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THE SELECTION OF SHELTER PLACE BY THE HOUSE CRICKET

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Abstract. The stimuli acting upon the choice of shelter and resting place by the house cricket, *Acheta domesticus* (L.) were analysed. The places of preference in different types of terraria as well as the choice of tubes of different diameter and of various light conditions were investigated. *Acheta domesticus* avoids open and illuminated space in its choice of resting place. It prefers dark places, enclosed by walls, like a clefts or boxes. The influence of the conditions of environment configuration at the larval period of the crickets' development upon their subsequent preference as to rest place, has not been stated. Neither was this influence observed on their behavioural reactions as connected with the former. Crickets attain their ethological praeferendum of resting site owing to their innate photo- and thigmo-kinesis which are supplemented by hygrophilia and thermophilia. The influence of the group effect on the cricket's individual rate of development was confirmed.

INTRODUCTION

The body of most insects is generally well protected against the loss of water. This protection is of great biological importance in the case of insects living on land.

The integument of *Orthoptera* — despite its rather thick cuticle — has an increased permeability to water owing to the presence of numerous bundles of microscopic canals in its exo- and endocuticular layer, as well as to a comparatively insignificant content of lipids in its exocuticle (3). The process of transpiration seems to be actively controlled by the insect. The mechanism of this regulation is possibly connected with the change of stigma diameter (16). In *Orthoptera,* the loss of water may be compensated by the intake of an increased amount of food. If there is an abundance of water, those animals may stand starvation. A strong transpiration may involve a fall of body temperature caused by a rapid evaporation of water from its surface. Insects living in conditions of high temperature joined with relatively insignificant air humidity, show special adaptations or behavioural reactions which make possible their defence against the harmful overheating of their body. Buxton (5) stated that in the desert *Orthoptera* showing day activity (*Acrotylus, Sphingonotus, Erimiaphila*), body temperature is much lower than that of the earth surface, as a result of their high transpiration. Many desert insects, e.g., the species of the *Eugryllodes* group, are night active, burried in sand in the daytime.

Moreover there are appropriate taxes and kineses (12) characteristic for crickets (*Gryllidae*), which represent mostly hygrophilous and photophobic insect form. Their consequence is the reaction of sheltering in humid and dark places.

The house cricket, *Acheta domesticus* (L.) needs also a high level of humidity for its normal development and life. It follows from the studies of Kemper (17) that the considerable mortality and cannibalism of those insects is just the consequence of a relatively low air humidity. The house cricket is a shadow-searching form and shows a distinct negative photo-taxis (11). In natural conditions, the house cricket shows its highest activity at night, exactly between 19.00–24.00 h. In the daytime it is mostly hidden in its retreat. Crickets leave their shelters, also during the day; however, any sudden external stimulus makes them escape towards their shelter. The reaction of searching for any suitable dark shelter in the illuminated cage in the daytime is more distinct in females than in males. Also the evening activity is shown earlier by females than by males. They leave the dark corners and shelters, appearing even in places lighted by a lamp (25). In the light condition nearest to natural (day–night) it shows a distinct rhythm, with highest activity occurring immediately after dusk (10).

The principal aim of our research has been the ethological analysis of stimuli acting upon the choice of shelter and rest place by the house cricket *Acheta domesticus*, as well as answering the question whether that choice depends on individual experience acquired in ontogenesis or is rather genetically controlled.

Two series of experiments have been planned for studying the behaviour of the house cricket in its choice of shelter place and for establishing the characters of places preferred by that insect:

Series I: the study of places preferred in different types of terraria;

Series II: the choice of tubes of different diameter and of various light conditions.

Moreover, we aimed at elucidating the possible influence of the group effect and territorialism in the behaviour of the house cricket.

SERIES I. STUDIES CARRIED OUT IN DIFFERENT TYPES OF TERRARIA

Method

Five types of glass terraria of dimensions 32 × 19 × 25 cm were prepared for the experiment. They had metal frames 1.5 cm wide and transparent glass walls. The terraria differed from one another by their inside equipment:

terrarium I	earth layer (10 cm) at the bottom;
terrarium II	earth layer (10 cm) at the bottom and a match box (p);
terrarium III	thin layer of sand (0.5 cm) at the bottom;
terrarium IV	thin layer of sand (0.5 cm) at the bottom and a match box;
terrarium V	thin layer of sand (0.5 cm) at the bottom, cardboard stairs (s) 5 cm high, 15 cm long and 4 cm wide, with a match box on top.

In every terrarium there was a water bowl (w) and a small open feeder (k). Positions of match boxes which might serve as shelter for crickets, as well as positions of terraria in relation to the source of day light (window), are shown in Fig. 1. Crickets were fed with pellets for rodents and with fresh raw meat. Water was poured into the water bowls every day, and the earth layers in the terraria were sprinkled with water. Crickets were supplied twice a week with leaves of lettuce or of spiderwart. Temperature and relative air humidity in the experimental room were stable and amounted to 22°C and 65–70% respectively. Every morning the relative humidity of air in the terraria with soil (I and II) was measured by means of Assmann psychrometer just at the earth surface.

