

INDIVIDUAL DEVELOPMENT OF THE RED MASON BEE (*Osmia rufa* L., *Megachilidae*) UNDER NATURAL AND LABORATORY CONDITIONS

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S u m m a r y

The objective of the study was to determine the duration of successive stages of the individual development of the solitary bee the red mason bee (*Osmia rufa* L.) under natural and laboratory conditions and to examine the possibilities to shorten the development of that bee.

The average duration under natural conditions of the egg stage was 7.6 days, of the feeding male larvae - 31.6 days, of the feeding female larva - 35.5 days. Under laboratory conditions at 28°C and at 70% relative humidity the respective durations of those stages were 3.1 days, 15.3 days and 17 days. The spinning larva stage was 3.7 days for males and 3.6 days for females under natural conditions and 2.9 days for males and 2.7 days for females under laboratory conditions. The successive instars of pre-pupa and pupa lasted jointly 52.6 days for males and 54.2 days for females under natural conditions. Under laboratory conditions the respective instars were shorter: 46.4 days and 47.2 days.

Under laboratory conditions the shortening of the development stages of the red mason bee resulted in the complete development time being shorter: in males by 28 and in females by 30 days as compared to the average development under natural conditions.

Keywords: *Osmia rufa* L., development.

INTRODUCTION

The basic information on the biology of the species *Osmia rufa*, including the development of its successive instars, was obtained as a result of investigations conducted in France (Tasei 1973), Poland (Wójtowski 1979), Germany (Hallmen 1989) and Denmark (Kristjansson 1992). The red mason bee was found to be a monovoltine species which completes its development from the egg to the imago stage in the spring and in the summer season. Under Poland's climatic conditions the red mason bee begins its flights in the first decade of April to finish them in the third decade of June. At that time the females build the nests and lay the eggs. The development of the new generation insects lasts through the summer and the cocooned adult forms emerge in September.

A good understanding of the development stages of the red mason bee and of their duration is a further step in improving rearing methods of that species. Faster development permits a quicker diapausing of the insects and, consequently, an earlier production of pollinator imagines, beyond their natural flight period. Besides, that knowledge allows the regulation of diapause in such a way so that the rate of consumption of storage substances in insect bodies is lowered and the insect vigour, the artificial delay of activation notwithstanding, is not diminished (Bosch and Blas 1994).

METHODS

The experiment was conducted in the years 2000-2001 during the individual development period of the red mason bee

(*Osmia rufa* L.). The experiment material consisted of bees reared in artificial nests made of reed stalks according to the method of Wójtowski and Wilkaniec (1978).

Reed nest tubes were collected from the artificial nests just before the construction of breeding chambers was completed by the females. The tubes were cut lengthwise from the top. Care was taken not to disturb the eggs and the pollen stores. Tubes thus prepared were arranged on styrofoam plates with grooves and put in an incubator at 28°C and 70% relative humidity or in wooden boxes protected against pests. The boxes were left outdoors under natural conditions. The developing insects were inspected daily during the egg, feeding larva and spinning larva stages and on every second day during the remaining development stages.

The sex of the insects was determined based on morphological differences at the pupa or imago stages. Only those eggs which were laid last before the sampling of tube nests i.e. those collected on the same day were assessed for the duration of embryonal development. The indication of that were the moist divisions of the breeding chambers or the absence thereof. The emergence of a silvery-white larva that still did not feed meant the commencement of the successive stage - that of the feeding larva. The stage ended with the first cocoon threads spun by the larva. The emergence of the fully developed tanned cocoon was taken as the end of the spinning larva stage. Starting with that moment the inspection of further development stages consisted in cutting open the same number of cocoons of the same age kept in the incubator and under natural conditions. The emergence of a white pupa with non-pigmented eyes was taken as the end of the pre-pupa stage. Further pupa stages were not taken into account. The emergence of an adult still not tanned or with folded wings, with the remains of fresh exuviae at the bottom side

of the abdomen meant the end of the pupa stage.

The results were subjected to statistical analysis and the means of the two groups were compared using the Student t-test. The durations of the development stages were compared in males vs. females and also in natural vs. artificial conditions for insects of the same sex. The statistical analysis was performed at $\alpha = 0,05$ significance level and critical significance levels p were determined.

