REPRODUCTION BIOLOGY OF TYROPHAGUS PUTRESCENTIAE (SCHR.) (ACARINA: ACARIDAE)

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ABSTRACT: Mating in *T. putrescentiae* (Schr.) usually follows in a few hours the hatching of adult mites. The starving adult mites are able to mate but such starved females do not lay eggs. The males sexual activity is usually more vigorous if he has been feeding for some time. Mating usually takes places after the accidental meeting of male and female. Females are attracted by touch and smell stimuli; males are stimulated only by smelling. The male distinguishes the female only at very close range. Pairing for the above species terminates after 1.5 hours, on an average. Only during half of the mentioned time does the male continue copulation movements. Mating interrupted up to the first 45 minutes is ineffective, as the female does not lay any eggs. The copulatory movements alone do not induce egglaying.

Related species of *Tyrophagus* mate easily, but the females do not lay eggs or from the few eggs laid no larvae hatch.

Males and females of *T. putrescentiae* can mate many times. One male can fertilize up to 450 females. The female is always attractive for the male and she is able to mate even every few hours; but with different males she may even mate in as short a time as 15 minutes after the first mating.

The female molested by always changing males dies earlier and lays fewer eggs. Even as old as 160 days virgin females are able to mate, but as the result of such mating they do not lay any eggs. Females older than 160 days of age are not able to mate.

As soon as 24 hours after the first mating females kept on rye germs at 20°C and 85% of relative humidity laid their first eggs. Such females are able to lay eggs throughout their life, but in order to do so she has to mate at least once a month. In order to achieve an optimal fecundity, about 500 eggs, a female has to mate at least fortnightly. A female kept as virgin and entering the reproduction period later in her life usually lays fewer eggs but lives longer, respectively.

Females prevail in *T. putrescentiae* populations. Sex ratio was not dependent upon the food, parental age or frequency of matings of the mother. It also did not depend on the fact if the female mated with only one or many males in her life.

Apart from broad studies on stored product mites, we have up to present very little information dealing with the reproduction biology of these animals. Such studies are necessary and they have special value when works on sex pheromones, sterilization

techniques and on other nonchemical methods of control are carried out. The studies also enable a better characterization of the species, help in the designation of its taxonomic position and species isolation in relation to other relative species (Wojcik[1]).

Many studies of this kind were conducted on insect pests of stored products (Wojcik [1]; Coffelt and Burkholder [2]; Stanley and Grundmann [3]) and on many other insects (Cross and Mitchel [4]; Cook [5]; Benz [6]).

Tyrophagus putrescentiae (Schr.), which is one of the most commonly occuring species in Poland and in many other regions of the world is an important pest in stored food products. It infests many different products. The biology and ecology of the species were worked out by many workers (Cunnington [7]; Golebiowska [8]).

METHODS: Observations on mating and egg-laying were carried out on mites in stock culture for which rye germ was used as food.

The mites were kept in cages in dessicators at 85% relative humidity. For observation the cages were transferred to a stereo microscope. Observations were made in a room with low intensity, evenly distributed light, at a temperature of 20-22°C.

Mites of a known age were observed. Inert deutonymphs were isolated on the preceding day in separate cages. After eclosion the mites were sexed and later paired. All observations were repeated many times. The cages for these observations had a volume of about 0.5 cm^3.

MATING BEHAVIOR: Premating - After emergence from the inert deutonymph, the body of the adult, female or male was light and shiny. They were motile and hunted food. One hour after their eclosion both female and male were able to mate. Early mating, however, occurred rarely. In many mites, mating was observed as late as 5-6 hours after hatching. The premating period depends to some extent upon the age of the partners. If a virgin male a few days old was paired with a freshly hatched female, mating occurred often in 1.5 or even in an hour after her hatching. On the other hand if a virgin female a few days old was paired with a freshly emerged male, mating rarely occurred within one hour, and usually not before 2-3 hours. Two, simultaneously hatched mites usually mated a few hours after hatching.