The first stage of the experiment lasted till the moment of reaching the imago stage by the insect. Into every terrarium, two cricket larvae of 10-days instar were placed on the 30th of March, 1972. Therefore, the sex distribution of crickets in the terraria was quite casual, as can be seen in Table I. Beginning with the 31st of March, 10 min inspections of the situation in each terrarium were made every week-day morning between 9 and 10 a.m. As the experiment period, which lasted to 29th September, comprised 150 week-days, as many records of each cricket have been made. For simplifying the observation of single in-

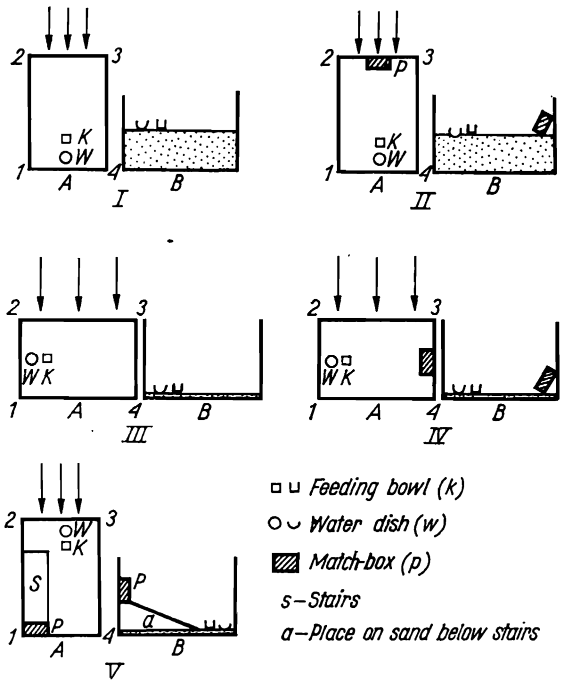

Fig. 1. Five types of terraria (I–V) with different inside equipment used in the series I of experiments. *A* — view from above; *B* — side view. Arrows indicate the direction of light coming from the window. Corners of the terraria are equally numbered, starting from the left one lying farther from the window.

dividuals, crickets were marked on thorax with "Wilbra" paints used for coloring leather.

In the second stage of the experiment the pairs of adult crickets were moved in various sequence into the remaining terraria. Considering the specific behaviour of insects in terraria with soil, the 1 and 2 cricket pairs were left in their "larval" terraria for another 2 wk after the last moulting. From the 30th of September up to the 17th of November,

TABLE I

Initial distribution of the crickets in the five types of terraria

No of terrarium	Specimens of *A. domesticus*, sex
I	pair 1 : A_1♀ and A_2♂
II	pair 2 : A_3♀ and A_4♂
III	pair 3 : A_5♂ and A_6♂
IV	pair 4 : A_7♀ and A_8♂
V	pair 5 : A_9♀ and A_{10}♀

A7♀ escaped on 30th September, only A8♂ participates further in the experiment

1972, all the insects changed their place of location four times staying for 8 days in each type of terrarium. On the first day of the experiment, observations were carried out at 1-hour intervals, later — 3 times a day at 9 a.m., 12 o'clock, and 3 p.m., each time for 10 min. Making observations during daytime in natural light conditions (day–night) enabled us to record the shelter places of the resting crickets. In the second stage of experiment, the terraria with soil were warmed during the day with refulgent lamps to test the behaviour of adult crickets in increased temperature. The routine measurements of air temperature and relative humidity in the terraria were continued. In the terraria I and II, the extremal air temperatures in the series were 27°C and 43°C, whereas the relative humidity ranged from 27% to 64%. However, in the terraria III, IV, V the temperature as well as the relative air humidity were more or less constant and amounted, similarly to the first stage of the experiment, to 22°C and 65–70% respectively.

Results

The results are presented in Fig. 2. The choice of place of sojourn and the initial behaviour of cricket larvae and, later on, of adult insects, were characteristic for each pair, especially for every terrarium type.

Cricket pair 1 was kept in the terraria according to the following sequence: I, V, IV, III, and II (Fig. 2). Crickets remained in terrarium I for the whole time of their larval stage and for two weeks of their imago stage. They remained most frequently in the dark corner 3. As adult insects, they rather preferred the dark corner 2. The female (A_1♀) once bored a hole in the humid earth near the water bowl. In the next terrarium — terrarium V — the male (A_2♂) found the box within 10 min, and he was seen in that place during all 27 consecutive observations of that series. The female, too, was seen 20 times in the box. In terrarium IV, A_1♀ as well as A_2♂ preferred the dark angle 3. However, already on its 2nd day in the new terrarium, A_2♂ stayed in the box, and was seen there later 9 times in 26 observations, whereas the female — only once. In terrarium III, the insects chose the dark corner 3 as their shelter place. Although in terrarium II A_1♀ entered the box already after 3 h, later on crickets were seen in this shelter only 3 times (out of 28 observations). They stayed most frequently in corner 2. Hole-digging was never observed in that terrarium.

Cricket pair 2. Sequence of sojourn in terraria: II, IV, V, III, I. The larval period and 2 weeks of the imago stage were spent by those insects in terrarium II. From the 33rd day of the experiment until their maturity both crickets stayed mostly in the box. They preferred that place also at their imago stage. The female (A_3♀) dug holes several times and found shelter in them. The male (A_4♂) was never seen in

