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A Study of Codling Moth Abundance As Influenced by Crop Failures

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The natural food of the codling moth larva, under Missouri conditions, consists of the pulp and seeds of apple, though it may also develop, to some extent, in pears, quinces, red haws, and other fruits. We have also reared it in the soft tip growth of water sprouts of apple, and have kept it alive for days on fresh apple foliage. While the apple worm does not absolutely depend on the fruit of apple for food, a large percent of the codling moths in the orchards of this state develop as worms in apples. This simply means, therefore, that when an orchard has a complete crop failure there will be few moths maturing in the orchard that summer. A crop failure will not absolutely eliminate the pest in an orchard, but it will so reduce a heavy infestation that the pest may require a few years to again build up its populations and do serious crop damage. Growers object to alternate bearing and, in recent years, have made every effort to prevent it, by girdling, pruning, thinning, and fertilizing. Regular bearing may be highly desirable from the standpoint of profitable apple growing, but, at the same time, it is one of the most important factors responsible for the overabundance of codling moths in Missouri orchards in recent years.

It has long been known that the codling moth requires regular crops and plenty of fruits for maximum increase, but we still have insufficient information regarding the real effects of complete crop failures or partial failures on the abundance of the pest for the next few years. Recently, the writers were given an opportunity to study this problem. The late spring freeze of 1938 in the southwest part of the state resulted in a complete crop failure in many orchards where the codling moth was very abundant. This offered an excellent opportunity to study the effect of crop failure on codling moth abundance that year, and to observe the pest's comeback during the next few years. In a second case, a man-made crop failure was brought about by spray removal of blossoms in a portion of an orchard in the northwest part of the state in the spring of 1939. A third series of observations were made on an orchard in the northeast part of the state, in which alternate bearing was combined with spray removal of blossoms to bring about crop failures on small plats in the orchard.

Crop Failure Due to Late Spring Freeze

In the area around Marionville, in southwest Missouri, the codling moth population in 1937 was considered to be normal, or at least within the fluctuations of a normal average for the previous five years. Codling moth injury throughout the district was severe. In the early part of April, 1938, a freeze occurred which killed practically all of the blossoms, then in the pink or pre-pink state, so that a condition existed throughout the district comparable to that induced by the application of bloom removal sprays in individual orchards. In most of the orchards, any apples which survived the freeze were pulled off and destroyed. This was the case in the Seneff Orchard at Marionville, in the King David and Jonathan blocks. However, it was not possible to remove all of the apples in the Bendavis block of the orchard, and a few apples matured.

The following diagrams show the bait trap records obtained in the Seneff Orchard for the years 1937, 1938, 1939, 1940, and 1941.

