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THE CANNIBALISTIC HABITS OF THE CORN EAR WORM
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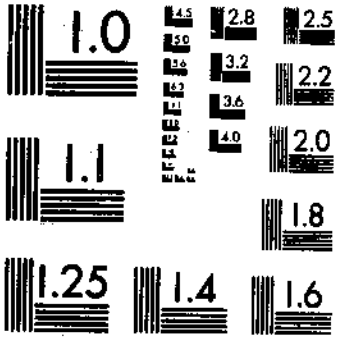

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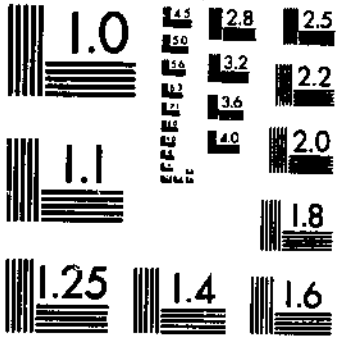

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THE CANNIBALISTIC HABITS OF THE CORN EAR WORM

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INTRODUCTION

For many years it has been known that the larvae of the corn ear worm (*Heliothis obsoleta* Fab.) are cannibalistic, under certain conditions killing and devouring fellow larvae, especially when competing for food. This habit makes possible the raising of corn over extensive sections where the corn ear worm is prevalent, for it is probable that, were the larvae tolerant of each other when feeding in close association, the original populations that annually attack cornfields could easily destroy the entire crop. In order to learn more about the cannibalistic habits of these larvae, a detailed study was made at Richmond, Va., in 1929, and at Savannah, Ga., during the years 1930 to 1932, inclusive.

EAR WORM INJURY TO THE CORN PLANT

During the several months that the corn plant is growing, its suitability as food for the corn ear worm varies. Although the larvae attack the leaves, tassels, husks, and cobs, particularly while these parts are young and tender, by far the largest populations are found on the silks and kernels, which consequently suffer the greatest injury.

The plant is most attractive to ear worm moths for egg laying while the silks of the developing ears are fresh, and usually more eggs are laid on such silks than on all the other parts of the plant. During the several weeks that the silks are moist, eggs are laid on them every

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night, the number depending on weather conditions, the variety of corn, and the abundance of the moths. In the Southern States hundreds of eggs may be deposited on the silks of a single ear. Larvae hatching from these eggs immediately seek the husk-enclosed portions of the silks and begin to feed. As a result they become concentrated in one part of the plant, in an environment that affords food sufficient for the nourishment of many larvae but is limited in area according to the stage of development of the surrounding husk.

After feeding downward in the husk-enclosed silk, the larvae eventually reach the kernels, which serve as the final larval food. Although many eggs are destroyed by insect enemies and otherwise, scores often hatch and the young larvae enter the ear frequently in populations potentially able to consume the entire ear. Yet, notwithstanding the large numbers of young larvae that enter the ear, few become full grown, and it is most common to find that only one larva has reached maturity in an ear, the others presumably having been destroyed.

DECREASE IN EAR WORM POPULATIONS THROUGH CANNIBALISM

To determine to what extent the ear worm populations of ear corn decrease as the larvae become full grown, ears from infested fields were examined and, as a check on the results obtained, caged larvae were studied. The experiments with the caged larvae were conducted under comparable conditions, but in the experiments with ears from infested fields variation in age, size, and husk characters could not be avoided.

IN EAR CORN IN THE FIELD

OBSERVATIONS AT RICHMOND

A 10-acre field of yellow dent corn at Richmond, Va., was selected in the fall of 1929 as suitable for observation because of uniformity in soil, plant growth, and distribution of the ear worm infestation. One thousand ears from this field were examined for infestation during the period September 23 to 25. At that time the ears were in the dough stage, larval activity was at its height, relatively few individuals had become full grown and deserted the ears, and all larval instars were represented. All the ears contained larvae, either in the silk or on the ear, and many of the larvae were being devoured by others. The number of larvae of each instar and the prevalence of partly devoured individuals are shown in table 1.

TABLE 1.—*Corn ear worm larvae of the different instars recovered from 1,000 ears of yellow dent field corn and prevalence of partly eaten individuals, Richmond, Va., 1929*

Instar	Larvae recovered		Larvae partly devoured		Larvae recovered that were partly devoured
	Number	*Percent*	*Number*	*Percent*	*Percent*
First	24	0.72	0	0.00	0.00
Second	340	10.16	1	.47	.29
Third	1,049	31.33	30	14.08	2.86
Fourth	902	26.94	84	39.43	9.31
Fifth	660	19.71	93	43.67	14.09
Sixth	373	11.14	5	2.35	1.34
Total, or weighted average	3,348		213		6.36

Partly devoured individuals were found in 192 ears. Of these ears 172 contained 1 partly devoured larva each, 19 ears contained 2 larvae each, and 1 ear contained 3 larvae. At the time of observation 6.36 percent of the recovered larvae had been partly devoured. Since larvae feed within the ears for several weeks, a continuous thinning of population, at the rate indicated at this examination, could easily account for the large reduction in numbers that has been observed to occur in nature. These and many other observations indicate that ear worm larvae usually devour other ear worm larvae that they attack; that is, they seldom leave killed individuals uneaten.

It was found that larval populations ranged from 1 to 10 per ear. Ears infested by large larvae contained fewer individuals than did ears infested by small larvae. Examination of these ears while the silks were moist and eggs were being deposited on them showed daily egg populations ranging from 5 to 25 each, and oviposition continued as long as the silks remained moist.

In table 2 the data on larval infestation of ears have been classified according to the number of larvae present and also according to the instar of the largest larva recovered in each ear. These data indicate a gradual thinning of larval populations from the time fourth-instar larvae began to appear, but they do not show the final extent of cannibalistic thinning of populations, as the larvae would have had to feed for different periods of time before completing their development. Figure 1 shows four ears, selected at random, containing larvae of various sizes, and indicates the decrease in population with increase in size of the larvae.