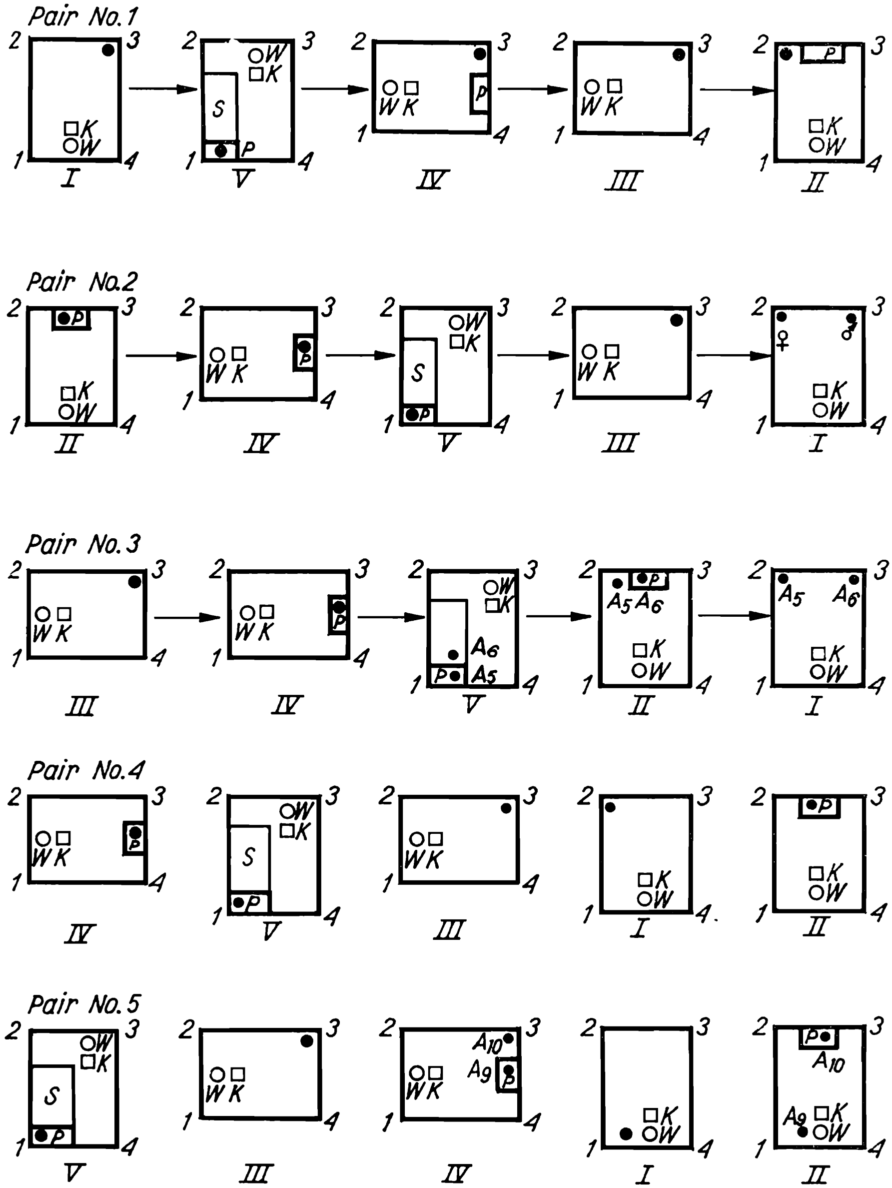

Fig. 2. Sequence of terraria types used in the series I of experiments. Places of sojourn of crickets are marked by black dots: small — 1 individual, larger — both individuals of the pair tested. For other explanations see Fig. 1.

the hole. In terrarium IV, the insects found the box just after 3 days and stayed there for the most part. Initially, the female was often found in the dark corner 3, whereas the male occupied the box from the beginning. In terrarium V, the crickets occupied the box placed on the stairs. The A_4♂ settled in the box after the first hour of its stay in that terrarium. The insects transported into terrarium III chose the shadowed dark corner 3. In terrarium I, the female mostly chose the dark corner 2, whereas the male stayed in corner 3. However, the male stayed more frequently on female territory in corner 2, than the female was seen on the male territory in corner 3. In that type of terrarium the insects never dug holes.

Cricket pair 3. Sequence of sojourn in terraria: III, IV, V, II, I. The larval period has been spent by those two males in terrarium III. There they decidedly chose the shadowed corner 3, where they stayed most often. After having been transported into terrarium IV, they found the box within 20 min, however, during the first 3 days the males stayed most often in the dark corner 3. Later on in all the subsequent observations they were found only in the box. The A_5♂ occupied the box just within 30 min of being transported to terrarium V, and in all the subsequent observations he was either in the box or near that hiding place. A_6♂ appeared in the box later, after 4 h, but did not stay in it permanently. He often remained on the stairs near the box, on the sand under the stairs or in the dark corner 3.

An aggressive reaction of A_5♂ was twice observed in the moment when A_6♂ approached the box, previously occupied by A_5♂. The existence of territory among male house crickets is proved by the distribution of places in terraria into which those insects had been successively transported. In terrarium II, A_6♂ occupied the box, whereas A_5♂ stayed most often near this refuge. Both males were observed only 5 times (out of 25 observations) sitting together in the box. In terrarium I, A_5♂ occupied the dark corner 2, and A_6♂ — the dark corner 3. In terrarium I, the crickets once only dug a hole 2.5 cm long and 1.5 cm wide.

Cricket pair 4. Sequence of sojourn in terraria: IV, V, III, I, II. At their larval stage the crickets stayed in terrarium IV, mostly in the box, already from the 17th day of observation. The male A_8♂, after having been transported subsequently into terrarium V, occupied the box on the following day and stayed mostly inside or near it. (Remarks concerning the female A_7♀ are enclosed in the paragraph on methods). In terrarium III, the cricket chose decidedly the dark corner 3. In terrarium I, he was most frequently found in the shadowed corner 2

TABLE II

Frequency (%) of choice of resting site by five

Terrarium	Form	Wandering	Place of sojourn							
			Sitting/							
			corner				wall			
			1	2	3	4	1-2	2-3	3-4	4-1
I earth	larvae	14.3	19	6.7	34.3	23	0	0	0	0
	imagines	33.7	8	23.3	13.4	2.7	0	0	0	0
II earth and box	larvae	9.4	6.3	6.3	3.3	0.7	0	2	0	0
	imagines	16.7	4	10.7	2	3.6	0	0	0	0
III sand	larvae	7	1	14.3	73.7	0	0	0	0	0
	imagines	25.8	4.7	4.1	53.4	8.8	0	0	0	0
IV sand and box	larvae	7.3	0	1.7	0	0	0	0	0	0
	imagines	20.2	2.4	1.4	33	3.7	0	0	0	0
V sand, stairs and box	larvae	0.7	0.3	0.3	0.3	0	0.7	0	0	0
	imagines	12.1	2.5	2	4.8	0	0	0	0	0

On the second day of sojourn in that terrarium the cricket dug a small hole 1.5 cm long in the moist earth near the water bowl and he was seen there several times in the course of observation. In terrarium II, the cricket preferred initially corner 1 and occupied the box only on the fifth day of its sojourn in the terrarium. He was found in the box on all the subsequent days of observations.