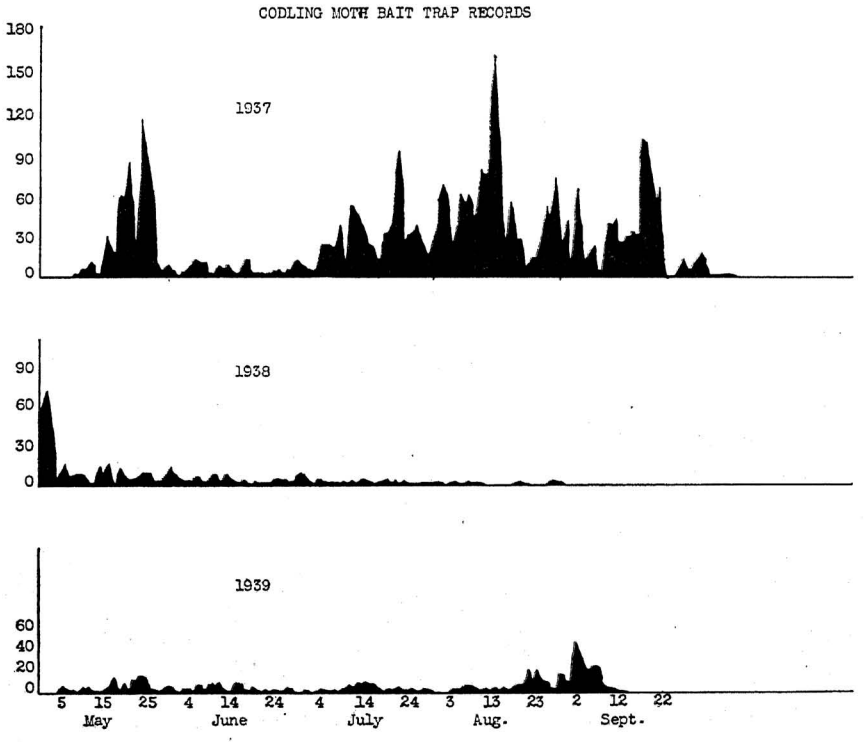

Fig. 1.—Graphs showing daily catch of codling moths at Marionville in 1937, 1938, and 1939.

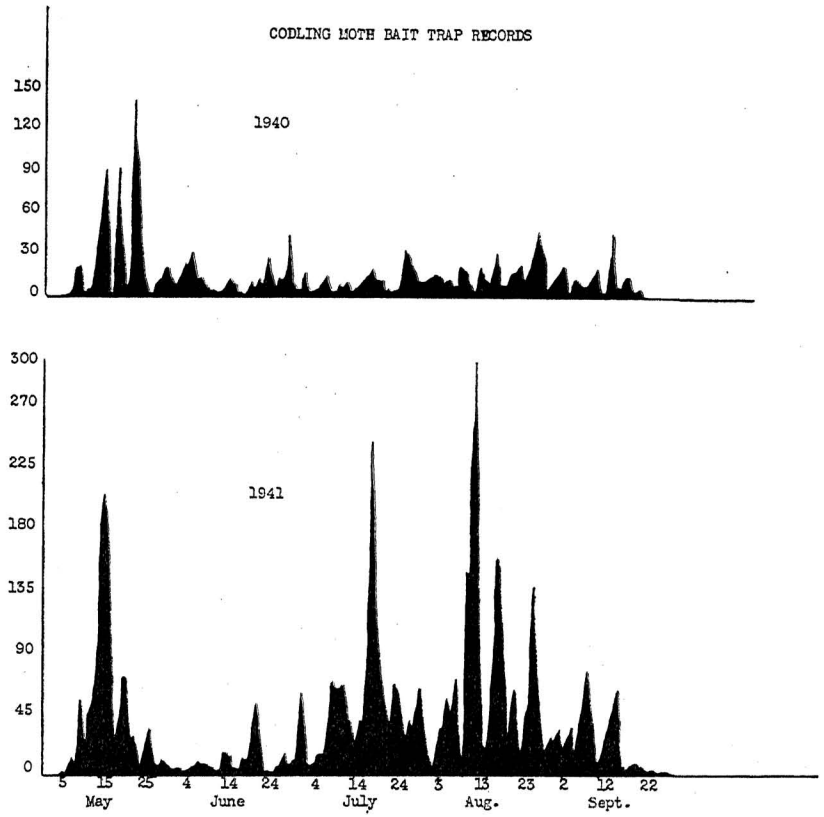

Fig. 2.—Graphs showing daily catch of codling moths at Marionville in 1940 and 1941.

The 1937 record shows the population of codling moths about as they would appear in normal years, though the large number of late moths in September may be somewhat abnormal. In 1938, when there was no crop in the orchard, it can be seen how the population dwindled until it became practically nonexistent in September. In 1939, the population remained low for most of the year but showed that it was beginning to build up again in early September. In 1940, the high peaks of early emergence gave warning that the codling moth population was well on its way toward a successful comeback, and fruit damage was again severe at the end of the season. In 1941, the population had made a complete return to normal and very severe fruit damage was apparent at the end of the season in most orchards, due chiefly to the entry of worms late in August.

