

The Effect of Temperature Upon the Development of Cockroaches

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In centuries past the ancestors of modern cockroaches lived in forests of tropical and semi-tropical regions. Gradually roaches have migrated to other areas and now are established in most tropical and temperate regions of the world. Food of those ancient forms consisted of vegetation and other organic matter, but in comparatively modern times certain species have found the environment and food of human habitations suitable for their existence. Man has carried these species through commerce to many countries until now some of them are household pests throughout most of the world. The limitations on the spread of these former inhabitants of the tropics are several in number, but the temperature factor is perhaps the most important in the distribution and development of the various species.

Several years ago a study was initiated on the biology of six species of roaches found in homes in Indiana. The six species involved are the American cockroach (*Periplaneta americana* Linn.), the Oriental cockroach (*Blatta orientalis* Linn.), the German cockroach (*Blattella germanica* Linn.), the brown-banded roach (*Supella supellectilium* Serv.), the Pennsylvania woods-roach (*Parcoblatta pennsylvanica* DeGeer), and the smoky brown cockroach (*Periplaneta fuliginosa* Serv.). In a recent publication Gould and Deay* have presented the information obtained in the study of the biology of the six species and included some data on the effect of temperature upon their development. This paper gives additional data on the temperature-development relationship and summarizes this information on all six species.

The most interesting species in regard to the effects of temperature is the brown-banded roach, an insect that in the past twelve or thirteen years has appeared and become established as a household pest in the United States. Previous to this a few records had been published on this roach from France, Africa and Australia. At the present time it is established in at least twenty states and thrives in heated homes, apartments and hospitals. Apparently the temperature requirements of this species has confined the colonies to buildings where moderately high temperatures are maintained. Undoubtedly individuals have attempted to establish colonies in other buildings, but winter conditions have killed off or forced the colony to move to warmer locations. Such a temperatory condition probably existed in a tourist cabin in Hiawatha, Kansas, where a single mature female was captured in September of 1940. This individual probably was transported in luggage by tourists from some southern city and could not possibly have continued to exist in this unheated cabin during the winter.

* Purdue University Agricultural Experiment Station Bulletin 451, 1940.

The brown-banded roach is not confined to any particular room in the house but does frequent such high locations as clothes closets, furniture and the backs of pictures. These locations have a higher temperature than hiding places in basements and behind baseboards that are frequented by other species. The habit of hiding themselves or depositing egg capsules in furniture and luggage probably accounts for the rapid spread of this insect in both southern and northern cities.

TABLE I.—The Average Duration of the Incubation Period of the Brown-Banded Cockroach at Four Temperature Levels.

	Location of Capsules				Total or Average
	Room	Shelf 1	Shelf 2	Shelf 3	
Number of capsules	425	200	500	100	1,225
Average temperature	76.8	78.9	80.8	85.9	79.7
Average incubation	73.8	57.2	43.1	36.9	57.6
Regression coefficient	6.7	...	3.4	...	5.1

The effect of temperature upon the duration of the incubation period has been studied over a period of 39 months. Capsules were removed upon deposition from rearing jars and placed either singly or in small groups in salve boxes. These boxes at first were placed on a table in the laboratory where the room temperature varied as much as 20 degrees daily and from 70° F. in spring and fall to over 90° F. in winter and summer. Later capsules were placed on different shelves in the constant temperature chamber where the temperature variation on each shelf was seldom more than five degrees. In addition the humidity in this chamber was kept at a more or less constant level of 65 per cent.

The results of these observations are shown in the accompanying table. The term regression coefficient indicates that within the limits of the values used the duration of the incubation period was shortened a calculated number of days for each degree rise in temperature. In the case of capsules kept on the top and third shelf of the chamber this figure was inconclusive, while under room conditions the period was shortened 6.7 days for each degree rise in temperature, on the second shelf 3.4 days and for all conditions 5.1 days. These results have a practical application in that they may aid the exterminator in predicting the proper time for a second application which would kill all young hatching from capsules produced before the first treatment. In other words, if the average temperature is 75° F., the capsules would hatch in 80 days or the second application should be made about three months after the first.

Temperature also had a decided influence upon the growth of the nymphs. The 147 individuals reared under room conditions where the average temperature was 76.9° F. required 164 days for development from hatching to maturity. In the constant temperature chamber where the average temperature was about 84° F. only 92 days were necessary on the average for the 240 nymphs to mature. The regression coefficient

between the length of nymphal development and temperature indicates that for each degree rise in temperature the developmental period was shortened 11 days.