Cricket pair 5. Sequence of sojourn in terraria: V, III, IV, I, II. The entire larval stage was spent by the insects in terrarium V. During the first 29 days of observation they were sitting on the sand below the stairs. In the subsequent observations they stayed nearly exclusively in the box. After having reached the imago stage, 2 females were transported into terrarium III and remained there most often in the shadowed corner 3. In terrarium IV, A_9♀ found the box already on the first day in 3 h, hid itself in it, and stayed there most often. A_{10}♀ stayed in the dark corner 3, and only on the two last days of her sojourn in that terrarium she was found in the box together with A_9♀. The crickets transported to terrarium I stayed mostly on humid soil near the water bowl. In terrarium II, A_9♀ was found most often on humid earth near the water bowl and there she dug her hole, whereas A_{10}♀

TABLE II

pairs of crickets in each type of terrarium

of crickets											
staying										laying eggs	Sum
in a box	at a box	on the stairs	under the stairs	in a hole	at a hole	digging a hole	eating	drin-king	at water		
—	—	—	—	0	0	0	1.7	0	1	—	300
—	—	—	—	2.4	0.8	0.4	3.1	1.1	10.7	0.4	261
61.4	6.3	—	—	0	0	0.3	3.7	0	0.3	—	300
37.5	10	—	—	2	0	0.4	1.6	0	10.7	0.8	251
—	—	—	—	—	—	—	4	0	0	—	300
—	—	—	—	—	—	—	1.6	1.6	0	0	193
80.3	10.4	—	—	—	—	—	0.3	0	0	—	300
35.9	2.4	—	—	—	—	—	0.5	0.5	0	0	212
73	0	2.7	22	—	—	—	0	0	0	—	300
59.7	12.6	1	4.8	—	—	—	0.5	0	0	0	191

was found in the box already on the second day at 9 a.m. In that place or near it, A_{10}♀ was to be found in the course of subsequent days of observation. A_9♀ was never seen in the box.

The results are presented in Table II.

In choosing their resting place in the 5 terraria, the 5 cricket pairs showed no essential differences of behaviour (Fig. 3). The consecutive pairs inhabiting the particular types of terraria chose the same hiding places independently of the sequence of sojourn in various types of

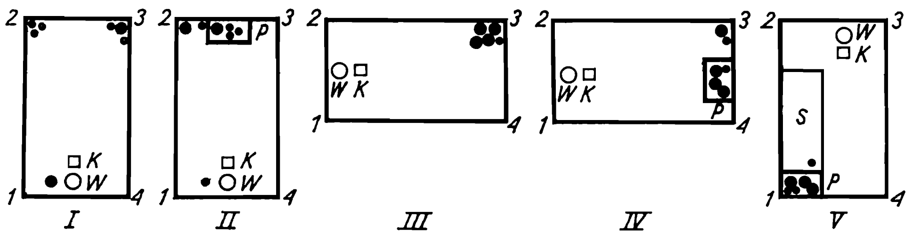

Fig. 3. Cumulative diagram of sites preferred by all the crickets used in the experiment with five terraria (I–V) in all tests. For explanation of symbols and letters see Fig. 1 and 2.

terraria. As shown on Fig. 2, irrespective of rearing conditions, the crickets transferred into another terrarium furnished with an empty match box (terraria II, IV, V) — in the majority of cases soon chose the box as a hiding place and remained there. However, in terraria without any hiding places, the crickets preferred the most shadowed spots. They selected, for instance, the corners 2 and 3 in the terraria I and III, where the metal frames shielded a certain area from the light (Fig. 3). Such a behaviour was characteristic for larvae as well as for adult insects.

Crickets placed in terraria in pairs kept always together. It was especially striking at their larval stage. About 70% of them were found in the box or in the corner of the terrarium sitting side by side. As imagines, crickets remained mostly together. Only in the cases when two males (A_5♂, A_6♂) or two females (A_9♀, A_{10}♀) composed one pair, the situation was different. On 10 to 12 day after their last moult, the circkets stayed in different places, e.g., one of them occupied the box in the terrarium, whereas the other stayed in one of the terrarium corners.

The observed aggressive reactions of A^5♂ against A^6♂, when the latter tried to enter the box already occupied by the former, were very characteristic. The cricket defending his hiding place protruded half of his body, dilated widely his mandibles, his body performed violent forward and backward movements and his tegmina (fore-wings), raised highly, produced an aggressive song (4). A_6♂ tried to approach the box, but at such symptoms always withdrew. A fight of males has never been observed. Aggressive behaviour among females was not observed either.

The fact that in each terrarium individuals of the same sex kept to a different place is evidently connected with the territorialism of adult individuals of *Acheta domesticus*. Such a behaviour of two males was observed by me 2 wk after their imaginal moult. The reaction of defence of one male's own territory against the other male was very clear in this experiment. The intolerance was apparently directed only against individuals of the same sex.