RESULTS

Under natural conditions the development of red mason bee proceeded at variable temperatures. With the average diurnal temperature of ca. 14°C the egg stage lasted from 4 to 9 days averaging 7.6 days. The larva started feeding more than a day after it was hatched from the egg. The supply of pollen was eaten by the male larvae within an average of 31.6 days and by female larvae within 35.5 days. The difference between those means was highly significant ($p < 0.001$). There was no significant difference, though, between the average cocooning time of the male larva (3.7 days) and the female larva (3.6 days). The majority of larvae formed cocoons in 3 days and only few in 6 days.

Further post-embryonal development of *Osmia rufa* from cocooning to the imago i.e. the stages of pre-pupa and pupa is completed in the cocoon. Average durations of that stage in males and females differed significantly ($p < 0.001$). The emergence of the imaginal stage occurred on average within 52.6 days after cocooning in males and in 54.2 days in females (Table 1).

A belated, as it turned out, inspection of the cocoons that were 25 - 39 days of age revealed the presence of pupae with already pigmented eyes. The female and male pupae at that stage of development emerged in 28.8 and 30.7 days, respectively, after the

Table 1

Development stages of the red mason bee under natural conditions (days)

Characteristics	Sex	Development stages			
		Egg	Feeding larva	Spinning larva	Pre-pupa + pupa
Mean	Males	7.6	31.6	3.7	52.6
	Females		35.5	3.6	54.2
Standard deviation	Males	1.33	2.41	0.96	2.03
	Females		1.99	1.09	2.34
Minimum	Males	4	27	2	47
	Females		31	2	49
Maximum	Males	9	38	6	61
	Females		39	6	59
N - number of observations	Males	44	55	46	68
	Females		30	42	48

spinning larva stage was completed. That means that the average duration of the pre-pupa stage must have been even shorter.

By adding up the durations of the individual development stages of the red mason bee the average total development time under natural conditions of the male (95.5 days) and of the female (100.8 days) were arrived at. From the eggs laid by females in mid-May insects were hatched which reached the adult stage at the end of August.

Under laboratory conditions the development of the insects proceeded at 28°C and at the relative humidity of 70%. Under such ambient conditions the embryonal development lasted 3.1 days. A day after hatching the larva started to feed on the pollen stored in the breeding chamber. The average length of the feeding period in males and in females differed significantly ($p=0.004$). The male larvae which had eaten up all pollen supply within 15.3 days stopped feeding two days earlier than females (17 days), on average. The duration of individual development stages varied from 10 to 24 days in males and from 12 to 24 days in females. It took males 2.9 days and females 2.7 days to form a cocoon. In the stage of spinning larva no significant differences

were recorded between the average cocooning time for the male larva and for the female larva.

The pre-pupa stage was the instar of the longest duration, the average time for males - 34 days - being significantly different from that for females - 36.3 days ($p=0.048$). There were no significant differences, though, between the average development period from the end of the spinning larva stage to the emergence of the imago (pre-pupa and pupa stage) in males (46.4 days) vs. females (47.2 days). The average duration of that phase of development minus the average duration of the pre-pupa stage is the approximate duration of the pupa stage. It was ca. 12.5 days in males and 11 days in females (Table 2).

By adding up the durations of the individual development stages of the red mason bee the average total development time under laboratory conditions of the male (67.6 days) and of the female (70 days) was arrived at.

Average durations of individual development stages of the red mason bee under natural vs. laboratory conditions differed much for each of the instars under comparison ($p<0.001$). Pairs of average values obtained for the same stages and for the same sexes

Table 2

Development stages of the red mason bee under laboratory conditions (days)

Characteristics	Sex	Development stages				
		Egg	Feeding larva	Spinning larva	Pre-pupa	Pre-pupa+ pupa
Mean	Males	3.1	15.3	2.9	34.0	46.4
	Females		17.0	2.7	36.3	47.2
Standard deviation	Males	0.36	3.36	0.89	4.44	5.03
	Females		3.21	0.66	5.64	5.90
Minimum	Males	3	10	2	27	32
	Females		12	2	26	32
Maximum	Males	4	24	6	42	56
	Females		24	6	45	56
N - number of observations	Males	14	59	34	33	62
	Females		74	50	45	61

but under different ambient conditions were compared. The egg stage and the feeding larva stage proceeded nearly twice as fast under laboratory conditions than in natural ambient conditions. Likewise, spinning larvae that were developing at a constant temperature of 28°C completed the cocoon nearly a day earlier. The development of the male from the end of the spinning larva stage to the imago stage was completed under laboratory conditions six days earlier by the males and 7 days earlier by the females as compared to the development under natural conditions.

