its bearing on radiation induced sterility. I-II. Kyushu Univ. Fac. Agr. J. 12: 359–404.

Walker, J. R., and T. A. Brindley. 1963. Effect of X-ray exposure on the European corn borer. J. Econ. Entomol. 56: 522–5.

Weiss, J., A. O. Allen, and H. A. Schwarz. 1956. Use of the Fricke ferrous sulfate dosimeter for gamma-ray doses in the range of 4 to 40 kr. Proc. Int. Conf. Peaceful Uses At. Energy, Geneva, 1955. Paper 155. 14: 179-81.

Estivation Studies of the Convergent Lady Beetle in Arkansas[1]

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ABSTRACT

An investigation was made to determine whether summer estivation of the convergent lady beetle, *Hippodamia convergens* Guérin-Méneville, occurs in Arkansas. Results showed that, beginning in June, the convergent lady beetle populations in cultivated crops dropped very sharply. The beetles remaining in most fields were sexually inactive, with undeveloped ovaries and a low rate of oxygen consumption. Aggregations of convergent lady beetles began to appear on Pinnacle and Sugarloaf Mountains from the first to the last week in June. Beetles collected on mountain tops had undeveloped ovaries, and their oxygen-consumption rate was low. Aggregations formed about June 3, 1965, on Pinnacle Mountain remained intact until February 1966. In 1966, for some unexplained reason, aggregations formed about June 28 disappeared in September of that year. Estivation appeared to be facultative and associated with low prey populations. When aphids were abundant, as in early spring and fall, the beetles tended to be sexually active and showed a high rate of oxygen consumption.

Several species of lady beetles are important predators on eggs of the bollworm, *Heliothis zea* (Boddie). They prey also upon the pea aphid, *Acyrthosiphon pisum* (Harris) (Hagen 1962); the cotton aphid, *Aphis gossypii* Glover (Michelbacher and Middlekauff 1950, Carnes 1912); the corn leaf aphid, *Rhopalosiphum maidis* (Fitch); and the spotted alfalfa aphid, *Therioaphis maculata* (Buckton) (Goodarzy and Davis 1958, Simpson and Burkhardt 1960). The 3 lady beetles that are of primary concern in Arkansas row crops are the convergent lady beetle, *Hippodamia convergens* Guérin-Méneville; *Coleomegilla maculata* (De Geer); and *Coccinella novemnotata* Herbst. These 3 species consume large numbers of bollworm eggs in the field (Whitcomb and Bell 1964). Any factor affecting the efficiency of any of these lady beetles in cotton or other crops would be of the utmost importance. Since Hagen (1962) and others have reported summer estivation of convergent lady beetles in California, the possibility of this occurring in Arkansas during the cotton-growing season was investigated.

The convergent lady beetle has been observed both in summer and winter aggregations for many years, but such aggregations have not been reported in the lower Mississippi Valley. Howard (1896) reported thousands of aggregating beetles on a chaparral bush near the top of Mount Tamalpais in the San Francisco Bay area on November 15. Carnes (1912) collected them from mountains in California, stored them throughout the winter, and released them in the spring in an effort to control cotton aphids. Ewing (1913) reported aggregations on Mount Chintimini in Oregon. Gillette (1923) reported aggregations in Colorado. Essig (1926) noted that the convergent lady beetle overwinters in valleys and in the Sierra Nevada in California. Hawkes (1926) observed aggregations in the Yosemite Valley in California. Douglass (1930) reported aggregations on a mountain peak in New Mexico. Rockwood (1952) noted that aggregations in western Oregon are usually near water, in cold, damp canyons. Hagen (1962) did much research in California and observed and studied aggregations in the Sierra Nevada.

Throne (1935) was apparently the first to report the massing of lady beetles east of the Rocky Mountains. He records finding convergent lady beetles at a high point on the north range of the Porcupine Mountains, Ontonagon County, Mich. The most thorough study of aggregations in the eastern United States was that of Sherman (1938). He reported finding convergent lady beetles from June 13 until February 3 on mountains in North and South Carolina and Georgia. In most cases, countless thousands of beetles were clustered on weeds, bushes, and among old leaves. He included a photograph of the massing of convergent lady beetles clustered 2–3 ft above the ground on green oak sprouts.