In the terraria I and II, with the bottom covered with a thick layer of earth, the crickets dug holes several times. These were corridors directed downwards and slightly obliquely, 1 to 1.5 cm wide and no longer than 4 cm. In relation to the total number of observations, the cases when crickets were found digging holes or staying in them were rather few. Maybe they do that after sunset, being insects of nocturnal activity. The experiment has not provided a direct answer to the question why the crickets sometimes dig holes. Temperature and relative air humidity seem to be the factors of essential influence upon the matter.

Table III presents examples of relative air humidity as well as temperature at which the crickets dug holes. When the air humidity was lower, they did not dig holes even if air temperature was still high (30–40°C). No observations were carried out at a higher air humidity. It was observed in 3 cases that holes appeared after a rather abrupt decrease of air humidity and increase of temperature as compared to the preceding day (see Table IV). In one case, however, even after a significant fall of relative air humidity (RH) and a simultaneous rise of temperature (RH: $38\% \rightarrow 28\%$; temp.: $36°C \rightarrow 42°C$), the crickets failed to dig holes.

TABLE III

Microclimatic conditicns in the terraria I and II on the days when the crickets were digging holes

Relative air humidity at the earth surface (%)	33	37	38	39	41
Temperature of the surface layer of soil (°C)	43	42	43	31	36

TABLE IV

Diurnal changes of microclimatic conditions in the terraria I and II on days prior to hole--digging

Relative air humidity (%)	Temperature (°C)
$52 \rightarrow 39$	$27 \rightarrow 31$
$56 \rightarrow 38$	$37 \rightarrow 43$
33	$37 \rightarrow 43$

The experiment yielded an additional result concerning the group effect in the crickets. It appeared that the larvae of *Acheta domesticus* used by us for the experiment in different types of terraria, reached the imago stage only after 6 mo, whereas the individual development of insects from our mass culture lasts on the average only 2.5 mo.

SERIES II. EXPERIMENT WITH TUBES

Method

Thirty adult individuals of *Acheta domesticus* (15♀♀ and 15♂♂) were used in the experiment. The experiment was performed in three stages at a uniform temperature and relative humidity of the air, maintained on the level of 23°C and 65–70% respectively. The whole experiment comprised 38 days of observation on week-days between 11th April to 30th May 1973. On a 1 cm layer of sand in a glass terrarium of dimensions 32 × 19 × 25 cm, there were placed glass tubes 8.5 cm long of the following diameters: Tube 1 — 4.0 cm, Tube 2 — 2.5 cm, Tube 3 — 2.0 cm and Tube 4 — 1.5 cm.

In the stage I of the experiment one set of those tubes was lined inside with transparent plastic foil, another one with black paper. After 10 days the arrangement of tubes has been changed, as well as the position of water container and feeder. Automatically controlled light conditions (LD 12 : 12) were provided by means of a 75W bulb fixed ca 1 m above the floor of the terrarium. This stage lasted from 12th April to 11th May, comprising 22 days of experimenting. The number of crickets staying in the tubes and in the open area was recorded 3 times a day, at 9 a.m., 12 o'clock, and 3 p.m.

That stage of experiment was additionally carried out in the same conditions in a separate terrarium with only one pair of crickets: a male and a female, to get the reference data on the crowd effect on the behaviour of imagines.

Fifty five records were made during the stage I of the experiment. As no statistically significant differences appeared in the distribution of crickets between subsequent observations, the duration of the two next stages was considerably reduced.

In the stage II of the group experiment which lasted for 10 week-days, from 12th up to 23rd May, only transparent tubes covered with plastic foil were used. The stable light was on for 24 h (conditions LL). During that stage only 26 observations have been made as no change of conditions was introduced.

The stage III has been carried out in permanent darkness (conditions DD). Just for the time of observation, a dim dark-room lamp was switched on, in such a position that the light did not fall directly upon the terrarium because the dark adapted crickets react to sudden illumination by violent movements and jumps — by escaping. Other conditions of the experiment remained unchanged. The experiment was repeated 16 times in the same conditions between 24th and 30th May.

Before each consecutive stage of the experiment, the glass tubes and foil were thoroughly washed with water and rinsed with alcohol.

Results

At the time of observation, during stage I of the experiment (LD), the majority of crickets (35.8%) stayed in the open area: 29.7% of insects occupied the opaque Tube 1 of the largest diameter. The frequency of seeking protection in other dark tubes was slightly lesser among the insects, and tubes of all diameters were equally preferred. The crickets were very rarelly found in transparent tubes (Table V).

The change of tube position in the terrarium had no effect upon their choice. During the experiment on a single cricket pair, the insects were generally found in the same opaque Tube 4 in all the 30 tests (Table VI).

TABLE V

Choice of resting place by 30 house crickets in stage I of experiment with tubes

Type	Frequency of sojourn (%)				
	Tube: number/diameter				Open area
	1 4.0 cm	2 2.5 cm	3 2.0 cm	4 1.5 cm	
transparent	0.3	0.5	0.3	2.1	35.8
opaque	29.7	10.1	8.5	12.7	

In stage II, when the terrarium was illuminated for 24 h (LL) and all the tubes were transparent, the majority of insects (74%) stayed permanetly in the open area. Those which looked for shelter in the tubes, occupied first of all type 4 tubes which had the smallest diameter.

TABLE VI

Distribution of sojourn of 2 house crickets (♂ and ♀) in various sites in stage I of experiment with tubes

Sex	Type	Frequency of sojourn (%)				
		Tube: number/diameter				Open area
		1 4.0 cm	2 2.5 cm	3 2.0 cm	4 1.5 cm	
♂	transparent	0	0	0	0	3.3
	opaque	0	0	3.3	93.4	
♀	transparent	0	0	0	0	33.3
	opaque	0	0	0	66.7	

Similar results were obtained in the third stage of the experiment (DD). In this case, also 74% of crickets were found out of tubes. The choice of tubes was inversely proportional to their diameter. Small diameter tubes were more often occupied by the crickets than the large diameter ones (Table VII).