TABLE 2.—*Population of ear worm larvae of different instars in 992 ears of corn at roasting-ear stage, Richmond, Va., Sept. 23–25, 1929*

Larvae recovered per ear (number)	Number and percentage of ears in which the largest larva was in the instar indicated [1]								Total ears
	Third		Fourth		Fifth		Sixth		
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number
1	5	6.09	3	1.42	41	11.33	110	32.74	159
2	4	4.88	22	10.38	87	24.04	116	34.52	229
3	16	19.51	38	17.92	103	28.45	65	19.35	222
4	27	32.93	49	23.59	64	17.68	33	9.83	174
5	15	18.29	46	21.69	37	10.22	6	1.79	104
6	9	10.98	28	13.21	17	4.69	4	1.19	58
7	5	6.09	11	5.19	8	2.21	1	.29	25
8	1	1.22	12	5.66	2	.55	1	.29	16
9			1	.47	3	.83			4
10			1	.47					1
Total ears	82		212		362		336		992
Total larvae	341		951		1,166		738		3,196
Average larvae per ear	4.16		4.49		3.22		2.20		3.22

[1] Ears with only first- or second-instar larvae were too few for tabulation.

OBSERVATIONS AT SAVANNAH

During 1931 and 1932 the study was continued at Savannah, Ga., where ears of corn at roasting-ear stage were examined for larval populations. This corn had been planted at varying intervals over a period of 3 to 4 months. Ears and silks were therefore exposed to oviposition over a rather long period and presumably received varying numbers of eggs, depending on the number of moths present in

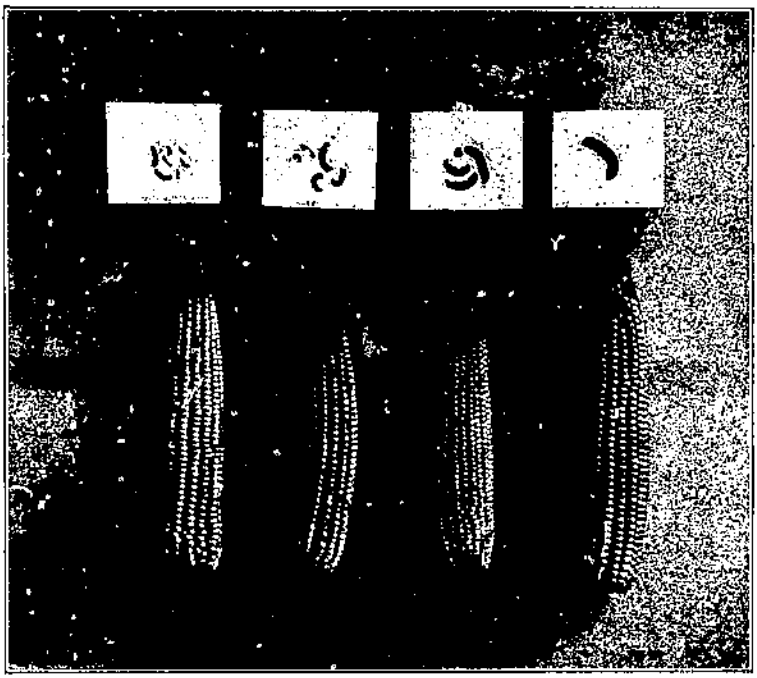

FIGURE 1.—Ears of corn and the populations of corn ear worm larvae they contained, illustrating the decrease in larval population from cannibalism as larvae increase in size.

the field. The data were classified according to the instar of the largest larva present in each ear; and the average larval populations, as well as the number of larvae in each instar, were determined for each class. The data obtained from 392 infested ears in 1931, and from 1,510 infested ears in 1932, are summarized in table 3. Here again ears that contained the larger larvae had considerably smaller populations than ears containing smaller larvae.

TABLE 3.—*Number of ear worm larvae of different instars inhabiting corn ears at roasting-ear stage, Savannah, Ga., 1931 and 1932*

Larvae recovered	Number of ears in which the largest larva was in the instar indicated										
	From plantings examined June 8 to Aug. 6, 1931					From plantings examined June 5 to Aug. 30, 1932					
	Third	Fourth	Fifth	Sixth	Full grown [1]	Second	Third	Fourth	Fifth	Sixth	Full grown
Per ear:											
1	2	28	55	74	111	0	49	112	271	241	249
2	1	8	26	28	13	2	26	48	108	85	72
3	2	2	13	8	5	2	14	32	55	21	22
4	-----	1	7	-----	0	1	1	15	27	8	7
5	-----	-----	2	2	1	-----	3	7	11	4	-----
6	-----	-----	2	1	-----	-----	1	1	4	-----	-----
7	-----	-----	-----	-----	-----	-----	-----	1	-----	-----	-----
8	-----	-----	-----	-----	-----	-----	-----	-----	1	-----	-----
9	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
10	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	-----
11	-----	-----	-----	-----	-----	-----	-----	-----	1	-----	-----
Total	5	39	105	113	130	11	94	216	478	360	350
	Number of larvae found of which the largest larva was in the instar indicated above										
In all ears:											
First instar	0	0	0	0	4	4	0	1	1	0	0
Second instar	2	0	0	2	0	16	38	35	29	6	0
Third instar	8	8	13	2	0	-----	130	103	100	35	15
Fourth instar	-----	46	50	14	3	-----	-----	273	174	49	36
Fifth instar	-----	-----	127	32	10	-----	-----	-----	554	67	56
Sixth instar	-----	-----	-----	120	8	-----	-----	-----	-----	379	14
Full grown	-----	-----	-----	-----	132	-----	-----	-----	-----	-----	366
Total	10	54	190	170	157	20	164	412	858	536	487
Average per ear	2.00	1.38	1.87	1.50	1.21	1.82	1.78	1.91	1.79	1.49	1.39

[1] Larvae that had already left the ear.