MATERIALS AND METHODS.—To determine whether summer estivation of convergent lady beetles occurred in Arkansas, a search was made for aggregations of beetles on mountain peaks. Male and female beetles from cultivated fields and from aggregations on the mountains were dissected to determine sexual development. Oxygen consumption was measured to determine the rate of activity.

All specimens taken for dissection were placed in Kahle's solution. Some were transferred to 70% ethanol after 48 hr, while others remained in the fixative for weeks, until they were dissected. Both methods proved satisfactory.

Ovary development was determined by dissection under a stereoscopic microscope. If at least 3 ovarioles were developing separate follicles, they were considered mature. Fat deposition could be observed both internally and externally. A specimen with high fat content usually had the abdomen distended and, when dissected, the fat could easily be seen as liquid and solid depositions. For this study, all specimens were dissected. Carotene content is relative; a deep yellow color was considered high, while a light yellow to almost white color was considered low.

Oxygen consumption was measured with a Gilson

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Differential Respirometer. Six beetles were placed in a flask, with a total of 6 flasks used. The readings were taken directly in μliters, and from this, a reading of μliters of oxygen per hour per beetle was computed. The temperature was a constant 18°C, and the bottom lights were not turned on. Each test lasted 4½ hr.

RESULTS.—*Aggregation Studies.*—In this study, the first aggregations were encountered June 7, 1965. The site was on the summit of Pinnacle Mountain, a cone-shaped peak approximately 20 miles west of Little Rock, Arkansas. The elevation of the mountain is 1900 ft. The flora of the peak is composed mostly of broom sedge, *Andropogon virginicus* L.; small oak trees, *Quercus* sp.; and small sassafras trees, *Sassafras albidum* (Nutt.) Nees. The convergent lady beetle was the only species of lady beetle present at that time. *Coccinella novemnotata* was sometimes collected on the mountain during the summer; however, no more than 3–5 specimens were collected on any 1 visit. *Coleomegilla maculata* was found on the mountain on only 1 occasion, December 15, 1966, when 2 were found in broom sedge.

The aggregations found on June 7, 1965, were located in the crevices of large rocks which occur on the peak. The size of the masses varied from a few individuals to a few thousand. Some of the masses were exposed between the crevices of the rocks, while others could be seen only by brushing aside the broom sedge and sassafras sprouts, which grew close to the rocks. The aggregations were inactive if left undisturbed, but they became very active if disturbed by the observer. Many beetles would move completely away from the site and crawl on neighboring plants. They would seldom fly, even during the summer months, and when they did fly, it was for a distance of only 2–10 ft. When a "handful" of beetles were lightly thrown into the air, most of them made no attempt to fly; they landed on the rocks and crawled either onto the plants or into crevices of the rocks.

The aggregations remained in the same places through November 9, 1965, with no noticeable change, except an increase in size of the masses during July. On December 9, 1965, a routine check of the massing sites revealed few beetles. None could be found in the crevices, but a few were present in the leaf trash at the base of the rocks. Very few specimens were collected on this date. Another search was made December 23. The beetles were found in clumps at the base of the broom sedge, exposed to the sun on the southernmost part of the peak. Although numbers were somewhat less than during the summer, a thorough search of the broom sedge revealed hundreds of beetles. They had left the rocks and protected themselves by crawling almost to ground level in the middle of the broom sedge clumps. They remained in or on the broom sedge until the middle of March. At 1 time they were collected by the removal of 10–12 in. of snow from the plants. A visit on February 8, 1966, showed the beetles still in aggregations, but some individuals were flying from rock to rock and crawling on dead leaves, broom sedge, and discarded plastic bags. There was some copulation. They seemed to be active, moving about when climatic conditions permitted. The temperature on this date was approximately 60°F. A visit on February 24 showed beetles still on the mountain. The next observations, those on March 10 and 24, revealed no beetles; they apparently left the mountain top around March 1.