In the course of observations, several crickets were often found there together in opaque tubes. It was surprising how many of them could stay in one place in a restricted space: we found 4, 5 and even 6

TABLE VII

Choice of resting place by 30 house crickets in stage II and III of experiment with tubes

Stage of experiment and light conditions	Frequency of sojourn (%)				
	Tube: number/diameter				Open area
	1 4.0 cm	2 2.5 cm	3 2.0 cm	4 1.5 cm	
Stage II (LL)	2	6	4	14	74
Stage III (DD)	1.5	5	9.5	10	74

crickets in the smallest diameter tube of a volume of 4.8 cm^3 only.

The results of the experiment with one pair of crickets proved that, in contrast to the female, the male left his shelter (the opaque Tube 4) very rarely. For 30 individual observations, only twice the male was found outside the tube. The female was found as often as 10 times outside the tube.

DISCUSSION

The problem of rest and the related problem of the insects' behaviour in selecting their place of shelter have rarely been the subject of experimental research.

It follows from the works of Tsutsumi (30, 31) on *Musca domestica* L., that the activity level of the fly, the beginning of the rest period and the lenght of its duration as well as the choice of resting place, depend on physiological state of those insects and on their diurnal rhythm which, in turn, may be controlled by the change of illumination in the cage.

Our observations confirmed the results of other authors (1, 6, 7, 11, 17, 25) and in some points brought interesting new results. *Acheta domesticus* selecting a rest-place shows preference not only to dark places, but to places limited by walls, like a cleft or a box (see Fig. 2 and Table V).

As known, there are two fundamental innate forms of behaviour which make the organism remain in its praeferendum, i.e., a place with preferred intensity of external factors (light, temperature, humidity). One of them are kineses (12), the other is tactic behaviour, i.e., elasis (8) based on tropotaxis (19). However, the latter leads to extremal intensities of the acting external stimulus. Consequently, only the negative elasis has an adaptative character (32). The positive elasis may lead to dangerous conditions in the case of a too high intensity of stimulus. However, in the intensity range of climatic agents taking place in natural circumstances, the occurring of the animal (especially of an invertebrate) in the ecological optimum may be also a consequence of positive tactic behaviour related to those factors (see 8, 27).

Federhen (11) showed that the choice of dark places for rest by the house cricket is, before all, the result of negative photo-taxis of that insect. Negative photo-taxis is characteristic for the adult crickets as well as for their larvae. *Acheta domesticus* shows besides the so-called "high thigmo-kinesis" (12), and its hiding in dark refuges is a result of escape from light. It seemed interesting to study this inclination in crickets choosing their hiding place. Such studies were carried out by Tsuji and Mizuno (29) on the cockroach *Periplaneta fuliginosa* S. and later on three other species: *Periplaneta americana* (L.), *P. japonica* Karny, *Blattella germanica* (L.) (23). The results were the same for the three species of *Pariplaneta*. The adult individuals decidely preferred tubes 1 cm in diameter to those of 2 cm and 0.5 cm. However, the larvae of those species mostly chose narrow diameter tubes. Groups as well as single individuals of *Blattella germanica* chose the tubes of a 0.5 cm diameter. So it may be postulated that in those tests the cockroaches are ruled by the "low thigmo-ortho-kinesis": their mobility diminishes under the influence of a touch contact.

Our experiments with dark and transparent tubes in various light conditions, performed in the same manner as the Japanese ones, although planned independently of them — showed an interaction of the light influence and of the contact with walls on the behaviour of the house cricket. The results of our experiment II are in accordance with the studies of Federhen (11): *Acheta domesticus* shows the so-called "high thigmo-ortho-kinesis", according to the terminology of Fraenkel and Gunn (12). That means that the mobility of individuals increases after contact with a hard object, which is demonstrated by a high percentage of cases (35.8–74%) where the insects were found in the daytime in an open space, as well as by the highest percentage of crickets ($\approx 30\%$) found in the stage I of the experiment in the largest opaque Tube 1 (see Tables V and VII). It was also proved that in the II (LL) and stage III (DD) of experiment II with tubes, the majority of insects were found not in the tubes but in the free space, as was also observed by Mizuno and Tsuji (23) on *Blattela germanica.*

The staying of crickets in transparent lighted tubes (stage I, Table V) similarly as in the stage II (Table VII), may presumably be considered accidental. An analogous case is their sojourn in tubes in darkness which is proved by a similar percentage of crickets which stayed in various tubes (stage III, Table VII). The results presented in Table V and VI indicate, however, the non-causal sojourn of crickets in opaque tubes. This might be interpreted as a result of the prevalence of shadow preference over a high thigmo-ortho-kinesis in the species. It may be presumed that the crickets penetrated into dark tubes by a random movement, and were retained inside by the factor of high photo-ortho-kinesis. Those simplest mechanisms would be sufficient for the interpretation of experimental facts. Since the narrowest tube is darkest, it has the strongest shadow attraction; therefore the majority of individual crickets were found there (Table VI). In some tubes where several crickets were present (I stage), their bodies might reduce the intensity of light which might explain the observed distribution of individuals in the tubes as presented in Table V.