STUDIES OF LARVAE IN EXPERIMENTAL CAGES

The decrease in larval populations through cannibalism was studied under controlled conditions in the laboratory. Ten series each of 5, 10, 15, 25, and 50 newly hatched larvae were confined in 2-ounce tin salve boxes, 60 mm in diameter and 20 mm in height, a type of cage that had previously been used successfully in studying larvae of this species and which provided conditions as close as possible to those in the field. These larvae were given as food equal quantities of moist silks and corn kernels in the dough stage, and every day the rate of growth and the number of individuals present were recorded.

Not more than one larva became full grown and pupated in any of the 50 cages. Not only were the other larvae in the cage killed, but they were usually completely devoured. Therefore, each full-grown individual had been nourished with plant and animal food in varying proportions. It is probable that many of the larvae devoured had, themselves, devoured other larvae, thus making the elimination of larvae a successive matter; that is to say, each larva that finally survived had fed upon others, which had fed upon others, and so on, depending upon the number of larvae in the cage. Although the larvae were well supplied with vegetable food at all times, in none of

the cages had this food been wholly consumed, and the larvae were not confined nearly so closely as they would have been in the husk-enclosed silks and kernels of an ear of corn.

Curves showing population decreases, as determined in these experiments, are given in figure 2, each curve representing the average

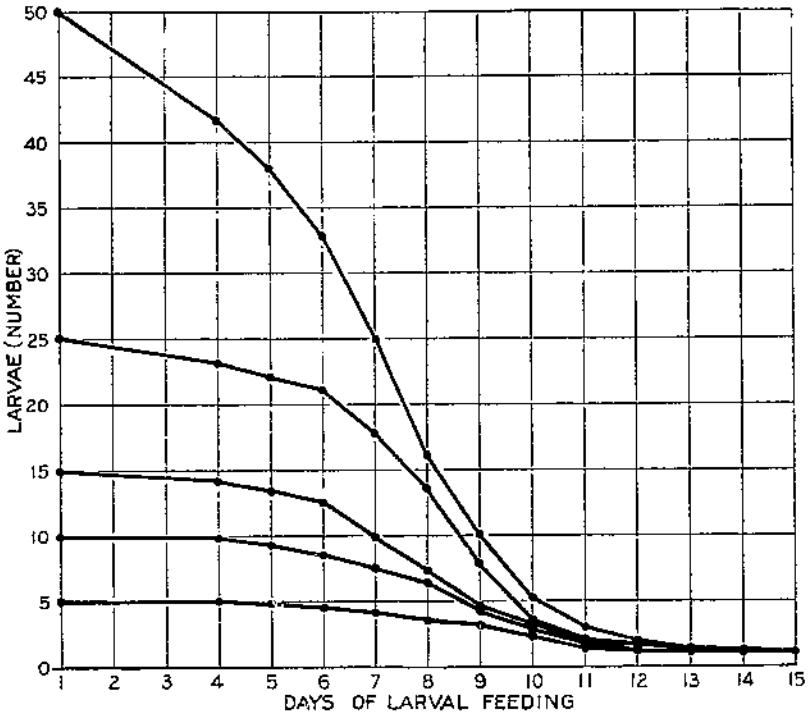

FIGURE 2.—Decrease in population of corn earn worm larvae confined in salve-box cages during feeding period.

for the 10 cages having the same number of larvae per cage. It was shown that in large populations cannibalism was displayed throughout the feeding period, whereas in smaller populations it was not manifest until the sixth day, or when the larvae had reached the third instar. In table 4 the numbers and percentages of larvae reaching the several stages of growth in these experiments are given.

TABLE 4.—*Corn ear worm larvae surviving to the different instars in various population concentrations in breeding cages*

Larvae introduced per cage (number)	Total larvae used	Larvae surviving to instar indicated										Full-grown larvae surviving
		Second		Third		Fourth		Fifth		Sixth		
	No.	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*
50	500	412	82.4	325	65.0	140	28.0	36	7.2	12	2.4	1
25	250	230	92.0	193	77.2	130	52.0	43	17.2	12	4.8	1
15	150	142	94.7	119	79.3	67	44.7	26	17.3	11	7.3	1
10	100	98	98.0	84	84.0	54	54.0	38	38.0	17	17.0	1
5	50	50	100.0	44	88.0	37	74.0	23	46.0	12	24.0	1

RELATION BETWEEN AGE OF LARVAE AND CANNIBALISTIC TENDENCY

Both the field and the laboratory experiments indicate that cannibalism increases in intensity with the age of the larvae. To study this factor further, varying populations of larvae of similar and of different instars were confined in salve-box cages to determine how quickly such populations would be reduced to a single individual.

This experiment, which is briefly summarized in table 5, shows that the larger larvae are the most intensely cannibalistic. Ear worm larvae usually complete their feeding in the first ears of corn they enter. They do not seek out fellow larvae as prey, but simply attack and devour those they meet in the course of burrowing and feeding through the silks or kernels. Since the feeding quarters are limited, the larger larvae are much more likely to meet while feeding than are the smaller ones. The chances of meeting appear to be proportional to the size of the larvae and the number in individual ears. Of the individuals that were supplied only with fellow larvae as food, the larger larvae—those in the fourth, fifth, and sixth instars—fed more readily and were much more easily reared to maturity than were the smaller ones.