The aggregations on Pinnacle Mountain did not form again until June. A visit on June 13 revealed no beetles, but when an ascent was made on June 28, several aggregations were found. The aggregations were formed close to the sites of those of 1965. By July 12, the aggregations had grown considerably in size. The largest aggregation was found on the side of a large rock protected by a small sassafras tree. When a check was made July 26, the aggregations had again increased in size. Hundreds of beetles were clustered between crevices in the rock and also in broom sedge. The aggregations remained about the same size and in the same places through August 9. On August 25, it was discovered that few beetles remained in the large aggregation on the rock by the sassafras tree. Most of the collections were from this site, but the collections alone would not account for the great reduction in numbers that had occurred. On September 6, the only beetles left in this aggregation were found on the sassafras tree; approximately 200 beetles were present on curled leaves. On September 22, no beetles could be found in the crevices between rocks, and only 1 specimen was taken on broom sedge. On the next visit, October 4, lady beetles were found in 1 clump of broom sedge, and 60 specimens were taken. No beetles were found in crevices of rocks or on the sassafras tree. Successive visits on October 27, November 8, November 22, and December 15 revealed few beetles. During this time, no more than 5 were found on any 1 visit.

The behavior of the aggregating beetles differed significantly in the 2 years they were studied. In 1965, the beetles were found throughout the fall and winter months until the 1st of March. During 1966, the beetles were numerous until the early part of September; after that time they were not found in large numbers again. No explanation can be offered as to why the beetles left the aggregation sites, but at the time the beetles apparently left the mountain a large number of arboreal aphids were found throughout the state. Maple trees, particularly in northwest Arkansas, were heavily infested with a maple aphid, *Drepanaphis spicata* Smith, and 20 convergent lady beetles were collected from 1 tree on October 14.

Dissection and Oxygen Consumption of Specimens from Pinnacle Mountain.—Beginning June 22, 1965, specimens from Pinnacle Mountain were dissected to determine ovary development, fat content, and carotene content (Table 1). In most cases, the dissections showed little or no ovary development. The only specimens found on the mountain with developed or developing ovaries were collected September 22, 1966. The fat content was usually high, particularly in the summer and fall months. As the winter progressed, the reserve fat was evidently used, and by January and February the fat content was considerably lower in the specimens dissected. It is interesting that the carotene content of the beetles on the mountain is usually high in the summer and fall months and then becomes increasingly lower as the winter progresses. Later in the spring, when the lady beetles were in the fields, the carotene was found almost entirely in maturing ovarioles, while the intestines and fat were gray.

A dissection of male convergent lady beetles also was included in the investigation. In contrast to the ovaries of the female, the testes of the male were

Table 1.—Ovary, fat, and carotene development of convergent lady beetles taken from Pinnacle Mountain.

Date	Total dissected	No. with ovary: Undeveloped	No. with ovary: Developed	No. with fat deposition: Low	No. with fat deposition: High	No. with carotene: Low	No. with carotene: High
June 1965–February 1966							
22 June	24	24	0	0	24	1	23
23 July	31	31	0	2	29	5	26
13 Aug.	23	23	0	0	23	11	12
23 Aug.	21	21	0	0	21	9	12
30 Aug.	25	25	0	–	–	–	–
5 Sept.	30	30	0	0	30	13	17
14 Sept.	30	30	0	0	30	21	9
28 Sept.	30	30	0	0	30	2	28
8 Oct.	30	30	0	0	30	21	9
9 Nov.	30	30	0	12	18	21	9
9 Dec.	27	27	0	17	10	18	9
23 Dec.	30	30	0	24	6	24	6
10 Jan.	30	30	0	12	18	11	19
26 Jan.	30	30	0	20	10	23	7
8 Feb.	30	30	0	16	14	21	9
24 Feb.	30	30	0	15	15	23	7
June 1966–October 1966							
28 June	30	30	0	0	30	8	22
12 July	30	30	0	0	30	0	30
26 July	30	30	0	0	30	4	26
9 Aug.	22	22	0	0	22	4	18
25 Aug.	28	28	0	3	25	12	16
6 Sept.	28	28	0	0	28	12	16
22 Sept.	5	3	2	0	5	5	0
4 Oct.	30	30	0	0	30	14	16
27 Oct.	3	3	0	1	2	1	2

