference was observed for any certain time. The number of bees leaving and entering nests rose during March and April, and a daily peak in activity was registered. At first it occurred in the warmer hours of the day, later it moved to the morning hours until it reached sunrise about the end of April. From May (Fig. 4) until the end of October, the main flight of the bees occurred about sunrise.

The intensity of nesting activity can be estimated from the amount of pollen-carrying trips in proportion to the trips without pollen (nectar carrying). In *X. pubescens*, pollen was carried to the nests mainly from March to November,

Month:		III	IV	V	VI	VII	VIII	IX
All trips	n	38	21	5	-	26	27	33
	$\bar{x}$	16.9	13.4	11	-	35.2	44.0	17.7
	sd	11.3	7.2	4.2	-	19.6	34.7	13.9
trips with pollen	n	17	6	1	-	2	3	3
	$\bar{x}$	15.6	10.8	10	-	60	67.6	16.6
	sd	6.9	2.0	-	-	-	63.5	5.7
trips without pollen	n	21	15	4	-	24	24	30
	$\bar{x}$	18.0	21.3	11.25	-	39.3	41.0	17.8
	sd	13.9	28.7	4.8	-	23.7	30.5	14.6

TABLE 1. Length (in minutes) of foraging trips of *Xylocopa pubescens*, at En Gedi, 1972.

	3rd and 10th September	17th September
n	20	13
$\bar{x}$	24.5	7.3
sd	14.2	2.6

TABLE 2. Length (in minutes) of foraging flights by *X. pubescens* during the first and third weeks of September.

but only during March did the ratio with/without pollen exceed unity (Fig. 5). This higher pollen-carrying activity in the spring is in accord with our observations indicating that although the bees nest throughout the spring and summer, most progeny are produced during the first generation.

The length of the foraging trips varied with the season. Trips were shorter in March, April and September than in July and August (Table 1). In September, the earlier trips were longer ($\bar{X}$ = 24.5 min) and the later ones, that were performed mainly by juveniles, were very short ($\bar{X}$ = 7.3) (Table 2).

Space for new cells is dug throughout the nesting period. Bees may dig and prepare the cavities either when no closed cells are present or, during the nesting period, parallel to occupied and sealed cells. In numerous cases observed, especially close to the end of the season, no nest occupation followed the excavation of a new tunnel.

We were able to follow 17 cases in which bee bread was prepared. The shortest time for this activity was 2 days. In several cases, it reached 9 or 10 days, and we assumed that this lengthy period was due to a delay in egg deposition on the ready bee bread. Old females, nesting from August on, may show abnormal behavior in regard to the bee bread preparation. This manifests itself by making incomplete bee bread, by joining partially complete bee breads into one, by depositing eggs on incomplete bee breads, and by depositing eggs on unshaped bee breads in unsealed cells.

The progeny remain in the cells, where they reach adulthood. In the last few days of the pupal life, the mother may manipulate them, after having broken the partition closest to her, by discarding some (sick or dead ones?) and pushing the rest together. Once emergence has started, the first to emerge breaks the partition and crawls out. In nests that are horizontal or pointed down, its sibs are then pushed into the empty cavity left at the distal end of the tunnel.

Females were usually faithful to their nests, and often intolerant of other individuals of their species trying to enter. However, the progeny might stay with the mother a few days or longer after emergence. The tolerance was sometimes also extended to other bees, as seen in a case (Fig. 6) when a female and then a male joined a nesting female close to the emergance of her progeny, and stayed there for some time after the emergence started. Occasionally, we found females entering more than one (alternating between 2) nest during the nesting period. Two such cases were followed. In each, the marked female had a "permanent" nest into which she usually flew. Yet, she was seen occasionally entering, staying in, and leaving a different nest hole.

BEHAVIOUR

Females often arrived directly at the nest, ready to enter. However, there were cases when manoeuvers were performed prior to entering the nest. These included hovering in front of the entrance, hovering in front of other entrances, and flying in to-and-fro patterns, that might or might not have been intercepted by occasional hovering. Fast-flying females sometimes flew in circles around the nest-site while facing it, before entering in rapid flight, or entered the thickets near the nests and flew there in circles for some time.

Each nest complex has one entrance hole, the use of which is limited to the resident females. The bees usually recognized their nest entrance, but occasionally they would enter another one - either intentionally of not. In another instance, the entering bee would realize her mistake and leave almost immediately. If the intruder continued to stay in the nest, the resident bee might react by buzzing and/or opening her mandibles. A short struggle might ensue and the invader usually would be evicted. Persistent invaders might

try to enter strange nests time and time again, with varying degrees of success.