Females and males which did not find any food in their cages after eclosion mated only rarely. Only about 50% of 3 day old starving males, paired with virgin females mated during the first 5 hours. However, 90% of similar males fed on rye germ mated, usually only minutes after they had been paired in a cage.

Immediately after emerging the mites were very active. They fed for short periods and wandered throughout the cage. If a female and a male were put in a cage they would sooner or later meet. After meeting they moved off in various directions or became motionless. Such meetings were apparently always accidental. No directional movement or attraction of one sex to the other was

observed. If, for example, a male was put in a cage with a virgin female a few days old (or vise versa) they did not move toward each other unless they met accidentally. After they met mutual excitation could be observed. The receptive female stopped and remained with a downward directed gnathosoma. The male, however, often moved around in the cage and sometimes came back to the place where he had met the female.

Mating - When, finally, the male stopped by the inert female, he ran his chelicerae and legs I and II along the female's opisthosoma. With this wipeing motion the male moved the hind setae of the female. After about 2-3 minutes of such motions the male then mounted the female.

After mounting the female, the male turned around and oriented his gnathosoma in the opposite direction to that of the female's. His body axis was placed obliquely to the female's body axis. At this stage it was observed that the male's copulating apparatus was lowered and placed at a right angle to his body axis. Subsequently, the male first fastened himself to the female with the anal suckers, next with a pair of tarsal IV suckers. He moved his third pair of legs backward and forward, thus fondling the sides of the female's opisthosoma. The fourth pair of legs was turned up and also was often used for fondling the female's body. At this point the copulation movements were begun. They were indicated externally by movements of his gnathosoma accompanied by movements of legs I and II. Copulation sometimes started only a few minutes after placing the male and female together in a cage; the first copulation movements might be observed within two minutes after this meeting.

It seemed that for mating, touch was the stimulus for females; but for the males it was olfaction. The male could distinguish the female only at a proximity of 0.1-0.2 mm. But it seemed that the male must also have had some olfactory influence on the female. The latter could be observed when a few virgin females and only one male were placed together in one cage. In such a case the male copulated with one of the first females he met; all other females remained more or less inert around the copulating couple. If, on the other hand, one female and a few males were placed in the cage, simultaneous attempts of several males were made to mate with that female. Besides the copulating male, sometimes there were two more males fixed to the female on her sides.

The copulating pair usually remained in the same place. Only rarely did the female move, seeking a better place or a small hollow in the substrate. During this period of about 50 minutes (40-65 minutes) the male performed copulating movements. Towards the end of the copulation the male's movements slowed down, which was followed by the end of the copulation. The male still stayed in the same position for a period ranging from several minutes to a few hours. While still on the female, but just after copulation had ended, the male rotated his body so that it was parallel to the female's he also turned up legs I and II and moved legs III and IV but was still fixed by his anal suckers. The male pressed down

the female's hairs from the apex of her opisthosoma with legs IV. Such movements were observed until the male dismounted.

The whole copulation lasted on average of 1.5-2.0 hours, but some old virgin males remained in the copulating position for up to 7 hours.

The females of the above and related species do not lay any eggs without previous mating. If the mating was interrupted during the first 45 minutes such females did not lay eggs. Therefore it can be concluded that copulation movements alone were not enough for egg-laying.

Postmating behaviour - After copulation the male's body seemed to be flattened with two noticeable subdorsal hollows. He usually was inert but remained near the female after the copulation took place. Such inert males and females remained near each other for up to two hours. The male and female did not start feeding just after the mating. Females were observed to feed after a few hours; but the males usually started feeding earlier.

The adults of related *Tyrophagus* species were able to mate interspecifically. It was observed that a similar mating behavior took place during the cross mating of *T. putrescentiae* with *T. palmarum*, *T. neiswanderi* and *T. longior*, regardless of which species the males or females belonged to. Cross-mated females did not lay any eggs or only laid a few eggs, but larvae did not hatch from these eggs.