apparently well developed in all specimens taken from the aggregation sites. However, there were fewer sperm bundles in the specimens taken in the summer and fall than in those collected in January and February from Pinnacle Mountain, although in both cases the males were apparently sexually active.

Table 2.—Oxygen consumption of convergent lady beetles taken from Pinnacle Mountain. November 1965–October 1966.

Date	Oxygen consumption μliters/hr[a]	Date	Oxygen consumption μliters/hr[a]
9 Nov.	5.2	12 July	5.4
9 Dec.	6.1	26 July	5.6
23 Dec.	7.9	9 Aug.	8.8
10 Jan.	5.9	25 Aug.	6.4
8 Feb.	8.1	7 Sept.	4.8
24 Feb.	6.7	4 Oct.	5.8
28 June	11.9		

[a] Average oxygen consumption of 36 specimens.

As a further check of sexual development, males from Pinnacle Mountain were dissected alive, and the testes were prepared on a glass slide in distilled water. The testes were then mashed with forceps, and a cover slip was applied. Using a magnification of 970×, live sperm could be observed.

Oxygen consumption also was studied (Table 2). The readings were taken from November 9, 1965, to October 4, 1966. The amount of oxygen consumed by specimens collected from November 9 until the aggregation sites were abandoned in early March was low and consistent (5.2–8.1 μliters/hr per beetle, in contrast to 29.1 on vetch in March in the lowland) (Table 6). When the aggregations were again formed in June, oxygen consumption was found to be 11.9 μliters/hr per beetle, the highest recording from aggregating specimens. After a period of 2 weeks, the amount consumed had decreased to 5.4 μliters/hr per beetle. The mean reading for all beetles taken on the mountain was 6.8 μliters/hr per beetle.

Activity in Cultivated Fields.—During the period of June 3–9, 1965, when aggregations were first found on Pinnacle Mountain, collections were made from cotton, alfalfa, and cornfields near Morrilton, Arkansas, approximately 35 miles from the mountain. Beetles were not so numerous as they had been 1

Table 3.—Ovary, fat, and carotene development of convergent lady beetles taken from cotton and corn in Conway County. June–August 1965.

Date	Crop	No. with ovary: Undeveloped	No. with ovary: Developed	No. with fat deposition: Low	No. with fat deposition: High	No. with carotene: Low	No. with carotene: High
3–9 June	Cotton	5	0	4	1		
	Corn	2	0	0	2		
10–16 June	Cotton	12	0	8	4		
	Corn	23	0	11	12		
17–23 June	Cotton	8	1	7	2	7	2
	Corn	4	1	4	1	4	1
24–30 June	Cotton	9	0	2	7	7	2
	Corn	16	4	9	11		
1–7 July	Cotton	12	0	8	4	10	2
	Corn	13	2	5	10	9	6
8–14 July	Cotton	17	1	8	10	14	4
	Corn	11	0	3	8	6	5
15–21 July	Cotton	6	1	1	6	6	1
	Corn	7	0	1	6	4	3
22–28 July	Cotton	1	1	0	2	2	0
	Corn	2	0	1	1	1	1
29 July–Aug. 4	Cotton	1	2	2	1	2	1
	Corn						
5–13 Aug.	Cotton	4	1	1	4	5	0
	Corn	15	2	5	12	9	8

Table 4.—Ovary, fat, and carotene development of convergent lady beetles collected in various counties during the summer of 1965.

