PRECIPITATION AS A FACTOR IN THE EMERGENCE OF *EPILACHNA CORRUPTA* FROM HIBERNATION

By J. R. DOUGLASS, *Bureau of Entomology, U. S. Department of Agriculture*

ABSTRACT

Three years' study of the emergence of the Mexican bean beetle (*Epilachna corrupta* Muls.) from hibernation show that there is a definite relation between precipitation and the emergence of the beetle and that the percentage emerging is influenced directly by the temperature during the period of rainfall. It is also apparent that heat alone is not sufficient stimulus to produce emergence, as no beetles emerged on some of the hottest days during the season, and that the period of emergence is governed by a combination of the two factors. Emergence rarely occurs when the mean temperature is below 55°F., and reaches its maximum at a mean temperature of 58° to 69°F. Beetles in hibernation respond to the effect of artificial precipitation during the emerging season.

METHOD OF INVESTIGATION

The emergence of the Mexican bean beetle from artificial and natural hibernation during the past three seasons has been studied, and some of the data obtained are given herewith. The experiments were carried on in Torrance County, New Mexico, at and 17 miles west of Estancia. The hibernation cages used during these investigations were constructed out of 2 x 4 inch lumber, and measured 4 feet wide, 6 feet long and 3½ to 4 feet high; they were covered with 14-mesh screen wire, and had removable tops. The tops were removed after the beetles had become dormant and were replaced before activity was manifested. In this manner conditions approximating, as nearly as possible, those prevailing under natural hibernation were obtained.

Cages Nos. 5, 6, 7 and 11 were located in the yellow-pine (*Pinus ponderosa*) region that covers the higher rolling hills along the foot of the Manzano Mountains. Cage No. 8 was located in the pinyon (*Pinus edulis*) formation that covers the intermediate forest region between the cedar (*Juniperus monsperma*) community, which clothes the lower rolling foothills that border the valley on the west, and the yellow-pine forest zone. Cage No. 10 was located in the short-grass or semi-desert formation of the Estancia Valley.

Cage No. 6, located at 7,000 feet elevation, has been in operation three years, oak leaves and pine needles having been used as the hibernation material. Cage No. 5, at an elevation of 7,050 feet, has been in use two seasons and the hibernation material has consisted of a combination of oak leaves and pine needles. Both cages are located on the south side of Tajique Canyon just below the first rim rock and are well protected. The following four cages have been in operation only one year: Cage No. 7, at an altitude of 6,975 feet, was located at the base of a steep hill or bluff, 30 feet from the canyon stream, with a northernly