This relationship between temperature and development offers an explanation of the rapid increase of roach populations in homes. As stated before, the brown-banded roach is of tropical origin and is found in the warmer locations of the house. In heated homes the temperature of the places frequented by this roach probably averages around 80° F. most of the year. At this temperature incubation would require 50 days and nymphal development 125 days, which indicates a possibility of two generations a year. Of course during the spring and fall homes are not heated and temperatures may be below the optimum for development, but at other times temperatures may be above the 80° mark. Suppose that a single capsule was brought into this home in luggage. According to figures previously published 13.2 nymphs should hatch from this capsule. If all individuals lived and half were females producing six capsules each, a possible population of 515 roaches would be in this house at the end of one year or 806,000 at the end of two years.

The higher temperatures also affected the adult stage. Reproduction was speeded up and longevity was greatly reduced at the higher temperature. Under room conditions females lived 206 days and in the constant temperature chamber 125 days. Excessively high temperatures existing at times on one shelf of the constant temperature chamber reduced egg production with a higher percentage of infertility and in some instances caused the death of adults and nymphs.

The American cockroach is one of the three common household species that has become acclimated to domestic life and thrives throughout the temperate zone of the world. In the southern states this species is found both in buildings and out-of-doors where it lives during most of the year under the bark of trees, in rubbish piles and other similar locations. In the North this roach may wander away from buildings and infest garbage dumps and trees during July and August, but for the most part its activities are confined to buildings where food is prepared, served or stored. The adults and nymphs prefer to congregate in dark damp locations where the temperature is about 82° F. However, they differ from the brown-banded roach in that they are active and continue normal functions at temperatures around 70° F. Under conditions found in buildings the American roach ranges over most of the basement and first floor, and even higher if food is available. For deposition of egg-capsules and congregating with other roaches, places near heat and water pipes are sought. The so-called "nests" mentioned by pest control operators are areas that roaches find favorable from the standpoint of temperature, humidity, darkness and nearness of food. Such areas are soon stained by the roaches and have a characteristic roachy odor. A "nest" of roaches was observed on a bare wall of a meat packing establishment. Apparently the roaches had congregated here while the temperature was high. At the time of collection the roaches were thoroughly numbed by the 50° temperature.

In the study of the American roach 988 capsules have been incubated at three temperature levels during a period of 77 months. Under room conditions the eggs hatched in an average of 58.5 days at an average temperature of 75.7° F., while on one shelf of the constant temperature chamber capsules hatched in an average of 48 days at 78.8° and on another shelf 34.5 days at 84.5°. The range of incubation of all capsules showed that at an average temperature of 70° F., 84.3 days were required by incubation and at 85.8° F. only 32.7 days. The gain per degree rise in temperature showed a shortening of the incubation period by 2.8 days. On the few occasions when temperatures of 88° or higher were maintained for any period of time, many of the capsules failed to hatch.

The duration of the nymphal developmental period for this species was more influenced by temperature than for any of the other species studied. Under room conditions where temperatures fluctuated around 76° F., 520 days were necessary on the average for development, while in the constant temperature chamber with an average of 83° F. only 195 days were necessary. Although the higher temperatures accelerated growth, it also speeded up the various life processes and caused an earlier death of adults. Under room conditions the females lived on an average 441 days and produced 57.6 capsules of which 32.6 were fertile. In the constant temperature chamber females lived 371 days and produced 47 capsules of which 28.2 were fertile.

The responses of the Oriental roach to temperature variations were similar to those of the American roach. This species was usually confined to the basement and first floor of business buildings, but in some instances colonized around heat and water pipes on higher floors where access to such locations was made easy by incinerators and plumbing. During the summer months colonies dispersed throughout the building and often spread to nearby dumps and garbage piles. One such infestation was observed in South Bend in the summer of 1938 when residents complained of this roach migrating from the city dump to their nearby homes. Apparently this dump was continuously inhabited by roaches as fishermen went there to collect them for fish bait. During the hot summer months colonies of roaches were found around foundations and back porches of homes, especially if the garbage pail was nearby. The common source of infestations in homes was by migrations through sewer and drainage pipes.

The duration of the incubation period fluctuated with the temperature similar to the responses of the American roach. The average incubation period was 57 days at an average temperature of 78° F. and 37 days at a temperature of about 85° F. In analyzing the regression between the duration of incubation of the 56 capsules and the temperatures at which they were kept, it was found that the incubation period was shortened 2.6 days for each degree rise in temperature.

The nymphal developmental period varied considerably even with roaches reared together in the same container. Some nymphs matured in about a year, while some required an additional year. Under room conditions the average length of the nymphal stages was 533 days, while in the constant temperature chamber it was 316 days.