Date	County	Host plant	No. with ovary		No. with fat deposition		No. with carotene	
			Undeveloped	Developed	Low	High	Low	High
12 Aug.	Pope	Cocklebur	0	7	0	7	2	5
17 Aug.	Lincoln	Cotton	16	16	23	9	24	8
18 Aug.	Miss.	Cotton	0	3	0	3	1	2
23 Aug.	Pope	Cocklebur	21	9	2	28	2	28
31 Aug.	Monroe	Cotton	0	6	0	6	0	6

week earlier and were more difficult to obtain (Table 3). All beetles taken had undeveloped ovaries. They differed from those collected on Pinnacle Mountain in that the fat content and amount of carotene were low. Three beetles had well-developed fat bodies. During the period June 10–16, 35 beetles were taken from cotton and corn near Morrilton. All specimens had undeveloped ovaries, and most showed low fat deposition. Throughout the rest of June and July beetles remained scarce, and most of those collected had undeveloped ovaries. Since the aphid population was low in fields examined after the middle of June, and since there was some chance that the ovary development might be different in a field with a high aphid population, a search was made for aphid-infested fields. On August 12, the senior investigator found a field of sorghum infested with cocklebur, *Xanthium* sp. The cocklebur supported a heavy population of the red composite aphid, *Dactynotus* sp. Eggs, larvae, and adults of convergent lady beetles were taken from these plants. Seven ♀ were dissected; all ovaries were well developed (Table 4). On August 17, an aphid-infested cottonfield was discovered in Lincoln County. Eggs, larvae, and adults of convergent lady beetles were numerous. Half the females dissected had well-developed ovaries (Table 4). Attempts to collect beetles from fields not infested with aphids met with failure; after August 15, the convergent lady beetle had almost disappeared from such fields. On August 18, another aphid-infested field was found near Manila in Mississippi County (Table 4). Convergent lady beetle pupae and adults were numerous. Most adults captured were teneral. However, 3 older females were dissected and were found to have well-developed ovaries. Another aphid-infested cottonfield was located on August 31 in Monroe County with eggs, larvae, and adult convergent lady beetles present. The 6 ♀ dissected had well-developed ovaries (Table 4). On September 27, a large number of convergent lady beetles were observed feeding on the green peach aphid, *Myzus persicae* (Sulzer), on bell pepper on the University Farm near Fayetteville.

During the winter, only 1 group of beetles was taken in hibernation in the lowland. These were dug from broom sedge clumps on February 18, 1966, in Washington County. Eight beetles were dissected; none had developed ovaries (Table 5). An oxygen-consumption check was run. The beetles consumed an average of 10.3 μliters of oxygen/hr per beetle (Table 6) in contrast to 6.7 μliters/hr per beetle for those taken from Pinnacle Mountain on February 24 (Table 2).

In the spring of 1966 after the aggregation sites were abandoned in early March, sexually active beetles were found in vetch and winter wheat in Washington County. The 1st specimens were taken March 17. Of the 30 ♀ dissected, 28 had mature or maturing ovaries. The beetles consumed 29.1 μliters of oxygen/hr per beetle (Table 6), which was the highest reading reported in any of our tests. This was an increase of 22.4 μliters of oxygen/hr per beetle over the last reading taken from Pinnacle Mountain. Dissection of 30 ♀ taken on vetch April 22 showed fully developed ovaries in every case (Table 5). The oxygen consumption was only slightly below the first reading

Table 5.—Ovary, fat, and carotene development of convergent lady beetles collected in Washington County in or near cultivated fields during 1966.

Date	Host plant	No. with ovary		No. with fat deposition		No. with carotene	
		Undeveloped	Developed	Low	High	Low	High
18 Feb.	Broom sedge	8	0	1	7	4	4
17 March	Vetch, winter wheat	2	28	30	0	30	0
24 March	Wheat	4	6	5	5	2	8
22 April	Vetch	0	30	24	6	13	17
3 May	Alfalfa	2	23	7	18	2	23
23 May	Vetch	11	19	0	30	5	25
16 June	Alfalfa, corn	8	16	6	18	10	14
30 June	Corn	18	8	2	24	10	16
15 July	Corn	26	4	4	26	22	8
27 July	Corn	27	3	3	27	17	13
10 Aug.	Corn	0	30	3	27	25	5
27 Aug.	Alfalfa	7	20	2	25	14	13
31 Oct.	Alfalfa	4	2	1	5	4	2

Table 6.—Oxygen consumption of convergent lady beetles found in or near cultivated fields. March 1966 to October 1966.