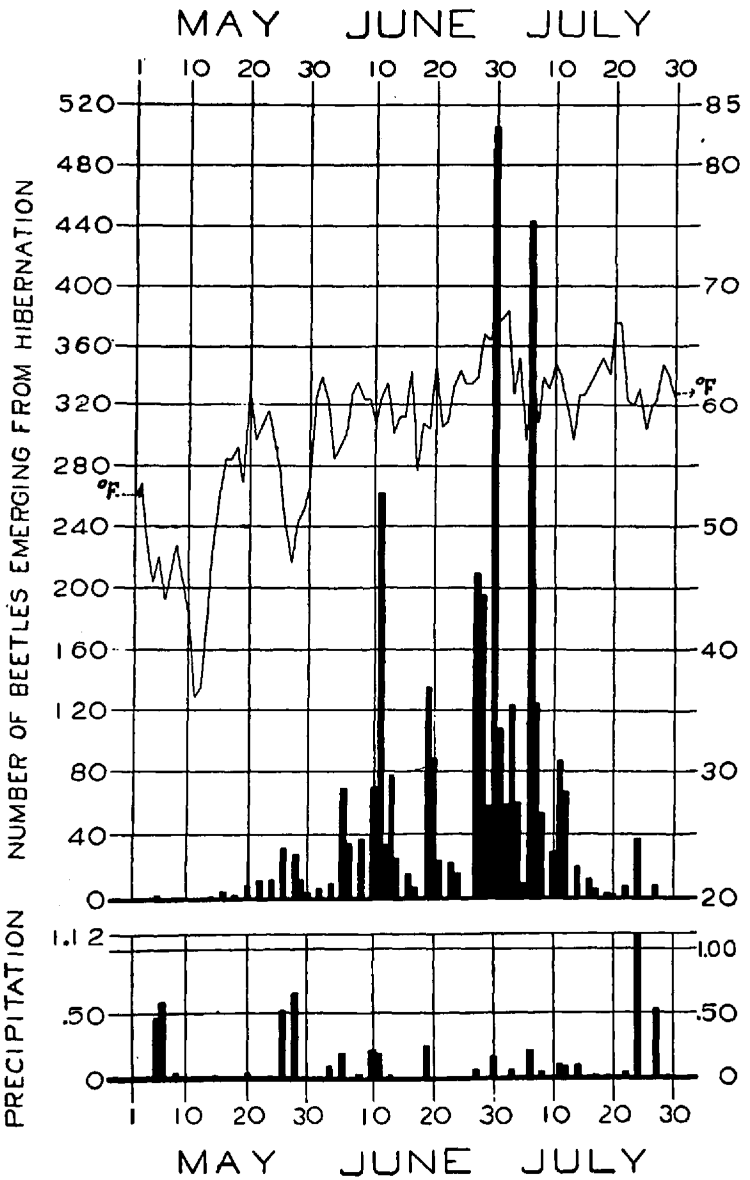

Fig. 16.—Mexican bean beetle: Graph Showing Emergence from Cages Nos. 5, 6 and 11, located in the yellow-pine forest zone, the beetle's natural hibernation quarters, during the emergence season of 1926.

exposure, where it would receive a large amount of moisture. The hibernation quarters consisted of pine needles and oak leaves. Cage No. 8 was located on the north side of a gentle rolling hill at an elevation of 6,800 feet in the juniper and nut-pine region, with pinyon needles as the hibernation material. Cage No. 10 was located out of the hibernation zone at an altitude of 6,100 feet, near the laboratory, in a suitable place where it would receive the maximum amount of snow without blowing; oak leaves, pine needles and bean vines were used as the hibernation material. Cage No. 11 was located at an elevation of 7,050 feet on the east side of a steep hill covered with large yellow pines, where the turf was heavy; pine needles were the hibernation material employed.

During the hibernation season of 1923–24, 5,540 beetles were placed in cage No. 6; in both 1924–25 and 1925–26 winters, 5,000 insects were used in this cage. In cage No. 5, 1,296 beetles were introduced during the fall of 1924 and 5,000 adults in 1925. During the fall of 1925, the following numbers of beetles were placed in the different cages: cage No. 7, 10,000; cage No. 8, 2,500; cage No. 10, 2,500; and cage No. 11, 1,500.

Beetles used during the hibernation season of 1923–24 were collected in irrigated gardens in the Estancia Valley. Adults for the season of 1924–25 were collected both in the foothill region of the Estancia Valley and in the Rio Grande River Valley, between Belen and Los Lunas, New Mexico. Insects hibernated in 1925–26 were collected in the irrigated area near Hoehne, Colorado, and in the Rio Grande River Valley, north of Albuquerque, New Mexico.

The temperatures given in Figure No. 16, and in Tables 1 to 3 inclusive, also for cages Nos. 5 and 6 in Table 5, are compiled from the meteorological records of cooperative observers. This station is located near Tajique, New Mexico, at an elevation of 7,100 feet, latitude 24° 48′, longitude 106° 18′, three miles northeast of the foothill experiments. The locations of the weather station and of the Tajique Canyon cages are very similar in regard to exposure, topography, drainage and environment. The precipitation data for the emergence seasons 1924 and 1925 were obtained from the same source. During the emergence season of 1926, rain gauges were established in close proximity to the different cages in order that more accurate data might be obtained. The meteorological data given in Table 4 and for cage No. 10 in Table 5 are those recorded by the writer at the laboratory 10 feet from the cage.

Observations of the foothill cages were made as often as time and conditions would allow, generally daily or at least every other day.

The cage located at the laboratory was observed daily. After emergence became general the active beetles were removed from the cages on days that an examination was made and the numbers thus removed were used in computing the percentages given in the tables.

Emergence From Artificial Hibernation

During the season of 1924 the first beetle emerged from cage No. 6 at 7,000 feet elevation on May 23 and emergence continued at irregular intervals until July 30. The emergence period for this season extended over a period of 68 days, as summarized in Table 1. The greatest number appeared over a rainy period of four days from July 1 to 4, inclusive, when 737 out of 1,304 beetles or 56.52 per cent emerged. It will be noted from a glance at Table 1, that 50.6°F. is the lowest average mean temperature at which emergence occurred and that this was during a period of precipitation. Table 1 shows that 176 and 123 beetles emerged during the periods ending June 9 and 23, respectively, without precipitation, but as the rain gauge was located three miles from the cage local showers could have occurred without being recorded.