As it was mentioned, temperature has a significant influence on the behaviour of *Orthoptera* and, consequently, upon their choice of resting place. The house cricket is a thermophilous species (9, 11, 17). It follows from the studies of Herter (15) that optimal day temperature is a few degrees higher than the optimal night temperature, and they amount to 27°C and 23.5°C respectively. However, Remmert (25) failed to confirm it, and stated that the optimal temperature for *Acheta domesticus* is 32°–33°C. Even after a short period of cooling, crickets placed in an environment of higher temperature quickly approach the source of warmth. As was shown by Federhen (11) the positive thermotaxis dominated distinctly over the negative photo-taxis of that insect. So the cricket may pass from a place which is dark and cooled with ice to a cage illuminated by sun rays. Thus, the presence of numerous photophobic crickets in the open area may be explained by the thermophilia of those insects. At the Ist stage, as well as at the IInd stage of the experiment with tubes, a lamp was used to illuminate of the terrarium. When lamp was switched off, the night temperature of sand fluctuated between 22°–25°C, whereas in the daytime — with the lamp lighted — it rose up to 28°–31°C.

Another cause of dispersion of the house crickets in tubes may be their rather well-marked territorialism, which is illustrated by the fact that in the IInd and IIIrd stage of experiment II only one or two crickets were most often found in one tube. Possibly those insects defended the entrance to their hiding place against other crickets.

Usually, in laboratory mass cultures, the aggressiveness of crickets is almost entirely extinct, and for that reason territorialism does not exist among those insects. Our results (series I of experiments) show, however, that if two crickets inhibit a sufficiently large space, they assume territories. The observations of insects in the series I of the experiments and in the experiment with the selection of tubes by 1 pair of crickets indicate that the males are much more aggressive than the females of the species. This explains the behaviour of insects connected with the defence of their territory. In the case of *Acheta domesticus*, the male — owner of the territory — usually defends it against another male, and he allows a female or larva to stay in it.

Consistent with the "Aschoff's rule" (2) crickets, as night active animals, show a circadian rhythm shorter than 24 h in a permanent darkness. Its duration is prolonged in a stable light (24). It is possible that the final results of the IInd and IIIrd stage of experiment II were influenced by a factor unsettling the resting behaviour in consequence of a disturbance of the diurnal rhythm (24 h of light during 12 days and 24 h of darkness for 7 days). No essential difference was observed in the behaviour of crickets on the first and last day of the consecutive stages.

Having the choice of places with a different degree of humidity, the house crickets — imagines as well as larvae — prefer those with a high relative humidity (11). Our above-described experiments, with the choice of place in different types of terraria — show also a distinct hygro-kinesis of the house cricket. In terraria I and II, heated in the daytime with an infrared bulb, i.e., in a place where the relative air humidity decreased constantly, crickets were often found sitting near the water bowl on the moist earth. One of the fundamental factors evoking the reaction of hole-digging by the house cricket seems to be a sudden fall of the relative air humidity.

A characteristic property of *Acheta domesticus* as revealed in both series of experiments, is their inclination to aggregate. In our culture cage, 10 adult individuals and larvae could sometimes be found in a single match-box. Similar facts were stated by Mizuno and Tsuji (23) on *Blattella germanica,* although is seems that here the aggregation of imagines is not a result of interaction between single individuals, because two adults, when tested in the same container, were usually found in separate tubes or out of them. The larvae tended to coexist in one of the tubes. The simplest interpretation of our results is that the observed accumulation of insects should be classified as a usual aggreagation, i.e., a result of simple behavioural mechanisms, making the crickets to strive for the optimal conditions (9). According to Grassé (13), such tendency of accumulation depends on taxes and kineses characteristic for crickets and is not a result of a gregarious instinct. The results of the latest studies indicate, however, that individuals of both sexes of *Acheta domesticus* produce the aggregation pheromones (28).

Basing on the division of social groups of invertebrates proposed by Le Masne (20), the aggregations of crickets may be included into the so-called non-coordinated and temporary groups. Nevertheless the activity of isolated crickets falls violently. The question arises whether the so-called "group effect" is observed here. This notion means the increase of the biotic potential of insects evoked by a definite and species-specific intensification of contacts with the individuals of the same — or also some other — species (21). The real group effect takes place only in the case when an insignificant number of animals, not overcrowded, live together having a surplus of food at their disposal (6).

As compared with single-reared larvae of *Acheta domesticus*, the more rapid individual development was observed in those living in groups, which agrees with the results obtained by Chauvin (7) with the same species as well as with *Gryllus bimaculatus* de Geer. The group effect is thus an important element in the individual development of crickets.

The problem of group effect is not, so far, sufficiently explanied. It is known that the sensory stimuli evoking the group effect are transmitted by the antennae and cerci of insects (7). According to the more recent studies of McFarlane (22), the more rapid growth and development of crickets in the mass cultures is evoked by pheromones produced by those animals. It may be very broadly said that, the neuroendocrinal system of the insect has a principal part in evoking the group effect. In insects, the changes are controlled by neural impulses evoked by a definite intensity of contacts of the individual with its conspecifics (21).

The concept of group effect should be distinguished from the so-called "mass effect" (14) or "interference effect" (26). The "mass effect" is the negative action of overcrowding. As was ascertained by Chauvin (7), the number of cricket larvae higher than 2–3 individuals on an area of about 30 cm^2 caused an effect opposite to the group effect, i.e., the delay of growth.

The preference for definite places in the five types of terraria did not depend on the course of our experiment, i.e., on the history of the given pair of crickets (see Fig. 2). The influence of the conditions of environment configuration at the larval period of the crickets' development upon their subsequent preference of rest place (box, stairs etc.) was never observed. Neither was this influence observed on other behavioural reactions of the insects (digging holes, climbing stairs to their hidding place) as connected with the former. It should be concluded that the gnostic and motor areas (18) of the brain of *Acheta domesticus* are innately preformed and fail to develop in ontogenesis. Crickets attain their ethological praeferendum of resting site owing to their innate photo- and thigmo-kinesis, which are supplemented by hygrophilia and thermophilia.