Date	County	Host plant	Prey	Oxygen consumed/ hr per beetle (μliters)
18 Feb.	Washington	Broom sedge	None	10.3
17 March	Washington	Vetch, winter wheat	Pea aphid	29.1
22 April	Washington	Vetch	Pea aphid	28.0
3 May	Washington	Alfalfa	Pea aphid	20.0
23 May	Washington	Vetch	Pea aphid	10.2
1 June	Conway	Alfalfa	Pea aphid	15.0
3 June	Mississippi	*Oenothera*	Unidentified aphid	10.3
6 June	Washington	Johnson grass	None	8.9
14 June	Conway	Corn	Corn leaf aphid	17.1
28 June	Conway	Alfalfa	None	13.5
9 July	Mississippi	Cotton	None[a]	5.0
12 July	Conway	Alfalfa	Pea aphid (scarce)	7.4
26 July	Conway	Cotton	None or scarce	8.5
27 July	Washington	Corn	Corn leaf aphid (scarce)	7.9
4 Oct.	Mississippi	Mustard	Unidentified aphid	18.3
26 Oct.	Crawford	Corn	None	7.4
31 Oct.	Washington	Alfalfa	Pea aphid, spotted alfalfa aphid	11.1

[a] All beetles taken on this date were collected on a sugar line (¼ mile of cotton row sprayed with 1 lb sugar to 1 gal water to attract bollworm moths).

(Table 6). Results of both dissections and oxygen-consumption tests continued about the same until after the second week in June, when aggregations were again found on Pinnacle Mountain. Dissection of females taken from corn June 30 in Washington County showed a complete reversal; 18 of 26 beetles had undeveloped ovaries. Most of the specimens dissected during July and early August in Washington County had undeveloped ovaries, and the oxygen consumption was low. On August 10, an aphid-infested cornfield was examined. All 30 ♀ dissected had well-developed ovaries (Table 5).

Examinations of beetles collected from alfalfa and cotton in Conway County in 1966 showed a situation similar to that of 1965. Of 19 ♀ taken June 1, 16 had well-developed ovaries. However, on June 28, of 30 ♀ dissected, not one had well-developed ovaries (Table 7). Most of the beetles taken from cotton on July 26 had undeveloped ovaries; the oxygen consumption was 8.5 μliters/hr per beetle (Table 6).

Miscellaneous tests in various parts of Arkansas during the summer and fall of 1966 (Table 7) further indicated that in the presence of prey, ovaries would be well developed, and the oxygen rate would tend to be high. In Crawford County, an alfalfa field infested with pea aphids was found June 27. Of 30 ♀, 23 had well-developed ovaries. These results contrasted sharply with dissections taken from an alfalfa field June 28 in Conway County. Prey was scarce in this field, and all the specimens had undeveloped ovaries. On October 4, beetles were collected from a patch of aphid-infested mustard, *Brassica* sp., in Mississippi County, and the oxygen rate was tested. The rate of oxygen consumed was 18.3 μliters/hr per beetle (Table 6). Beetles collected from young green corn in Crawford County October 26 averaged 7.4 μliters of oxygen/hr (Table 6).

DISCUSSION.—In Arkansas, the convergent lady beetles leave hibernation sites in early March and begin to feed on pea aphids in early-season legumes such as

Table 7.—Miscellaneous dissections of convergent lady beetles in or near cultivated fields during the summer and fall of 1966.