Table 1. Emergence form Hibernation in Cage No. 6, at 7,000 Feet Elevation During 1924

Weekly Period Ending	Average Mean Temperature For Period (°F.)	Precipitation (Inches)	Number of Beetles Emerging
May 26.........	56.8	0.00	3
June 2.........	50.5	.56*	35
9.........	61.5	.00	176
16.........	65.7	.20	62
23.........	65.5	.00	123
30.........	66.4	.42	91
July 7.........	60.4	1.31	737
14.........	63.8	.26	65
21.........	65.6	.75	21
28.........	60.2	2.91	1
Aug. 4.........	62.3	.29	1

*0.08 inch snow May 28.

The first beetle to emerge in 1925 was on April 12, in cage No. 6 at 7,000 feet elevation, but it reentered the hibernation material by April 14. The next beetle to emerge was on May 17 and emergence continued intermittently until August 1. The emergence period extended over a period of 76 days, with two distinct peaks of intense emergence, as shown in Table 2. The first peak centered on June 22 and the second on July 5. The heaviest emergence took place from July 2, to 6 inclusive,

TABLE 2. EMERGENCE FROM HIBERNATION IN CAGE NO. 5 AT 7,050 FEET ELEVATION AND CAGE NO. 6 AT 7,000 FEET ELEVATION DURING 1925

Weekly Period Ending	Average Mean Temperature For Period (°F.)	Precipitation (Inches)	Number of Beetles Emerging	
			Cage No. 5	Cage No. 6
May 19.......	54.7	.00	0	5
26.......	59.0	T	0	1
June 2.......	56.7	.08	1	3
9.......	57.9	.00	1	1
16.......	62.5	.02	64*	1
23.......	62.6	.43	14	57
30.......	60.6	.03	4	1
July 7.......	63.3	.54	34	235
14.......	65.9	.05	11	40
21.......	70.2	.19	1	6
28.......	63.5	1.66	0	11
Aug. 4.......	59.4	.86	0	7

*1¼ inches artificial precipitation June 10.

when during a period of five days 234 out of 363 beetles or 64.46 per cent emerged from cage No. 6. In cage No. 5 at 7,050 feet elevation the greatest number of beetles emerged June 10, when within a period of five hours, during an experiment in which water approximating 1¼ inches of precipitation was sprayed into the cage, 64 beetles or 49.23 per cent emerged. Under natural conditions 51.51 per cent of the re-

TABLE 3. EMERGENCE FROM HIBERNATION IN CAGE NO. 5 AT 7,050 FEET ELEVATION, CAGE NO. 6 AT 7,000 FEET, CAGE NO. 7 AT 6,975 FEET, CAGE NO. 8 AT 6,800 FEET AND CAGE NO. 11 AT 7,050 FEET DURING 1926

Weekly Period Ending	Average Mean Temperature For Period (°F.)	Precipitation (Inches)	Number of Beetles Emerging				
			Cage No. 5	Cage No. 6	Cage No. 7	Cage No. 8	Cage No. 11
May 5.....	48.8	.48	0	1	2	0	1
12.....	42.8	.64	0	0	0	0	0
19.....	52.0	.01	1	5	0	0	0
26.....	56.8	.55	12	41	3	0	8
June 2.....	55.1	.71	17	30	10	0	0
9.....	59.1	.29	80	57	17	0	12
16.....	59.9	.41	205	186	7	1	86
23.....	59.9	.25	95	150	3	8	32
30.....	63.9	.22	391	548	7	19	46
July 7.....	62.3	.26	254	597	37	27	77
14.....	60.4	.30	47	166	14	11	43
21.....	63.7	T	1	17	13	0	4
28.....	60.6	1.70	9	14	64	1	30
Aug. 4.....	63.6	.06	0	0	6	0	0

maining beetles emerged during a period of three days from July 4 to 6, inclusive. Table 2 shows similar emergence in the two cages and that the peaks of emergence and of precipitation occur together. The effect of precipitation as the stimulus influencing emergence is best illustrated by the data for the weekly period ending June 16. The greatest emergence in cage No. 5 was during the artificial precipitation, when 64 insects issued, as compared to one adult emerged in cage No. 6 during the period.