The crop conditions and the spray schedule used in the Seneff Orchard probably had much to do with the rapid comeback of the

codling moth following the freeze-out in 1938. In 1939, there was a fairly good crop on all varieties, and especially on the Bendavis. The orchard, in general, had four cover sprays of lead arsenate, lime, and soybean flour, following the cluster bud and calyx sprays, which proved to be insufficient to thoroughly control second and third brood worms. In 1940, there was a light crop on all varieties in the orchard, except on the King David block, but sufficient fruit to enable the codling moth to continue to build up. The orchard, in general, received five cover sprays of lead arsenate and lime, with some oil added in peak sprays, which again was not sufficient to prevent the continued build-up of the pest.

The heavy crop in 1939 tended to mask the damage done by codling moths in that year, especially late in the season. As a result, the 1940 spray program was a little too light to control the rapidly increasing codling moth population. The spray schedule used in 1940 permitted the pest to build up to such an extent that it was necessary to use a very heavy schedule in 1941 to obtain reasonable control.

Observations made in connection with scraping and banding of trees in 1939 in the Seneff Orchard showed that the average number of worms per tree on the Jonathans as less than one, on King David five worms, and on Bendavis eighteen worms. These averages are believed to be generally comparable to those of other orchards in the same locality.

Scraping and Banding Studies

Scraping and banding studies were made in various orchards in the locality of the Seneff Orchard in southwest Missouri to determine the average number of overwintering codling moth larvae on tree trunks in 1940 and 1941, as shown in the following table:

TABLE 1.—RESULTS OF SCRAPING AND BANDING STUDIES

Orchard & Location	Variety	Age of Trees	Av. No. of Worms per Tree Scraping 1940	Banding 1941
E. L. Beal Republic	Jonathan	10-11 years	.33	51.0 (6 Lead Ars.
	Starking	10-11 years	.00	39.3 & Oil cover
	B. Bendavis	10-11 years	.00	128.0 sprays.)
G. P. White Marionville	Jonathan	11-12 years	.40	12.7 (8 Lead Ars. & Oil covers;
	Grimes	11-12 years	1.00	16.7 1 B.L. 155
	York	9-10 years	.60	41.0 cover.)
H. Gardner Aurora	Jonathan	21-22 years	4.20	156.3 (5 Lead Ars. & Oil covers;
	R. Delicious	21-22 years	2.70	115.7 4 B.L. 155
	B. Bendavis	21-22 years	14.60	69.3 covers.)
H. Seneff Marionville	Jonathan	23-24 years	4.30 (5 Lead Ars. & Soybean Flour sprays)	21.7 (7 Lead Ars. & Soybean Flour sprays.)

Weather also had its effect in helping the codling moth to make such a quick return to normal. In general, it may be said that the late summer temperatures of the three years following 1938 were high and rainfall was scanty. These conditions tended to reduce the efficiency of the lead arsenate sprays and also favored the development of large numbers of late moths and worms.

These records show clearly how a complete crop failure due to a late spring freeze may all but temporarily wipe out the populations of codling moths in an orchard. They also show how the pest with three broods a year may stage a rapid comeback. In this case, with favorable weather, with a lighter than normal control program and with heavy to average crops immediately following the crop failure, the codling moth was able to rebuild its populations in three years.

Crop Failures Caused by Bloom Removal Sprays

Bloom removal as a means of controlling alternate bearing in apples has been studied for several years at the State Fruit Experiment Station* at Mountain Grove, Missouri. As a result of this work, a number of Missouri growers became interested in the possibility of using bloom removal as a means of reducing codling moth infestations in the orchard.

In the spring of 1939, Mr. C. E. Hitz of Fortescue, Missouri, sprayed seventy-five acres of a 90-acre orchard with 1.7 per cent cresylic acid just as the blossoms were opening. About 95 per cent of the crop was removed by this application. The remainder of the crop in this area was removed by hand. He ran out of materials before covering the entire orchard and the buds were opening so rapidly that there was not enough time to get more spray material soon enough to finish the job. The remaining block of fifteen acres was left to bear a crop, without any sprays being applied for codling moth control. This provided an opportunity to study codling moth populations under two different conditions in the same orchard.