Date	County	Host plant	No. with ovary		No. with fat deposition		No. with carotene	
			Undeveloped	Developed	Low	High	Low	High
1 June	Conway	Alfalfa	3	16	10	9	9	10
3 June	Miss.	Vetch-*Oenothera*	13	9	8	14	11	11
6 June	Wash.	Johnson grass	16	14	4	26	11	19
27 June	Crawford	Alfalfa	7	23	1	29	7	23
28 June	Conway	Alfalfa	30	0	7	23	29	1
9 July	Miss.	Cotton[a]	30	0	26	4	6	24
12 July	Conway	Alfalfa	10	0	6	4	9	1
15 July	Miss.	Cotton[a]	13	0	6	7	5	8
26 July	Conway	Cotton	5	4	7	2	6	3
4 Oct.	Miss.	Mustard	1	29	11	19	1	29
11 Oct.	Miss.	Horse-weed	29	1	3	27	0	30
26 Oct.	Crawford	Corn	8	5	8	5	12	1

[a] All beetles taken on these dates were collected on a sugar line in a cottonfield (¼ mile of cotton row sprayed with 1 lb sugar to 1 gal water to attract bollworm moths).

vetch and crimson clover and on aphids in small grain and other hosts. Reproduction begins almost immediately. The highest rate of oxygen consumption during the entire year was found at this time. First-generation adults appear in April and May. In May, the older beetles apparently begin to die, although this matter still remains unclear. Beginning in June, convergent lady beetle populations in cultivated crops and alfalfa dropped very sharply. Those beetles remaining in most fields were sexually inactive, with undeveloped ovaries and a low rate of oxygen consumption. Aggregations of convergent lady beetles began to appear on mountain peaks such as Pinnacle and Sugarloaf from the first to the last week in June. Aggregations were made up almost entirely of the 1 species, although a few *Coccinella novemnotata* were found, as well as 2 specimens of *Coleomegilla maculata*. Beetles collected on mountain tops had undeveloped ovaries, and their oxygen-consumption rate was low. They differed from beetles collected in cultivated fields at this time in that the fat bodies were well developed and the carotene content was high. Estivation appeared to be facultative and associated with low prey populations. Where aphids were abundant, many of the specimens collected were sexually active. Where aphids were scarce, there were few beetles, and they tended to be sexually inactive. Since prey tends to be scarce in July and August in most of Arkansas, beetles collected then usually have undeveloped ovaries and show a low rate of oxygen consumption. As aphids become more abundant in September and October, more sexually active beetles are found. In 1965, aggregations on Pinnacle Mountain remained intact until February 1966. In 1966, aggregations disappeared in September. In Arkansas, convergent lady beetles hibernate on mountain tops and in the lowland in broom sedge and under rocks and boards.

REFERENCES CITED

Carnes, E. K. 1912. Collecting ladybirds (Coccinellidae) by the ton. California State Comm. Hort. Monthly Bull. 1: 71–81.

Douglass, J. R. 1930. Hibernation of the convergent lady beetle, *Hippodamia convergens* Guer., on a mountain peak in New Mexico. J. Econ. Entomol. 23: 288.

Essig, E. O. 1926. Insects of Western North America. Macmillan Co., New York. 1035 p.

Ewing, H. E. 1913. Notes on Oregon Coccinellidae. J. Econ. Entomol. 6: 404–7.

Gillette, C. P. 1923. Ladybeetle, *Hippodamia convergens* Guer., hibernation notes. Colorado State Entomol. Rep. 14: 20.

Goodarzy, K., and D. W. Davis. 1958. Natural enemies of the spotted alfalfa aphid in Utah. J. Econ. Entomol. 51: 612–6.

Hagen, K. S. 1962. Biology and ecology of predaceous Coccinellidae. Annu. Rev. Entomol. 7: 289–326.

Hawkes, O. A. M. 1926. On the massing of the ladybird, *Hippodamia convergens* in the Yosemite Valley. Proc. Zool. Soc. London 1926: 693–705.

Howard, L. O. 1896. Note on *Hippodamia convergens* aggregation in California. Proc. Entomol. Soc. Washington 4: 412.