Males and females of *T. putrescentiae* may mate many times during their lives. When one pair was enclosed in the cage, the second mating was usually observed after an elapse of 3 hours, often after 4-5 hours. But if a few males were enclosed in the cage with one female, the second mating of the same female was observed only a few minutes later and such a procedure was repeated throughout the female's entire life. This indicates that such a female holds a continuous olfactory attraction for the male. Her glands continuously secrete a sex pheromone.

The sexual capacity of *T. putrescentiae* males is large. One male was able to impregnate up to 450 females during his life and he lived up to 85 days. The sexual activity of younger males, of 50-60 days of age, was especially high. Such a male was able to impregnate 12-15 females a day, meaning that nearly half of his life was spent in copulation. He could start the next copulation with another female within 15 minutes after the first copulation occurred and both females were fertile. Older males were able to impregnate 0-7 females daily, but more often such males did not copulate every day or they mated with only a single female.

Oviposition behavior - Under our experimental conditions, when rye germ was used as food, the females laid their first eggs 23 hours after the first mating at the earliest, but usually 26 hours after the mating had occurred, which makes 30-36 hours after they emerged as adults. The period between mating and the first egg-laying depended upon the different food provided. This period could range from a few to several days.

The process of laying the eggs did not take long. The females laid eggs while feeding or walking through the cage. When

the female found herself on the cage wall and happened to lay eggs she stopped for a short while and dropped the egg which became stuck to the product or to the wall of the cage. The eggs sometimes stuck to the mites and this is why one often could observe mites carrying such eggs. In the cages from which the food had been removed, the females which had been starved before mating did not lay any eggs or laid only a few (1-3 eggs). It seemed that single eggs were being laid only if in the empty cage the female found some trace of mould, because the eggs, as is also the case with the fungi, can start their development at 85% r.h.

Under favourable temperature, humidity and food conditions the female continued egg laying throughout her whole life, which was about 60 days. Under our experimental conditions, the *T. putrescentiae* female laid about 500 eggs. In order to lay a maximum number of eggs the female had to mate at least every fortnight. For continuous egg-laying throughout her whole life the female had to mate at least 3 times, at monthly intervals.

With one mating only, a female kept on rye germ laid about 180 eggs during the period of one month. A mating repeated one month later made it possible for the female to lay a further 160 eggs during the second month of her life, but after the third mating the female laid only about 40 eggs. A female mated weekly laid 50 eggs per week up to the first 9 weeks. Later her fecundity gradually dropped and when old the female stopped egg laying completely. However, even old females copulated and the process of mating was normal. The virgin female, beginning oviposition later in her life, usually laid a few eggs daily (less if each day of the detention was counted). Aging in females can be observed in a reduction of their fecundity after the 10th day of their life onwards. Aging in males affected the females' sexual capacity from 60 days old onwards. Females mated with old males laid fewer eggs. Females beginning reproduction later in their lives usually lived longer. Virgin females lived longest - up to 200 days. Most of such females (up to 150 days old) were able to mate and often laid eggs; but many virgin females 160 days old mated but were not able to lay any eggs. Females 170 days old and older did not even try to mate.

If the female mated often, she usually finished oviposition a few weeks before her death. If the female mated rarely, then her oviposition period could be stretched through her whole life. It was observed that the female sometimes died within 24 hours after laying her last eggs.

The total number of eggs laid, speed of egg-laying and the oviposition period (its beginning and duration) depended on the outside rearing conditions, but mainly depended on the food. Food also had a major influence (besides the temperature and humidity) on the mortality of different developmental stages, and on the length and duration of each generation of the mites.

In *T. putrescentiae* populations originating from the laboratory stock cultures or from natural sites, there were always more females than males. Such a female:male ratio was not influenced

by the food product. This sex ratio remained constant and similar independent of the age of parental mites and frequency of parental matings. The above mentioned ratio was similar when the mother mated during her whole life with a single male or with many different males.

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