TABLE 5.—*Cannibalism of ear worm larvae of the same and of different instars when confined in varying numbers in salve-box cages*

Instar of larvae	Cages	Larvae per cage	Average time before population was reduced to one larva per cage	Instar of larvae	Cages	Larvae per cage	Average time before population was reduced to one larva per cage
Larvae of the same instar:	*Number*	*Number*	*Days*	Larvae in different instars:[1]	*Number*	*Number*	*Days*
First	6	3 to 25	12.2	Second	1	10	8.0
Second	2	10	8.5	Third	5	6 to 10	4.4
Third	6	2 to 5	3.2	Fourth	9	3 to 26	3.4
Fourth	10	2 to 5	3.2	Fifth	6	4 to 10	3.5
Fifth	12	4 to 6	2.7	Sixth	13	4 to 14	1.9
Sixth	8	2 to 3	1.7				

[1] The instars given in this series refer to the instar of the largest larva in the cage.

FOOD PREFERENCES OF LARVAE FOR CORN PLANT OR FELLOW LARVAE

Various reasons have been given for the habit of cannibalism among ear worm larvae. Plant food may have been insufficient or competing larvae may have interfered with one another's normal feeding, either cause leading to combat between larvae and finally to the devouring of the vanquished by the victor. A study of cannibalism was made, therefore, under conditions in which no competition existed and food was abundant. Larvae of various instars were confined singly in salve boxes containing an abundant supply of fresh corn silks and fresh kernels in the dough stage, and such food was renewed daily. In addition, a freshly maimed larva of the same or the preceding or following instar was placed in each cage every day. These larvae were maimed by crushing their heads, which rendered them inactive and unable to compete for food.

The feeding was observed to vary. On some days the larvae fed only on plant material, on other days on both the plant material and the maimed larvae, and rarely on only the maimed larvae. It was found that second-instar larvae fed only on plant material about as frequently as on both fellow larvae and plant material, whereas larger larvae more often consumed both animal and vegetable food, the likelihood of such mixed feeding increasing in proportion to the size of the larvae. Fifth-instar larvae selected a mixed ration nearly four times as often as one of plant food only. Larvae rarely fed entirely on their fellow larvae when an abundance of plant food was available. Nevertheless, they often chose the maimed larvae as food when they had no competitors and were abundantly supplied with their preferred plant food, although there was no indication that they actually searched for the animal food. The results of these experiments are given in table 6.

TABLE 6.—*Food preference of corn ear worm larvae when offered maimed ear worm larvae together with fresh corn silks and kernels in the dough stage*

Instar of larvae	Larvae observed	Larvae feeding on—					
		Corn silks or kernels only		Corn silks or kernels and maimed larvae		Maimed larvae only	
	Number	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Second	51	25	49.0	24	47.1	2	3.9
Third	37	16	43.2	20	54.1	1	2.7
Fourth	70	26	37.1	41	58.6	3	4.2
Fifth	63	13	20.6	48	76.2	2	3.2
Sixth	53	18	33.9	33	62.3	2	3.8

DEVELOPMENT OF LARVAE WHEN FED FELLOW LARVAE EXCLUSIVELY

The degree to which the cannibalistic habit of ear worm larvae is fixed is demonstrated in their ability to develop to maturity from any larval instar exclusively as predators, entirely without plant food. When individuals were reared from egg to adult in this way, they were as large as ear worms ever become when feeding on their preferred food, and they were of the usual vigor. To rear ear worms successfully in this way, care must be taken to keep fresh food before them at all times. The feeding larvae were confined singly in salve boxes lined with absorbent paper, and were fed maimed larvae of the same or the succeeding instar. Although many of the maimed larvae lived more than 24 hours, decomposition of the crushed parts was often noticeable in from 6 to 8 hours, and this rendered the larvae unfit for food, as individuals that fed upon such decomposing matter died before reaching maturity. Through artificial control of bacteria in the laboratory, nearly perfect rearings of these predacious larvae could no doubt be made.

Larvae of each instar were taken from corn ears in which they had fed normally and were reared to adults by the method described. In addition, ear worm eggs were taken from oviposition cages and confined in lots of 10 in concave cells ground in microscope slides, covered with plain slides. In each lot the population of larvae that hatched from the eggs was usually reduced to a single individual within a few

days through cannibalism. The surviving individuals were reared singly in vials or salve boxes wholly upon maimed larvae, as previously described. In one series of 16 larvae, 12, or 75 percent, of the individuals became full-grown larvae; 9, or 56.3 percent, pupated; and 7, or 43.8 percent, developed into healthy and active moths.

The voracity with which ear worms attack their fellow larvae when given the latter as food reminds one of the more ruthless, solely predacious insects. The ear worm larvae usually attacked the ventral surface of the abdomen of its prey. One bite penetrated the exoskeleton; then the feeder plunged its mouth parts into the blood and internal structures thus exposed and fed eagerly. When a small larva attacked a larger one, it often curved its body laterally about its prey, holding on tenaciously while the latter tried to dislodge it. In many instances after a few hours all that remained of a maimed larva was the empty head capsule, the exoskeleton of which was apparently too hard to be eaten by the predator.

Larvae of the corn ear worm, when feeding upon unprotected vegetation, such as the exposed seeds of *Meibomia purpurea*, protect themselves from parasites, other small insects, and fellow larvae by a method practiced by many lepidopterous larvae. When the larva is touched on any part of its body, it instantly stops feeding and, with its mouth parts in readiness for biting, makes a quick lunge in the direction of the attack, often regurgitating a drop of liquid at the same time. It then draws back its head and remains motionless, ready to strike again. Two antagonistic larvae of equal size, in such a pose of alert preparedness, are an interesting sight, and if they could snarl or growl or hiss the spectacle of ferocity thus presented would be complete. In ear corn, however, such free fighting is impossible, because the larvae cannot move freely, and the advantage is with the larva that makes contact with the unprotected parts of another which, because of cramped quarters, cannot protect itself.

The time required for the development of wholly predacious ear worm larvae, as compared with that for individuals fed upon corn silks and kernels, is shown in table 7. The former required an average of about 3 weeks, the latter about 2 weeks.