Results

By harvest time, ninety per cent of the apples in the untreated 15-acre area were on the ground, due mostly to worm injury. In October, 1939, a number of trees in both the bloom removal area and the untreated area were scraped and the number of codling moth larvae per tree recorded. Table 2 gives the results of these counts.

*Shepard, Paul H. Spraying Apples for the Prevention of Fruit Set. Mo. State Fruit Expt. Sta. Cir. 28, June 1939.

TABLE 2.—THE NUMBER OF CODLING MOTH LARVAE FOUND ON THE TRUNKS OF APPLE TREES IN THE C. E. HITZ ORCHARD IN OCTOBER, 1939.

Variety	Treatment	No. Trees Checked	Total Larvae	Av. Larvae per Tree
Jonathan	Bloom removed	7	3	.43
Bendavis	Bloom removed	10	7	.7
Jonathan	Unsprayed—Full crop	10	104	10.4
Bendavis	Unsprayed—Full crop	10	425	42.5

These data show how a complete crop failure, on the portion of the orchard where blossoms were sprayed off, resulted in an almost complete elimination of the codling moth for that season. On the adjoining portion of the orchard which bore a crop that was left unsprayed most of the fruit was wormy and there was a high count of overwintering worms on the tree trunks in the fall. As would be expected there were many more larvae on the Bendavis trees than on the fall variety, Jonathan. In this case, where part of the orchard bore a crop and part did not, there was, no doubt, some movement of spring brood moths from the portion which had no fruit to that which had a crop, thereby somewhat increasing the infestation where there was fruit.

TABLE 3.—DEGREE OF WORM INFESTATION IN DROPS AND TREE FRUIT ON AUGUST 27, 1940. ALL THE DROPS UNDER EACH TREE WERE CHECKED.

Test Trees Sprayed 1940	Total Apples	% Wormy	% Stung	% Clean
Unsprayed 1939 (No bloom removal) 5 Jonathan trees				
Tree fruits	600	15.99	21.	64.16
Drops	991	46.3	17.6	39.1
Bloom Removed in 1939 (Adoining no bloom removal) 5 Jonathan trees				
Tree fruits	500	8.	10.6	81.4
Drops	765	18.56	11.6	70.8
Bloom Removed in 1939 (5 rows from no bloom removal) 1 Jonathan tree				
Tree fruits	100	5.	4.	91.
Drops	63	6.34	3.17	94.7
Bloom Removed in 1939 (10 rows from no bloom removal) 3 Jonathan trees				
Tree fruits	300	1.33	8.3	90.33
Drops	323	9.6	4.6	88.5

In 1940, the entire orchard bore a crop and received a full schedule of sprays for codling moth control. The area from which the blooms were not removed in 1939 received one more application of lead arsenate than was given to the area from which the blooms were removed. Counts were made on August 27 to determine the percentage of wormy apples on the trees, and also the percentage of wormy drops.

These counts were made in four sections of the orchard, as follows: (1) In the area of no bloom removal, (2) adjoining the area of no bloom removal, (3) five rows from the area of no bloom removal, and (4) ten rows from the area of no bloom removal.

These data show how the codling moth tended to rebuild its populations the following summer in the different parts of the orchard under observation. Where there was no crop and, therefore, few worms the previous year, moths flew in from the heavily infested part of the orchard to help increase the number of worms and the extent of their injury to fruit. These records would indicate that in this case the gradual influx of moths had extended in only about five tree rows or 200 feet by the last of August, when the counts were made on Jonathan apples. A month later, similar counts on Bendavis apples would undoubtedly have shown a heavier and a deeper penetration of the orchard by the pest, as might be indicated by the data in Table 4.

In October, 1940, counts were made to determine the number of larvae hibernating on the tree trunks in the bloom removal area, on the tree trunks one to three rows from the bloom removal area, and on tree trunks ten rows from the bloom removal area. Table 4 gives the results of these counts.