The first emergence in the foothills during the season of 1926 was on April 8, when five adults were found on the screen in cage No. 7. These beetles later reentered the hibernation material. Permanent emergence occurred on May 2 and continued irregularly until July 30. This emergence period extended over 89 days and was very general and intensive for several weeks in the yellow-pine forest zone. The greatest number emerged from cage No. 6 at 7,000 feet elevation from June 27 to July 8, inclusive, when during a period of 12 days 1,171 out of 1,812 beetles or 64.62 per cent emerged. During the same period 645 beetles out of 1,112 or 58 per cent emerged in cage No. 5 at 7,050 feet elevation. From cage No. 7 the heaviest emergence took place from July 22 to 27, inclusive, when 64 beetles emerged or 34.97 per cent in a period of six days. In cage No. 8 the peak of emergence occurred in a period of five days from July 3 to 7, inclusive, when 27 beetles or 38.57 per cent emerged. The greatest emergence from cage No. 11 occurred on June 11 when 69 beetles or 20.35 per cent emerged. Table 3 shows that the periods and peaks of emergence from cage hibernation in the same canyon within two miles varies under varying circumstances, depending

Table 4. Emergence from Hibernation in Cage No. 10 at 6,100 Feet Elevation During 1926

Weekly Period Ending	Average Mean Temperature For Period (°F.)	Precipitation (Inches)	Number of Beetles Emerging
May 5.......	52.2	0.74	15
12.......	49.8	.01	0
19.......	55.4	.02	104
26.......	62.8	.38	37
June 2.......	58.4	.58*	49
9.......	63.8	.22	40
16.......	66.2	.39**	40
23.......	65.8	.02	33
30.......	69.1	T	41
July 7.......	67.8	1.04	182
14.......	64.6	.06	7

*Hail. **0.30 inch hail.

upon local conditions, but under natural conditions it is doubtful if beetles in search of hibernation quarters would attempt to hibernate in locations approximating conditions found in cages 7 and 8.

Active beetles appeared in cage No. 10 at 6,100 feet elevation on April 9, when 15 beetles were noted crawling over the hibernation material during a rain and sleet storm, but later in the day they re-entered the material. This appearing and disappearing continued with every period of precipitation until May 5; after that time no beetles emerged until the 15th, when two beetles appeared very active, as the temperature on top of the hibernation material was 104°F. May 16, 99 beetles or 18.16 per cent emerged within two hours during a slight sprinkle of rain with an average temperature of 74°F. for the period. From July 4 to 6, inclusive, 154 beetles or 28.26 per cent emerged in a period of three days in which 0.72 inch of rain fell. The last beetle emerged in this cage on July 14, as shown in Table 4.

Figure 15 shows the daily emergence from hibernation during 1926 in cages Nos. 5, 6 and 11, which were located in the yellow-pine forest zone. The location of these cages represents a typical cross section of the natural hibernation quarters. The emergence from these cages is summarized in Table 3. It will be noted that the rates of emergence from these three cages are very similar and that in general they respond together to the stimulus effecting emergence. The effect of the combination factors, temperature and precipitation, is best illustrated by the data given in Figure 15, which show a definite relation between rainfall and emergence and that the intensity of emergence is governed by the temperature. The indications are that rainfall starts the emergence and the prevailing temperature during the period of precipitation or just following it is the accelerator. Figure 15 shows that three beetles emerged when the mean temperature was below 50°F., and that 79 beetles issued at temperatures between 50° and 55°F. No major emergence occurred on days in which the mean temperature was below 57°F. The greatest number of beetles emerged on days when precipitation occurred and decreased as the hibernation material dried out. At 50.5°F., it required 0.66 inch of precipitation to influence 28 beetles to emerge. Then at 60.5°F., 0.18 inch of rain brought out 263 beetles. Again, 66.5°F. and 0.16 inch of rainfall stimulated 505 beetles to issue.

From Natural Hibernation

Data upon emergence of the beetles from natural hibernation were obtained by recording the increase of beetles in fields located in canyons nearest the mountains, the natural hibernation quarters. In 1922 a few beetles were taken in irrigated gardens on June 13 by J. E. Graf,[1] who states that "apparently the heaviest emergence took place from June 19th to June 24th." From a study of the daily precipitation recorded in the hibernation area for the month of June, one finds that 5 of the 6 days given above were rainy, and that 0.91 inch of precipitation fell during that time. Preceding this period was a dry spell with a considerable excess of temperature for 16 days.