TABLE 7.—*Period of larval development of the corn ear worm when fed only on maimed ear worm larvae, and when fed only on silks and corn kernels, at Savannah, Ga., 1930*

Larval food	Hatching date	Individuals	Average time in each larval instar						Average larval period
			First	Second	Third	Fourth	Fifth	Sixth	
		Number	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*
Larvae	July 9–27	44	4.33	2.53	2.38	2.80	3.67	3.86	18.55
	Aug. 13–18	25	5.32	3.84	2.92	2.65	4.05	4.67	22.90
Corn silks and kernels	July 18	25	4.12	2.08	1.76	1.64	1.68	2.82	14.16
	Sept. 2	50	2.16	2.30	1.92	2.26	[1] 3.79	.....	[1] 12.75
							[2] 2.71	[2] 3.00	[2] 13.59

[1] Larvae of 5 instars. [2] Larvae of 6 instars

The total number of fellow larvae devoured by wholly predacious ear worm larvae while completing their development varied, as did also

the rate of consumption of such food in any one instar. When a predator larva fed on maimed larvae of the same instar, the total number of fellow larvae consumed by the surviving predator during its entire larval period was about 20, and relatively the largest quantities of food were consumed during the first and last instars. The last-instar larva usually consumed 1 fellow larva of its own size each day, but sometimes it completely devoured 2. When a large predacious larva was fed smaller larvae, the total number of individuals devoured was naturally much greater. The numbers and instars of fellow larvae devoured by 25 individuals while in the last 3 instars are given in table 8. These studies indicate that in times of heavy infestation the consumption of larvae by fellow larvae occurs at a rate sufficient to account for the destruction of scores, or even hundreds, of larvae by successive elimination during a period of several days or weeks.

TABLE 8.—*Number of maimed corn ear worm larvae devoured by individuals of the same species in their last three instars, Savannah, Ga., 1930*

Instar in which larva began cannibalistic feeding [1]	Date feeding began	Date larvae became full grown	Number of larvae of instars indicated devoured by individuals in—								
			Fourth instar		Fifth instar				Sixth instar		
			Fourth	Fifth	Third	Fourth	Fifth	Sixth	Fourth	Fifth	Sixth
Third	July 11	July 25	2				3.0				5.5
	July 12	(2)	2	0.5							
	do	July 26		2.0				2.5			6.0
	July 16	July 30	2	.5			3.0	1.0		2	5.0
	do	July 27	1				2.0	.5		2	3.0
	July 9	(2)					2.0	1.0		2	3.0
	do	July 17					2.0			1	3.0
	do	(2)				1	2.0				
Fourth	do	(2)					2.5				
	July 12	July 25					3.0	1.0			6.0
	do	July 23				1	2.0			2	4.0
	July 16	July 27				1	1.0	1.0		1	4.0
	July 9	July 19			1	1	1.0			2	3.0
	do	July 16									4.0
Fifth	July 11	do							3	2	2.0
	do	do								1	4.0
	do	July 15								2.5	2.0
	July 16	July 27					2.0	1.0			5.0
	July 24	July 29									4.0
	do	do									4.0
	do	July 26									3.0
Sixth	July 27	July 30								1	4.0
	do	July 29									4.0
	do	July 30								1	4.0
	do	July 29								1	2.0

[1] 1 larva in each cage.

[2] Larva did not mature.

RELATION BETWEEN CORN-HUSK TYPE AND CANNIBALISM OF THE EAR WORM

The growing ears of different varieties of corn, or even ears of the same variety, differ greatly in the character of their husks. The husks may be nearly lacking, as in tassel ears (fig. 3); they may not be long enough to envelop the ear completely (fig. 4); they may be just long enough to enclose completely and tightly envelop the ear (fig. 5); they may be extended far beyond the tip of the ear (fig. 6); or they may occur in all intermediate lengths. The husks also vary

in the number of leaves of which they are composed and in the tightness with which these leaves are wrapped about the ear, the latter characteristic depending somewhat upon the stage of growth of the grain. The factors enumerated determine the feeding areas attainable by ear worm larvae, the comparative ease with which the several parts are reached, and the degree of competition among the larvae in their quest for food.

The habit of ear worm larvae of seeking protected places for feeding is important in this connection. It was found that when the husks were partly removed, exposing the upper half or a longitudinal strip

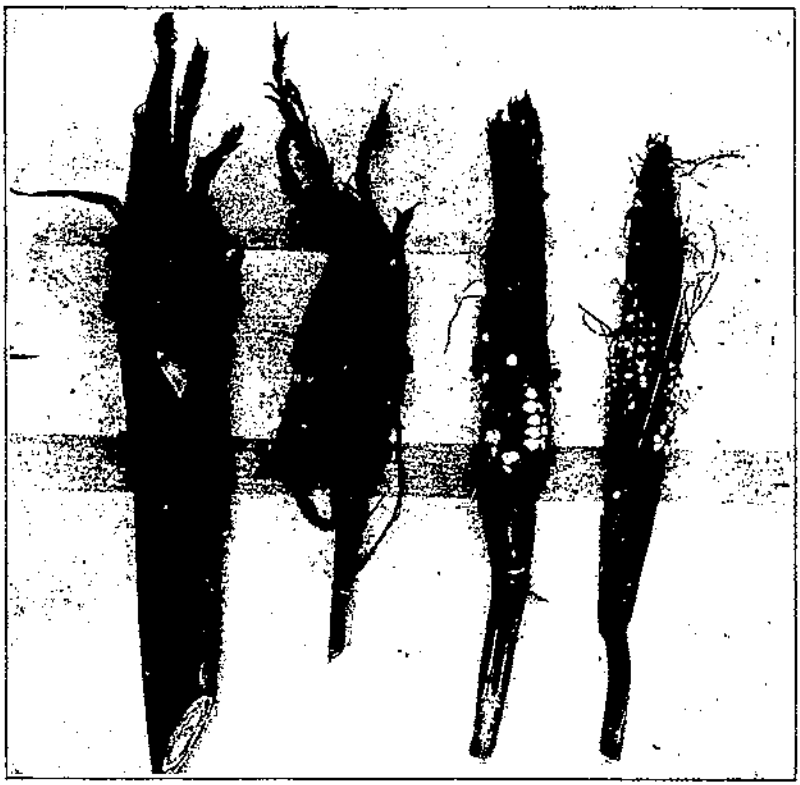

FIGURE 3.—Tassel ears of corn, with loose, poorly developed husks, which favor the feeding of larvae on all parts of the ear.