At times, a bee would leave her hole but not fly out. Instead it would enter other nesting holes. Such wandering bees were seen being evicted from nests, but occasionally they were also spotted carrying off bee bread from a nest, whose resident was not present.

Except when on foraging trips, the females stayed in their nests. They were usually in the tunnels and out of sight. Occasionally they remained close to the entrance hole, either facing it or facing inwards, plugging the entrance with their abdomen.

When entering the nest with pollen, which is carried primarily on the hind legs, the females appeared to pull the appendages close to their body. Nevertheless, some pollen might be scraped off at the entrance and lost. Pollen-carrying females appeared to have occasional difficulties in entering their nests, and their attempts to enter would be accompanied by loud buzzing.

Moving of the bee-containing nests during the winter, from one location to another, usually does not disrupt successful nesting the following spring at the new location. Moving the nest during the nesting period does not disrupt normal nesting activities, when it is for very short distances only (1-2 meters), since the bees, which leave the nest without noticing its new location, are able to locate it in its new place after some search. Likewise, when the nests were removed at night to an entirely new location, most of the numerous nesting bees were able to continue nesting activities. The rest were presumably lost.

A few changes were made by us in order to test the bees' capability to recognize their nests. These consisted of altering the external surroundings by trimming the vegetation around the nest, or covering the hole area with a loose piece of paper, and of plugging the entrance itself with wood bark. The bees located their holes in all cases. They approached the paper-covered nests by crawling around and under the paper, whereas the bark-plugged holes were approached, and the bees attempted to dig and remove the bark. When unsuccessful, they left and flew off, whereupon we removed the bark from the holes. When the bees returned later, each found and entered its hole in the normal fashion.