Although the Oriental roach lived throughout most of the year in heated buildings, this species still showed an indication of a seasonal cycle. Adults both in rearing jars and in nature appeared in the spring months and died in the late summer or fall. Nymphs in many instances required nearly two years for development and yet they never matured except in the spring months. Adults living only during the summer months also influenced egg production and incubation.

The third common household species is the German roach. This pest is well established in homes throughout the world and is found in buildings where food is prepared, served or stored. Under favorable conditions of food and temperature this little species is able to pass through a complete cycle in about 100 days and accordingly can soon become numerous about an infested premise. In our studies capsules hatched in 28 days at a temperature of 76° F. and in 17 days at an average temperature of 85° F. At exceedingly high temperatures the duration of the incubation period was still shorter but the percentage of infertility was considerably higher. Under natural conditions the capsules of this species are probably exposed more to a favorable temperature than are other species, for this is the only instance among home-inhabiting forms that the female carries the capsule during incubation. The regression coefficient, in our studies, between duration of incubation and temperature showed that for each degree rise in temperature the incubation period was shortened 1.6 days.

Nymphs reared at an average room temperature of 76° F. required 135 days for development, while at 85° F. only 74 days were necessary. Adult roaches confined at the higher temperature lived 145 days as against 232 days for those at room temperature and, as might be expected, they produced fewer capsules.

Of the various species studied the woods-roach showed the least response to temperature fluctuations, for in its natural habitat under the bark of trees, nymphs remain active throughout the year. Young nymphs exposed to freezing temperatures in mid-winter were still active and able to scurry for shelter. In the spring and early summer months these nymphs matured. Flights of winged males were observed in May and June. Homes in or near wooded areas were frequently infested with males or by the crawling females or nymphs. This invasion of homes by this species was more by accident than by design, as they do not breed in homes.

Under natural conditions the woods-roach has a definite seasonal cycle with one generation a year. Adults appear in early summer and produce egg capsules during the summer months. In captivity they had the same cycle except that certain individuals required two years to complete development. Egg capsules which were present in summer and fall months only had an incubation temperature of 81° F. and hatched in 34 days. At the high temperature of 85° F. in the constant temperature chamber few of the capsules hatched. Conditions in this chamber also had an adverse effect upon nymphal development, as only two matured and they required over a year.

TABLE II.—Summary of the life-cycle of the Common Cockroaches Reared at Two Temperature Levels.

Roach	Temperature Range*	Length of Adult Life in Days	Number of Capsules Per Female	Number of Nymphs Hatching Per Capsule	Duration of Incubation Period in Days	Number of Days for Nymphal Development
American	Room	441	58	13	58	520
	High	371	47	15	41	225
Oriental	Room	110	9	13	62	533
	High	100	6	8	45	316
German	Room	232	5	32	28	135
	High	145	5	27	20	95
Brown-banded	Room	206	13	13	74	174
	High	150	12	13	42	125
Smoky brown	Room	250	17	18	59	344
	High	43	405**
Woods	Room	150	284
	High	...	20	26	34	383

* Temperatures under room conditions varied from 69 to 90° F. and are used in this table as an average of 76° F. Temperatures used in the high column were obtained in the constant temperature chamber where the range was from 78 to 88° F. Figures in the high column are calculated on an average of 81° F. The adults of the woods roach were present in the summer months.

** Based on a few records where average temperatures were a bout 85° F.

The smoky brown roach, a native of the southern United States, has been found on a few occasions in heated buildings in the North. This species is closely related to the American roach and like it responded to temperature ranges to the same degree. In a greenhouse this roach has undergone a continuous development for the past five years. It exhibited no tendency for a seasonal cycle as adults were present throughout the year.

Egg capsules, which were kept under room conditions, hatched in 70 days at an average temperature of 73° F., 60 days at 75° F., 56 days at 78° F., and 43 days at 81° F. The average of all capsules kept under room conditions showed that incubation required 58 days at 75.7° F. In the constant temperature chamber incubation required an average of 37 days at 85° F. Nymphal development under room temperatures varying between 72 and 81° F. required 274 to 439 days with an average of 344. The growth rate of this species was not accelerated by the higher temperatures in the constant temperature chamber, as 405 days were required for development at an average temperature of 85° F.

Summary. The three common species of roaches infesting buildings, the German roach, the American roach, and the Oriental roach, showed a decided similarity in the temperature requirements for development. The temperature range from 74 to 83° F. was the most favorable for incubation and nymphal development. The brown-banded roach required higher temperatures for normal development, while the wood-roach responded to lower temperatures. Acceleration of development of all species continued up to 84° F. and in some cases even higher, although higher temperatures were detrimental to capsule production and shortened the lives of adults.