of the cob and kernels, the feeding was usually confined to the part of the ear that was still protected by the husks. This evident desire for protection leads to concentration of larval population in parts of the ear that can be penetrated, and the degree of such concentration depends upon the type of husk and upon the original population of larvae. The ear is seldom penetrated except at the tip, where the silk is exposed.

The nature of the husk determines the chance that the larvae will meet one another. In ears such as are shown in figure 3 larvae can enter on all sides, seek shelter behind the loose husks, and feed unmo-

lested on the different parts of the ear, with little chance of meeting other larvae. On the other hand, in ears such as are shown in figure 6 the larvae can enter only at the point of extrusion of the silks, and they must feed on the tightly wrapped silks in a tubelike passage before they can reach the kernels. In such ears the individuals, being more narrowly confined, are far more likely to meet one another and reduce the population through cannibalism. The degree of cannibalistic feeding in the ears with husk type between these two extremes varies accordingly.

Previous work concerned with the economic value of the husk in limiting ear worm injury to ear corn bears out these statements.[1] Study of many thousand ears of corn, both in the field and in the laboratory, showed important differences in grain losses that de-

FIGURE 4.—Corn ears with short, loose husks, which allow ear worm larvae to feed on all sides of the ear with little competition.

pended on the character of the husk, because this greatly influenced the number of larvae that successfully fed on the ear. The condition can easily be observed in most cornfields, although, of course, the final results of cannibalism cannot be determined until the larvae have completed feeding.

Five hundred and nineteen of the ears from which the data given in table 2 were taken were classified according to husk length, and the position occupied by the feeding larvae in these ears was observed. The data obtained are given in table 9. Much variation was found in the positions occupied by the larvae. In general, as the length of the husk beyond the tip of the ear increased, fewer larvae were

[1] PHILLIPS, W. J., and BARBER, G. W. THE VALUE OF HUSK PROTECTION TO CORN EARS IN LIMITING CORN EAR WORM INJURY. Va. Agr. Expt. Sta. Tech. Bull. 43, 24 pp., illus. 1931.

found feeding on the kernels and more were found in the silks. Furthermore, the average numbers of larvae found in these ears decreased

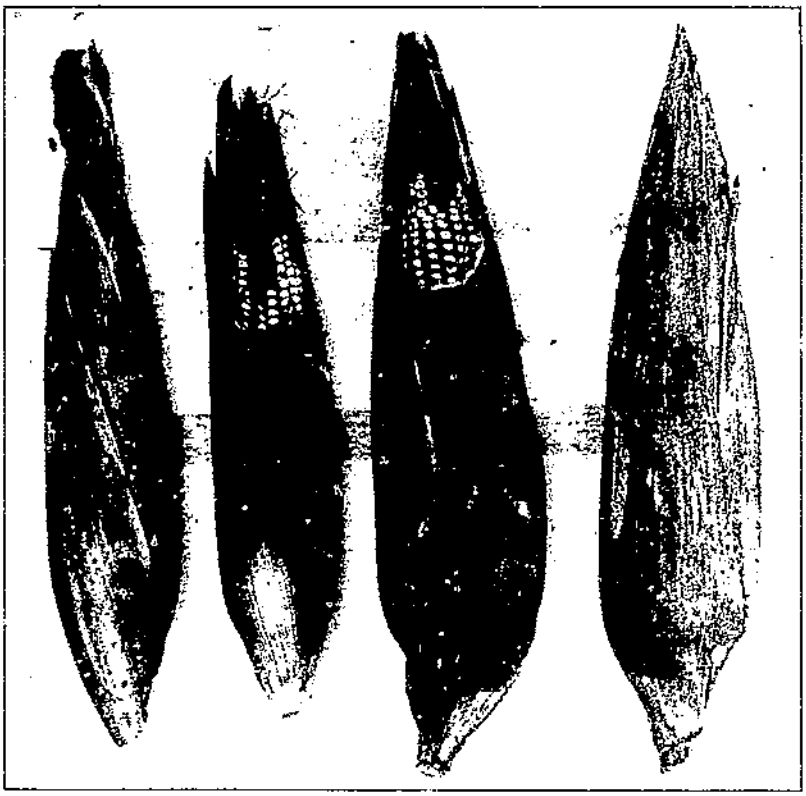

FIGURE 5.—Corn ears with husks long enough to enclose completely and tightly envelop the ear, with little injury by ear worms because cannibalism is developed through competition in feeding

as the length of the husk increased, suggesting a proportional increase in the degree of cannibalism. This condition is shown graphically in figure 7.