During the season of 1924 the first beetles appeared in the fields on June 20, six days after 0.20 inch of rain, the first precipitation during June, and increased until June 23. From June 24 to 30 there was little increase in infestation. General rains fell in the mountains from June 28 to July 4, inclusive, when a precipitation of 1.73 inches was recorded for the period and was followed by a gradual increase in the number of beetles entering the fields from July 1 to 11, inclusive. In one small bean field the number of overwintered beetles increased from 2 on June 20 to 15 on June 23 and 33 on June 28, and from 98 on July 3 to 557 on July 9. In another field the insects increased from 2 on June 21 to 4 on July 2, and from 290 on July 5 to 2,556 on July 11.

The first beetles appeared in 1925 on June 18 in a field of volunteer beans located in Canyon De Los Migos at an elevation of 7,100 feet, near the foot of the mountains. On June 17, 0.29 inch of rain fell over the area drained by this canyon. Four light showers fell from June 1 to 15, totalling 0.05 inch of precipitation. There was a great increase in infestation from June 18 to 21, when the first peak of infestation occurred. This peak was followed by a gradual decrease in beetles entering the field from hibernation and a gradual increase in adults leaving the field. There was little change in infestation from June 21 to 28, when as many as 30 beetles were noted on the larger plants. A general migration from the field was observed June 28, July 2 and 3, when beetles were noted on weeds, cedar, oak and pine trees in the canyon below the bean field. Very few beetles entered the field from hibernation during the period from June 28 to July 4. General rains fell in the canyons from July 3 to 5, inclusive, and were followed by a rapid increase in the number of beetles that entered the field from July 5 to 7, inclusive, when the second peak of infestation occurred. By July 8 the majority of the leaves on the volunteer (early) bean plants were destroyed and the beetles left the field and continued their migration down the canyon. From July 8 to 13 few beetles entered the field, since infestation was very light on the 13th.

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[1]Unpublished data by J. E. Graf, Bureau of Entomology.

In 1926 the first beetles were found on June 17 in fields located in canyons near the foot of the mountains. There was little or no change in the infestation until June 28 and 29, when there was a slight increase in infestation, followed by a lull until July 2, when again the number of overwintered beetles increased until July 6. The next increase was noted from July 10 to 12, inclusive, when the first large increase of the season occurred. This was followed by a four-day period when no noticeable change in infestation could be observed, as beetles migrate in and out of the fields during the entire spring migration period. The last migration period of the season was from July 17 to 22, inclusive, when a 49 per cent increase in overwintered beetles was noted over that of July 12.

These results show that emergence from natural hibernation is slower than from cage hibernation, but this is readily understood when it is known that beetles become semi-active during periods when factors are favorable for emergence in the early spring, and Howard[2] has shown that the majority of beetles move about their hibernation quarters on warm days. The great range in temperature in the Southwest would tend to cause the beetles to become active in the day and reenter their hibernation material late in the afternoon; as it is not uncommon to have a daily range of over 40°F. during the spring. Beetles emerging from natural hibernation enter the field before being recorded, which process requires some time, depending upon distance and other factors influencing flight.

Factors Influencing Emergence

Temperature is a factor in the emergence of the bean beetle from hibernation, as it has been observed that emergence in the spring begins during the first warm days the latter part of May, especially if there has been rainfall. An examination of Figure 16 and Tables 1 to 4 will show that emergence rarely occurs when the mean temperature is below 55°F. and attains its maximum at a mean temperature of 58° to 69°F. Two major emergences occurred on days with a mean temperature of 56.5° and 57.5°F., as shown in Table 5, but the precipitation fell and the insects emerged during the heat of the day. No major emergence occurs from the effect of temperature alone; as it will be noted from Table 5, that no emergence occurred from cage No. 10 on June 12, 23 and July 2, when the mean temperature was 70.5°, 71° and 73°F., respectively; though a few beetles may emerge on warm days

[2]Howard, Neale F., and English, L. L., 1924. Studies of the Mexican bean beetle in the Southeast. U. S. Dept. Agri. Bul. 1243, p. 50.

without the aid of rainfall, especially if the hibernation material is damp.