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REFERENCES

1. ALEXANDER, R. D. 1961. Aggressiveness, territoriality and sexual behavior in field crickets. Behaviour 17: 130–223.
2. ASCHOFF, J. (ed.) 1965. Circadian clocks. North-Holland Publ. Co., Amsterdam. 479 p.
3. BEIER, M. 1972. *Saltatoria* (Grillen und Heuschrecken). Handbuch der Zoologie 4 (2), 2/9: 1–217.
4. BUSNEL, R. G. (ed.) 1963. Acoustic behaviour of animals. Elsevier, Amsterdam. 933 p.
5. BUXTON, P. A. 1924. Heat, moisture and animal life in deserts. Proc. R. Soc. (London) 96*B*: 123–131. *Quoted* Chopard (9).
6. CHAUVIN, R. 1952. L'effet de groupe. Coll. Int. C.N.R.S. Structure et physiologie des sociétés animales. 34: 81–90.
7. CHAUVIN, R. 1958. L'action du groupement sur la croissance des grillons (*Gryllulus domesticus*). J. Insect Physiol. 2: 235–248.
8. CHMURZYŃSKI, J. A. 1973. Photic reactions in flies (in Polish). Nencki Inst. Exp. Biol., Warsaw. 94 p.
9. CHOPARD, L. 1938. La biologie des Orthoptères. Lechevalier, Paris. 549 p.
10. CYMBOROWSKI, B. 1969. The effect of light on the circadian rhythm of locomotor activity of the house cricket (*Acheta domesticus* L.). Zool. Pol. 19: 85–95.
11. FEDERHEN, M. T. 1955. Zur Biologie und Physiologie der Hausgrille. Z. Angew. Ent. 38: 224–244.
12. FRAENKEL, G. S., and GUNN, D. L. 1961. The orientation of animals. Kineses, taxes and compass reactions. Dover Publ., Inc., New York. 376 p.
13. GRASSÉ, P. P. (dir.) 1949. Traité de zoologie. Vol. 9 Masson et Cie Éditeurs, Paris. 1117 p.
14. GRASSÉ, P. P., and CHAUVIN, R. 1944. L'effet de groupe et la survie des neutres dans les sociétés animales. Rev. Sci. 82. *Quoted* Leśniak (21).
15. HERTER, K. 1923. Untersuchungen über den Temperatursinn der Hausgrille (*Acheta domestica* L.) und der roten Waldameise (*Formica rufa* L.). Biol. Zbl. 43: 282–285. *Quoted* Beier (3).
16. JAKOVLEV, V., and KRÜGER, F. 1954. Untersuchungen zur Transpiration der Hausgrille (*Gryllus domesticus* L.). Z. Vgl. Physiol. 37: 57–77.

17. KEMPER, H. 1937. Beobachtungen über die Biologie der Hausgrille. Z. Hyg. Zool. 29: 69–86.
18. KONORSKI, J. 1967. Integrative activity of the brain. An interdisciplinary approach. Univ. Chicago Press, Chicago. 531 p.
19. KÜHN, A. 1919. Die Orientierung der Tiere im Raum. Gustav Fischer, Jena. 71 p.
20. LE MASNE, G. 1952. Classification et caractéristiques des principaux types des groupements sociaux réalisés chez les Invértebrés. Coll. Int. C.N.R.S. Structure et physiologie des sociétés animales. 34: 19–70.
21. LEŚNIAK, A. 1974. Group effect in insect populations (in Polish, English summary). Wiad. Ekol. 20: 14–20.
22. McFARLANE, J. E. 1966. Studies on group effects in crickets. I. Effect of methyl linolenate, methyl linoleate, and vitamin E. J. Insect Physiol. 12: 179–188.
23. MIZUNO, T., and TSUJI, H. 1974. Harbouring behaviour of three species of cockroaches, *Periplaneta americana, P. japonica*, and *Blattella germanica*. Jap. J. Sanit. Zool. 24: 237–240.
24. NOWOSIELSKI, J. W., and PATTON, R. L. 1963. Studies on circadian rhythm of the house cricket, *Gryllus domesticus* L. J. Insect Physiol. 9: 401–410.
25. REMMERT, H. 1960. Über tagesperiodische Änderungen des Licht- und Temperaturpräferendums bei Insekten (Untersuchungen an *Cicindela campestris* und *Gryllus domesticus*). Biol. Zbl. 79: 577–584.
26. SCHWERDTFEGER, F. 1957. Die Waldkrankheiten. P. Parey, Hamburg-Berlin. 543 p. *Quoted* Leśniak (21).
27. SCHWERDTFEGER, F. 1963. Ökologie der Tiere, Bd. I. Autökologie. P. Parey, Hamburg 461 p.
28. SEXTON, O. J., and HESS, E. H. 1968. A pheromone-like dispersant affecting the local distribution of the European house cricket, *Acheta domestica*. Biol. Bull. 134: 490–502.
29. TSUJI, H., and MIZUNO, T. 1973. Behavioural interaction between two harbouring individuals of the smoky brown cockroach, *Periplaneta fuliginosa* S. Jap. J. Sanit. Zool. 24: 65–72.
30. TSUTSUMI, C. 1966. Studies on the behavior of the housefly, *Musca domestica* L. I. The behavior and activity patterns under experimental conditions with special reference to the nighttime resting habit. Jap. J. Med. Sci. Biol. 19: 155–164.
31. TSUTSUMI, C. 1968. Studies on the behavior of the housefly *Musca domestica* L. II. Some environmental factors affecting the nighttime resting behavior of flies. Jap. J. Med. Sci. Biol. 21: 195–204.
32. VIAUD, G. 1959. Les instincts. Presses Univ. France, Paris. 188 p.

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