TABLE 4.—COUNTS ON CODLING MOTH LARVAE ON THE TRUNKS IN OCTOBER, 1940.

Variety	Treatment	No. Trees Checked	Total Larvae	Av. Larvae per Tree	Distance from Untreated Rows
Bendavis	None	5	267	53.4	None
Bendavis	Bloom Removed in 1939	5	102	20.4	1-4 rows
Bendavis	Ditto	5	63	12.2	10 rows

By comparing the figures in Table 2 and 4, it will be seen that the average number of overwintering codling moth larvae on Bendavis trees, which bore a crop that was unsprayed in 1939 and which had a full crop well sprayed in 1940, increased only slightly from 42 worms per tree in 1939 to 53 in 1940. This represents a population increase of only 24 per cent. On the other hand, the average number of larvae on adjoining Bendavis trees, which bore no crop in 1939, increased from less than one worm per tree to 20 worms per tree, while similar trees ten rows away from the heavily infested part of the orchard showed an increase from less than one worm per tree to 12 worms to the tree. These represent population increases of 2,000 per cent and 1,200 per cent respectively. These enormous population increases are undoubtedly due, in part, to the flight of moths from the heavily infested portion back into the lightly infested portion of the orchard

under observation. These records show how large codling moth populations may be reduced to almost nothing by a crop failure, but with this set-up it was not possible to follow the natural rebuilding of moth populations from the low level back to the original high level, as was the case with the previous orchard where the late freeze resulted in a crop failure on the whole orchard. In this case, only a part of the orchard had the crop sprayed off in 1939, and besides the severe freeze in the fall of 1940 destroyed the entire orchard and prevented further observations.

Studies on Northeastern Missouri Orchard

In 1941, the bloom was sprayed off of two rows of Golden Delicious trees in an orchard in Northeastern Missouri in studying the effect of bloom removal on alternate bearing. The two rows had practically no fruit in 1941. In 1942, these two rows bore a full crop, while the adjoining rows of Golden Delicious trees, which did not have the bloom sprayed off in 1941, were practically without a crop. Treated bands were examined in the fall of 1942 from both the full crop and the no crop rows in order to determine the abundance of worms in each of the two plats. There was a marked difference in worm abundance, as can be seen by the following table:

TABLE 5.—INELUENCE OF REMOVAL OF BLOOM ON CODLING MOTH NUMBERS

Date	No. of Trees	Variety of Apples	Crop	Worms under Treated Bands	Aver.
1942	2	Golden Delicious	Full crop (Bloom removed 1941)	214	107.0
1942	2	Golden Delicious	No crop (Bloom not removed 1941)	0	0

In another part of this same Northeast Missouri orchard, worm counts were made under treated bands in the fall of 1940, 1941 and 1942 to determine their abundance as influenced by the size of the crop in succeeding years. The counts were made in the same part of the orchard each year on both Black Ben and Golden Delicious trees. In 1940, the trees had about 40 per cent of a crop, in 1941 a full crop, and in 1942 few or no fruit at all. While other factors undoubtedly had some influence on worm populations, it is believed that the number of worms each year, as shown in the following table, was due in large part to the size of the crop.

TABLE 5.—INFLUENCE OF REMOVAL OF BLOOM ON CODLING MOTH NUMBERS.

Date	No. of Trees	Variety of Apples	Crop	Worms under Treated Bands	Aver.
1940	3	Golden Delicious	40%	134	47.
1941	3	Golden Delicious	100%	1053	351.
1942	3	Golden Delicious	No Crop	5	1.6
1940	3	Black Ben	40%	107	35.6
1941	3	Black Ben	100%	895	298.3
1942	3	Black Ben	.5%	4	1.3

These results all indicate that there is a marked reduction in codling moth populations in heavily infested orchards in years of light crops and years of complete crop failures. This seems to hold true where the bloom is sprayed off the same as where a late freeze causes complete crop failure. However, while alternate bearing or an occasional crop failure greatly reduces worm populations, these data indicate that the pest is capable of quickly rebuilding its populations if there is any let-up in control measures.