Michelbacher, A. E., and W. W. Middlekauff. 1950. Control of the melon aphid in northern California. J. Econ. Entomol. 43: 444–7.

Rockwood, L. P. 1952. Notes on coccinellids in the Pacific Northwest (Coleoptera). Pan-Pacific Entomol. 28: 139–47.

Sherman, F. 1938. Massing of convergent ladybeetle at summits of mountains in Southeastern United States. J. Econ. Entomol. 31: 320–2.

Simpson, R. G., and C. C. Burkhardt. 1960. Biology and evaluation of certain predators of *Therioaphis maculata* (Buckton). J. Econ. Entomol. 53: 89–94.

Throne, A. H. 1935. An unusual occurrence of the convergent lady beetle. Ecology 16: 125.

Whitcomb, W. H., and K. Bell. 1964. Predaceous insects, spiders, and mites of Arkansas cotton fields. Arkansas Agr. Exp. Sta. Bull. 690: 1–84.

Control of the Lone Star Tick[1] on Cattle[2]

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ABSTRACT

The following treatments sprayed onto cattle gave >90% reduction of adult lone star ticks, *Amblyomma americanum* (L.), at 1 day posttreatment compared with numbers on untreated cattle: 0.25% Banol® (6-chloro-3,4-xylyl methylcarbamate); 0.05–0.25% Bay 39007 (*o*-isopropoxyphenyl methylcarbamate); 1% bromophos; 0.5% carbaryl; 0.3% Ciodrin® (*alpha*-methylbenzyl 3-hydroxycrotonate dimethyl phosphate); 0.1% Compound 4072 (2-chloro-1-(2,4-dichlorophenyl) vinyl diethyl phosphate); 0.25% coumaphos; 0.03% diazinon (EC); 0.025–0.1% Dursban® (*O,O*-diethyl *O*-3,5,6-trichloro-2-pyridyl phosphorothioate); 0.125–0.25% Imidan® (*O,O*-dimethyl *S*-phthalimidomethyl phosphorodithioate); 0.1–0.5% Shell SD-8447 (2-chloro-1-(2,4,5-trichlorophenyl)vinyl dimethyl phosphate); 0.1% Shell SD-8448 (2-chloro-1-(2,4,5-trichlorophenyl)vinyl diethyl phosphate); 1% trichlorfon; and 0.5% toxaphene (the standard treatment).

Treatments giving less than 90% reduction were: 0.1% Banol; 0.1–0.25% Bay 37341 (*O,O*-diethyl *O*-[4-(methylthio)-3,5-xylyl] phosphorothioate); 0.375% bromophos; 0.25% bromophos-ethyl; 0.05% carbophenothion; 0.03% diazinon (WP); 0.1% Dowco® 175 (2,4-dichlorophenyl propyl methylphosphoramidate); 0.01% Dursban; 0.1% fenthion; 0.1% Imidan; and 0.5% menazon.

At 1 week posttreatment, the following sprays gave reduction equal to or greater than the 64% reduction given by 0.5% toxaphene: 0.25% Bay 37341, 0.1% Bay 39007, 0.5% carbaryl, 0.1% Compound 4072, 0.25% coumaphos, 0.1% Dowco 175, 0.05% Dursban, 0.1 and 0.25% Imidan, 0.1% Shell SD-8448, and 1% trichlorfon. At 2 weeks posttreatment, all treatments except 0.25% coumaphos gave little or no reduction in numbers of ticks. A pouron of 2% Bay 37341 at 1 oz per cwt gave only 39% reduction at 1 day posttreatment, whereas a pouron of 8% trichlorfon at ½ oz per cwt gave 72% reduction at 1 day and 44% reduction at 1 week posttreatment.

The lone star tick, *Amblyomma americanum* (L.), a 3-host species that parasitizes a variety of birds and mammals (Hooker et al. 1912, Brennan 1945), is found in large numbers on cattle in the spring and

[1] Acarina (Ixodides): Ixodidae.

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