TABLE 9.—*Number of ear worm larvae recovered in the silks and on the kernels of ears of corn with husks of various lengths, at Richmond, Va., 1929*

Length of husk beyond tip of ear (inches)[1]	Ear	Average larvae per ear in instar indicated											Average larvae of all instars per ear			Larval population recovered	
		On the kernels					In the silks										
		Second	Third	Fourth	Fifth	Sixth	First	Second	Third	Fourth	Fifth	Sixth	On kernels	In silk	Total	On kernels	In silk
	No.	*Pct.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*Pct.*	*Pct.*
0.0	66	13.2	0.15	0.67	1.12	0.89	0.05	.....	0.03	0.05	0.01	.....	3.45	0.09	3.57	97.48	2.52
0.1 to 1.0	139	27.8	.16	.50	.89	.69	.36	.....	.21	.65	.22	0.05	2.87	1.15	4.03	71.75	28.25
1.1 to 2.0	122	24.4	.09	.50	.47	.39	.36	0.005	.25	.84	.40	.15	1.89	1.09	3.49	54.59	45.41
2.1 to 3.0	94	18.8	.03	.21	.39	.35	.29	.01	.29	.83	.42	.22	1.27	1.82	3.09	41.10	58.90
3.1 to 4.0	45	9.0	.....	.07	.29	.31	.20	.....	.20	.78	.56	.31	.87	1.96	2.83	30.74	69.26
4.1 to 5.0	38	3.8	.....	.16	.....	.21	.....	.....	.42	1.32	.47	.42	.37	2.68	3.05	12.13	87.87
5.1 to 9.0	15	3.0	.....	.07	.07	.33	.20	.....	.....	.47	.33	.40	.20	.07	1.40	2.07	32.37	67.63

[1] Tip of ear exposed.

The relation between corn-husk type and cannibalism of ear worms was also studied under conditions in which the number of larvae entering the corn ears could be controlled. Twenty-four uninfested ears with husks ranging from very short to very long were selected. In 12 of these ears the husk was loosened to allow the larvae easier entrance, but in the other 12 ears the husk was not disturbed. Each ear was placed in an upright position in a cylindrical box upon a

FIGURE 6.—Corn ears having long, tight husks, with practically no grain injury, and where cannibalism by ear worms can be intensely developed.

nail driven through the bottom, so that no part of the ear touched the side of the box. Each ear in both series was then artificially infested with 10 newly hatched ear worm larvae. No other larvae were allowed to enter or leave these cages. At the end of 10 days the cages were examined, and larvae were still feeding, most of them being in the fourth or fifth instar. There was considerable difference in the extent of injury to the kernels, and also in the degree of larval survival, between the ears protected by tight husks and those in

which the husks had been loosened. The 12 ears with tight husks showed a total of 337 injured kernels, representing a grain loss of 4.3 percent, and 34 of the original 120 larvae remained, an average of 2.8 larvae per ear. In the 12 ears with the loosened husks there were 776 injured kernels, or a grain loss of 11.87 percent, and 56 of the original 120 larvae remained, an average of 4.7 per ear.

A third series of 12 uninfested ears, as nearly alike as possible, were artificially infested with newly hatched larvae in the same manner as before. Before being placed in the cages, however, the husks of 4 ears were loosened about the kernels, those of 4 others were removed on half of each ear, and the husks of the 4 remaining ears were left undisturbed. One ear of each group was infested with 10 larvae, one with 20, one with 30, and one with 40. When the ears were examined, after 18 days, larvae were still feeding, being in the fifth or sixth instar.

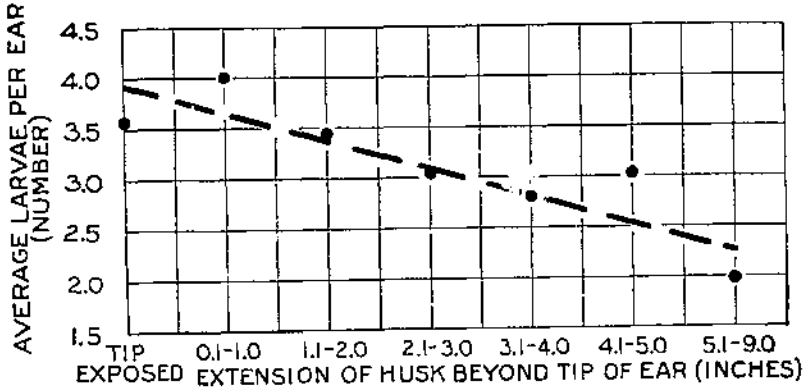

FIGURE 7.—Populations of ear worm larvae recovered in ear corn having husks of various lengths, showing the relation of husk character to cannibalism of the larvae.

There were notable differences in the extent of kernel injury and in the degree of larval survival, depending on the protection afforded by the husks. The results of this series of experiments are shown in table 10.

TABLE 10.—*Injury to kernels and survival of corn ear worm larvae in artificially infested ears of corn originally similar but with the husks loosened, partly cut away, or undisturbed, Richmond, Va., 1929*

Larvae introduced per ear (number)	Husks loosened about ear			Husks cut away on half of ear			Husks undisturbed		
	Kernels injured		Larvae recovered	Kernels injured		Larvae recovered	Kernels injured		Larvae recovered
	Number	*Percent*	*Number*	*Percent*	*Number*	*Number*	*Number*	*Percent*	*Number*
10	147	22.83	3	50	8.17	2	35	6.08	1
20	234	30.49	5	118	20.49	4	85	13.12	3
30	202	40.89	4	221	32.22	7	101	13.15	2
40	391	66.49	7	364	56.52	7	122	21.63	3
Total			19			20			9
Average		39.20	4.8		26.90	5.0		13.42	2.3

The results of all these experiments in which the original number of larvae was controlled indicate that the type of husk is an important factor influencing the extent of cannibalistic feeding by ear worm larvae in corn ears. Loose husks through which the tip of the ear extends unprotected permit larvae to enter the ear at all sides and to feed at all points upon the grain, and this reduces their chance of meeting one another. On the other hand, ears having long husks tightly wrapped about the ears and the silks present but a single point of attack, where the silk is exposed, and this condition affords the most favorable opportunity for cannibalism. Such feeding quarters are also more favorable to cannibalism than are afforded by any other part of the corn plant.