The effect of precipitation on emergence is best illustrated by the data presented in Table 5, which show by comparison that rainfall is the greatest of the two stimuli influencing the emergence of the Mexican bean beetle from hibernation, especially after the mean temperature has increased to 50°F. Emergence occurs at much lower temperature during periods of precipitation, but in such cases the beetles resume hibernation after the precipitation ceases. Local showers during the heat of the day will bring out of hibernation more beetles than the same amount of precipitation under lower temperatures. Local rainfall over one canyon area will have no effect on the insects about to emerge in the adjacent canyons. It will be noted from Tables 1 and 2 that

TABLE 5. EMERGENCE FROM HIBERNATION ON SOME OF THE HOTTEST AND WETTEST DAYS

Year	Cage	Date	Temperature (°F.) Max.	Min.	Mean	Precipitation (Inches)	Number of Beetles Emerging	Per cent Emerging
1924	6	June 17	86	48	67	0.00	3	0.23
		24	85	50	67.5	.00	8	.61
		July 1	76	44	60	1.10	428	32.82
		2	67	50	58.5	.18	199	15.26
1925	6	June 14	79	55	67	.00	0	.00
		27	79	52	65.5	.00	1	.27
	5	June 10	73	44	56.5	1.25*	64	49.23
	6	July 5	74	50	62	.31	92	25.34
		6	78	48	63	.06	42	11.57
1926	6	June 24	79	47	63	.00	9	.49
		29	84	47	65.5	.00	26	1.43
		July 2	84	52	68	.00	36	1.99
		June 27	79	46	62.5	.06	133	7.34
		30	83	50	66.5	.16	297	16.39
		July 6	74	47	60.5	.21	283	15.62
	10	June 12	84	57	70.5	.00	0	.00
		23	87	55	71	.00	0	.00
		29	93	49	71	.00	1	.18
		July 2	93	53	73	.00	0	.00
		May 16	78	37	57.5	.02	99	18.16
		July 5	84	55	69.5	.32	91	16.70

*Artificial precipitation.

whenever heavy rains are preceded by hot, dry weather, the majority of the beetles emerge in a period of a very few days; as during the emergence seasons of 1924 and 1925. In 1926 little precipitation was recorded every week during the emergence season, as shown in Tables 3 and 4, with the result that emergence was general and intensive over a period of 6 weeks in the foothills and 8 weeks at the laboratory.

The effect of precipitation in the form of hail on emergence is best illustrated by the data for cage No. 10 at 6,100 feet elevation. On May 27, 0.58 inch of rain and hail fell and decreased the mean temperature from 64° to 50.5°F. without influencing the emergence of a single beetle. Again on June 9, 0.30 inch of rain and hail fell and decreased the temperature from 83° to 54°F. within three hours without stimulating emergence. Figure 16 and Tables 1 to 5 show that there is a definite relation between the precipitation and emergence of the Mexican bean beetle from hibernation and that the percentage emerging is directly influenced by the temperature during the period of rainfall. Similar results have been obtained at Birmingham, Alabama, and in Ohio.[3]

DIFFERENTIAL EFFECTS OF CONSTANT HUMIDITIES ON *PROTOPARCE QUINQUEMACULATUS* HAWORTH, AND ITS PARASITE, *WINTHEMIA QUADRIPUSTULATA* FABRICUS

By HAROLD M. HEFLEY, *Zoological Laboratory, University of Wisconsin*[1]

ABSTRACT

Tomato moth larvae, both parasitized and unparasitized by the Tachinid, *W. quadripustulata* were subjected to different constant humidity percentages at constant temperature during the pupal period of both host and parasite. The effects of the moisture on the length of the pupal period and the viability were noted.

It was found that as the humidity increased the viability of the host decreased, while that of the parasite increased. Both host and parasite showed a maximum rate of metamorphosis near 73.4% humidity at 27 degrees Centigrade.

INTRODUCTION

Most workers investigating the problem of the effect of external conditions on the rate of insect matamorphosis have dealt mainly with temperature, and attributed most of the changes in rate to this factor. In most cases the experiments reported have been conducted with very accurately controlled temperatures, but without similar control of the humidity. To be convincing the experiments should be repeated with carefully controlled humidity as well as temperature. Sanderson, (1910), was one of the first to recognize that humidity is a factor that should be taken into consideration by the economic worker dealing with the

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[3]Data from correspondence with Neale F. Howard, Bureau of Entomology.

[1]Contribution from the Zoological Laboratory, University of Oklahoma.