Under natural conditions the duration of the pre-pupa stage was not assessed. However, it was determined that male larvae with pigmented eyes emerged, on average, within 28.3 days and the female larvae within 30.7 days after the spinning larva stage was completed. It follows that the pre-pupa stage must have been even shorter. Under laboratory conditions the average duration of that stage was 34 days for males and 36.3 days for females and it was longer than under natural conditions.

The overall acceleration of the development time that occurred under laboratory conditions, being 28 days for males and 30

days for females, was related to the shortening of several development stages. The greatest contribution was that of the feeding larva stage which was shortened by more than two weeks under the constant elevated temperature.

DISCUSSION

In the experiment of this study under natural conditions the complete development of the red mason bee averaged 95.5 days for males, 101 days for females. Under laboratory conditions at 28°C it was 68 and 70 days respectively for males and females. Tasei (1973) reports that at a temperature of 22°C the development of *Osmia rufa* was completed within 97.6 days and the egg stage lasted for 7.1 days. In this experiment under natural conditions the egg stage averaged 7.6 days with the diurnal air temperature in that season averaging 14.4°C. Under laboratory conditions at 28°C the egg stage lasted 3 - 4 days.

The same stage in *Osmia rufa cornigera*, a subspecies native to southern Europe, lasted 96 - 100 hours at a constant temperature of 23°C, and the feeding larva stage lasted ca. 10 days (Rust et al. 1989). However, those investigators do not make a dis-

tion of gender and insect sex has been shown in this study to affect significantly the length of post-embryonal development stages. In the experience of the authors of this study pollen supplies were eaten up within 17 days by female larvae and within 15 days by male larvae feeding at a temperature of 28°C. Only a few male larvae fed for 10 days and that was the minimum duration of that stage.

Late embryogenesis and the larval development of *Osmia rufa cornigera* are almost the same as those of *Osmia lignaria*, a species occurring in North America (Rust in. 1989; Torchio 1989). Bosch and Kemp (2000) report that all the instars of *Osmia lignaria* become shorter with the rise in ambient temperature. In this study the development of the red mason bee under natural conditions lasted about a month longer than it did under laboratory conditions at constant temperature and humidity. Under laboratory conditions, a shortening of all development stages save for the pre-pupa stage was observed, the latter being shorter under natural conditions. In the experiment by Bosch and Kemp (2000) the pre-pupa stage became shorter with rising temperature but it was the shortest at alternating temperatures of 14°C and 27°C. The investigators refer to that stage as intermediary diapause which allows the insect to live through adverse weather conditions (high temperature, low relative air humidity) prevailing in summer whereas they consider variable temperature to be a factor that brings on the termination of the pre-pupa stage.

In this study under natural conditions all cocooned individuals emerged by the end of August. Wójtowski (1979) reports that cocooned imagines emerge in September and they overwinter in that form. In another population of *Osmia rufa* investigated in the Hanau region, Germany, pupa was found to be the overwintering form (Hallmen 1989). However, it is commonly believed,

which has been borne out by this study, that diapause at the imago stage is characteristic of monovoltine bees of the genus *Osmia* (Torchio 1991).

Individuals of *Osmia lignaria* at the pupa stage were artificially diapaused by rearing them under laboratory conditions at 18°C. After the diapause they completed pupation but their activation was not possible (Bosch and Kemp 2000). For another species, *Megachile rotundata*, the temperature of 18°C proved to be not high enough to complete the development (Kemp and Bosch 2000).

It cannot be excluded that the handling of developing insects necessary to carry out inspections may have influenced the length of development stages. In a reference experiment Ladurner et al. (1999) found that the very shifting of eggs significantly affected the rate of development of feeding larvae of *Osmia cornuta*.

CONCLUSIONS

1. Exposure to a temperature higher than that in natural environment and to a constant air humidity brings about the shortening of the development stages of the red mason bee *Osmia rufa*, with the exception of the pre-pupa stage.
2. With the exception of the spinning larva stage, all the remaining development stages of the red mason bee males were shorter than those of the females regardless of the ambient temperature conditions.
3. The red mason bee can shorten its immature development as compared to that under natural conditions if exposed to constant elevated ambient temperature.