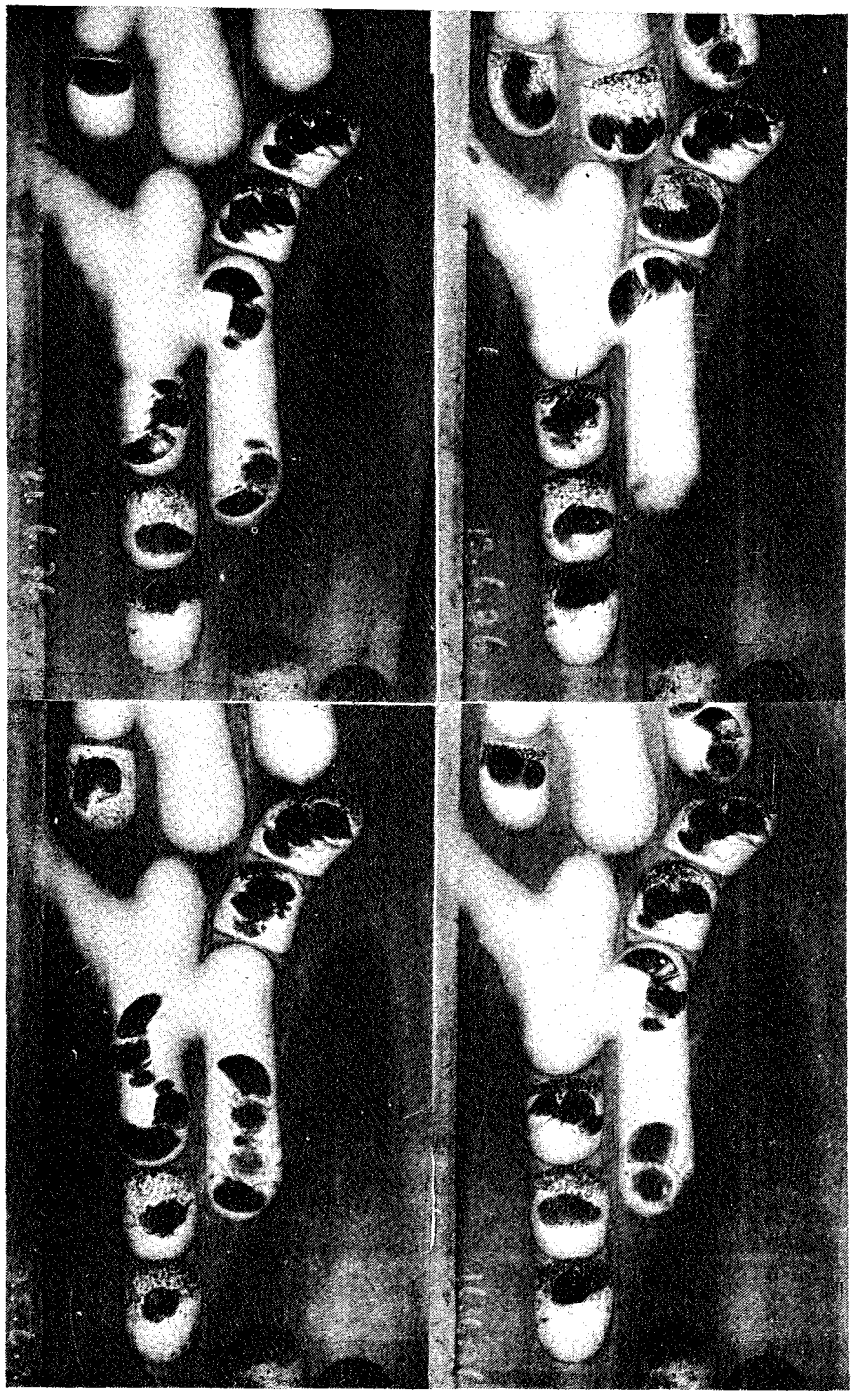

Fig. 6. X-ray radiogram of nest of *Xylocopa pubescens* showing the joining of bees to an active nest.

THE MALES

Both sexes develop in the same tunnels and emerge together. The males are distinguishable by a yellow-olive pubescence that covers them completely. They are somewhat smaller than the females and have a distincly narrower head. They are active in warm days from February till November, during which they do not live in nests with the females, but occupy various refuges, such as old nests and various holes in the vicinity of the active nest. The refuges usually harbor 2-5 males contemporaneously. Males often return to the same refuge after each flight, but occasional changes may occur. They may also prevent a second male from entering the refuge, or make unsuccessful, or successful (Fig. 6) attempts to establish themselves in nests that are occupied by females.

Males are primarily seen engaged in 2 activities: feeding, and territorial flights. The first takes place throughout the year, weather permitting; whereas the second is most prevalent in the early spring and summer. The territorial flights start with the onset of warm weather in February and March, and occur intermittently until November. They are very prevalent until April, when their frequency declines. From the middle of May on, a new peak of flights is observable, and another appears later, in August and Spetember. This temporal distribution of male activity coincides with the approximate development of the carpenter bee generations, and indicates that continuous emergence and mortality occur throughout the spring, summer and fall with 3 peaks of maximum emergence.

The territorial flight consists of to-and-fro flights, usually around branches of *Tamarix*, palm or acacia trees.

Flights were also seen about the tops of thickets of *Arundo donax* and other plants. The height of the flight varied from a few centimeters above the ground to several meters.

DISCUSSION

X. pubescens tends to nest in groups. When nesting in wooden logs, many nests are found in the same log. When they nest in thinner materials, the bees often occupy sites adjacent to each other. The inhabitants of one log were, in the cases examined by us, progeny of the same founding bee

that had established the first nest in that log. Within the nest, the *X. pubescens* female is solitary, while establishing her first spring generation. Later, from the time of progeny emergence till summer's end we can often see additional individuals (her progeny) in the nest. However, it is not clear if they participate in her various nesting activities.

Among the different kinds of nests, the ramified excavation in wood is by far the more abundant nesting form and constitutes a much more complex endeavor than the straight-tunnel nests. Likewise, the entrance hole that is perpendicular to the grain seems to be the regular form of gaining access to the ramified tunnels. The entrance hole that is in direct continuation with the nesting tunnel occurs mainly in hollow-stem and cane nests, and may be a secondary adaptation to this form of nesting. *X. pubescens* can possibly be regarded either as an opportunistic species that is able to utilize different substances for nesting and change its nesting habits accordingly, or is in the process of exploiting new nesting situations and spreading out into new niches due to genetic flexibility.

The fact that a single hole may serve as an entrance to more than one nest is economical in work and nest guarding possibilities. As seen, bees do rob each other's nests thus gaining easy access to food supplies, and possibly also in order to destroy other bees' progeny.

The shortest field trips were registered during March, April and September. The latter is not a "nesting month", and the bees probably cared only for their own nutrition.

March and April, on the other hand, are characterized by the most extensive nesting, and by the most intensive bloom of the local flora. Hence, we can find abundant food, many new nests, and probably also an acute danger of being robbed. The short field trips that are made possible by the abundance of food, probably help to minimize the danger of such theft.

During the summer the bees concentrate their collecting activity to the early morning hours. This has the advantage of cropping the fresh pollen and nectar of the flowers before the former becomes too concentrated and the latter is collected by others.

ACKNOWLEDGEMENTS

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