EXTENT OF CANNIBALISM AS RELATED TO GRAIN LOSSES

Concerning the relation between cannibalism and grain losses, the results obtained in a previous study of injury to more than 50,000 corn ears, representing numerous varieties grown in different years, and in different localities, have been given in an earlier paper.[2] In this bulletin only additional evidence obtained from artificially infested ears, where the ear worm populations were definitely known, is introduced. Extreme types of ears were used, and the husks were in some instances loosened. The injury caused by ear worm larvae to the kernels of the ears is summarized in table 11. In the ears having the most poorly developed husks an average destruction of 52.77 percent of the kernels was recorded, whereas in those ears having husks extending 3 inches or more beyond the cob, and closely wrapped about the entire ear, only 1.53 percent of the kernels were injured. It was observed that the length and the tightness of the husks were both of importance in protecting the ears from injury.

TABLE 11.—*Injury to kernels on ears having various types of husk protection and artificially infested with known numbers of ear worm larvae*

Husk protection of ears	Ears	Total larvae introduced	Average larvae per ear	Average period of observation	Average kernels per ear prior to attack	Average kernels injured per ear	
	Number	*Number*	*Number*	*Days*	*Number*	*Number*	*Percent*
Tassel ears, husks poorly developed	6	68	11.3	10.3	433.0	228.5	52.77
Tip of ears exposed, protection poor:							
Husk tight	13	109	8.4	12.9	864.7	116.4	13.62
Husk loosened	10	90	9.0	11.0	892.0	184.4	20.67
Husk loose in general:							
Short:[1]							
Husk tight	3	30	10.0	13.7	953.0	216.5	22.72
Husk loosened	9	90	10.0	12.4	971.1	227.7	23.46
Medium:[2]							
Husk tight	9	72	8.0	12.0	912.6	110.3	12.09
Husk loosened	8	76	9.5	12.1	751.3	109.8	14.61
Long:[3]							
Husk tight	16	177	11.1	11.3	859.5	67.9	7.90
Husk loosened	6	60	10.0	12.3	539.7	80.5	14.92
Husk tight in general:							
Short,[1] husk tight	14	166	11.9	11.4	840.0	68.1	8.11
Medium:[2]							
Husk tight	20	198	9.9	12.9	775.6	53.3	6.87
Husk loosened	8	80	10.0	17.1	885.2	168.2	17.97
Long,[3] husk tight	10	100	10.0	11.7	639.9	9.8	1.53

[1] 0 to 1.5 inches long. [2] 1.5 to 3 inches in length. [3] 3 inches or longer.

[2] PHILLIPS, W. J., and BARBER, G. W. See footnote 1.

BREEDING CORN TYPES TO PROMOTE CANNIBALISM

The husk of the corn ear, if perfectly developed, would afford almost complete protection for the seed. If the corn plant in the course of its development ever occurred without a husk, thus freely exposing the seed to the attack of insects, birds, and mammals, man could hardly have improved the plant better than by introducing the husk to protect the ear. Since in many varieties of corn the husk in its present form does not completely envelop the ear, it can, no doubt, be still further improved through plant breeding. To take advantage of such a peculiar and well-fixed instinct as cannibalism of the ear worm larvae, the improvement of the ear should be such as to limit the points of entry and the feeding space available to the larvae. This can best be accomplished by developing a longer husk, which will completely surround the ear and the silk for from 4 to 6 inches beyond the tip, and which will throughout its length be tightly wrapped about the ear. An improved corn ear of this type, as proposed by Kyle,[3] would not only result in generally decreased populations of this insect through an intensification of cannibalistic feeding, but would make more difficult attack by other insect enemies, such as weevils and grain moths. Moreover, with a reduction in numbers of the ear worm other crops attacked by these larvae would probably be benefited.

SUMMARY

Cannibalism is shown to be a well-fixed habit among corn ear worm larvae. When feeding in corn ears or in small cages, they attack one another with great voracity, not only killing but completely devouring their fellow larvae.

Although this habit seems to be most highly developed in the older larvae, it is characteristic of all larval instars, the intensity of its manifestation at any time depending on the size of the larvae, their number, and the degree of crowding to which they are subjected. In experiments in which various numbers were confined in salve-box cages never did more than one individual in each cage become full grown and pupate.

Individuals were reared to adults from all larval instars and from the egg, when fed entirely upon maimed ear worm larvae, provided the food material was kept fresh. Ear worms reared under such conditions usually required about one-half more time to develop from egg to adult than those maintained on the usual diet of combined plant and animal food. Individuals reared solely on the animal food were of normal size and vigor.

Most larvae developing in corn ears where the insect is numerous apparently subsist on a mixed diet consisting of corn silks and kernels and other ear worm larvae. When offered a choice of such foods in cages, the larger larvae accepted the animal food much more readily than did the smaller larvae.

One ear worm larva in a cage, feeding entirely as a cannibal, consumed about 20 fellow larvae of about its own size in the several instars through which it passed to complete its growth, but by progressive cannibalistic feeding—larvae feeding upon others, which had fed upon others, and so on—it is possible, after several days or weeks, to find one larva remaining in an ear of corn, the sole representative of a larger population that entered the ear to feed.

[3] KYLE, C. H. SHUCK PROTECTION FOR EAR CORN. U. S. Dept. Agr. Bull. 768, 16 pp., illus. 1918.

The extent to which cannibalism by ear worm larvae occurs in ear corn depends largely on the character of the husk, whether it is loose or tight, and on its length relative to the ear, as this determines the points of entry of larvae into the ear and the feeding area within the ear. The most rapid and extensive reduction in numbers through cannibalism occurs in ears having long, tightly wrapped husks, because they present the fewest points of entry and larvae that do enter are brought into closest contact with one another. There is consequently much greater grain injury in ears that are poorly protected by the husks and thus permit larger numbers of larvae to survive cannibalism.

Cannibalism in the corn ear worm can be increased with benefit by improving the nature of the husk protection to corn ears. Experiments have indicated that such improved protection would not only result in less injury to corn but also would limit the numbers of ear worms that develop in cornfields, thereby decreasing the likelihood of serious injury to secondary host plants.

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