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ROZWÓJ OSOBNICZY MURARKI OGRODOWEJ (*Osmia rufa* L., *Megachilidae*) W WARUNKACH NATURALNYCH I LABORATORYJNYCH

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S t r e s z c z e n i e

Doświadczenie przeprowadzono w latach 2000-2001 w okresie rozwoju pszczoły murarki ogrodowej (*Osmia rufa* L.). Materiał doświadczalny stanowiły pszczoły pochodzące z hodowli prowadzonej w sztucznych gniazdach wykonanych z łądy trzciny pospolitej. Rurki gniazdowe pobierano ze sztucznych gniazd tuż przed zakończeniem budowy w nich komór lęgowych przez samice. Rozcinając je wzdłuż otwierano komory lęgowe od góry, zwracając uwagę by nie naruszyć jaj i zapasów pyłku kwiatowego. Tak przygotowane rurki gniazdowe układano na

płytkach styropianowych z wyżłobionymi rowkami i umieszczano je w cieplarni w temperaturze 28°C i 70% wilgotności względnej powietrza lub w drewnianych skrzynkach zabezpieczających przed pasożytami, które pozostawiano na zewnątrz w warunkach naturalnych. Kontrolę rozwijających się owadów w rurkach gniazdowych przeprowadzano codziennie, podczas trwania stadium jaja, larwy żerującej i przędzącej oraz co dwa dni w przypadku pozostałych stadiów rozwojowych. Płeć owadów ustalano na podstawie różnic morfologicznych w stadium poczwarki lub imago.

Średni czas trwania stadium jaja w warunkach naturalnych (7,6 dnia) wysoce istotnie różnił się od średniego czasu trwania tego stadium w warunkach laboratoryjnych (3,1 dnia), podobnie jak pozostałe porównywane między sobą kolejne etapy rozwoju owadów tej samej płci. W warunkach naturalnych larwy samców zjadały zapas pyłku kwiatowego średnio w ciągu 31,6 dnia, a larwy samic 35,5 dnia, w warunkach laboratoryjnych odpowiednio 15,3 dnia i 17,0 dni. W obydwu środowiskach różnice między średnimi czasami trwania tego stadium dla samca i samicy były statystycznie wysoce istotne ($p < 0,001$). Istotnej różnicy natomiast nie stwierdzono między średnim czasem oprzędzania się larwy samca (3,7 dnia) a samicy (3,6 dnia) w warunkach naturalnych podobnie jak w warunkach laboratoryjnych gdzie samce oprzędzały się w ciągu 2,9 dnia, a samice 2,7 dnia. Dalszy rozwój postembrionalny *Osmia rufa* od zakończenia oprzędzania się larwy do przeobrażenia w postać dorosłą, czyli stadia przedpoczwarki i poczwarki, zachodzi w oprzędzie. Pojawienie się postaci imaginalnej samców w warunkach naturalnych następowało przeciętnie po upływie 52,6 dnia od momentu wytworzenia oprzędu, a samic 54,2 dnia, w warunkach laboratoryjnych odpowiednio 46,4 i 47,2 dnia. Istotne różnice między średnim czasem trwania tego okresu samca i samicy zanotowano tylko w warunkach naturalnych. Sumując przeciętne czasy trwania poszczególnych stadiów rozwojowych murarki ogrodowej uzyskano średni czas całkowitego rozwoju samca wynoszący 95,5 dnia i samicy 100,8 dnia w warunkach naturalnych oraz odpowiednio 67,6 dnia i 70,0 dni w warunkach laboratoryjnych.

Zapewnienie wyższej temperatury, aniżeli w naturalnych warunkach środowiska oraz stałej wilgotności względnej powietrza w okresie rozwoju osobniczego pszczoły murarki ogrodowej (*Osmia rufa* L.) skutkuje skróceniem stadiów rozwojowych owada, z wyjątkiem stadium przedpoczwarki, w konsekwencji skróceniu ulega cały rozwój osobniczy. Oprócz stadium larwy przędzącej, wszystkie pozostałe stadia rozwojowe samców murarki ogrodowej trwały krócej aniżeli samic, niezależnie od warunków termicznych środowiska, w którym przebiegał rozwój.

Słowa kluczowe: *Osmia rufa* L., rozwój osobniczy.