CORN EARWORM REARING MECHANIZATION

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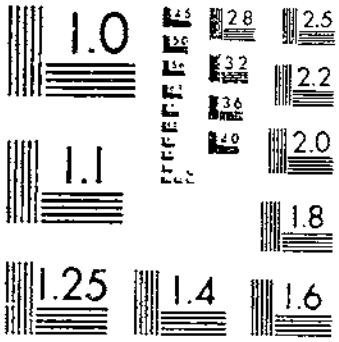

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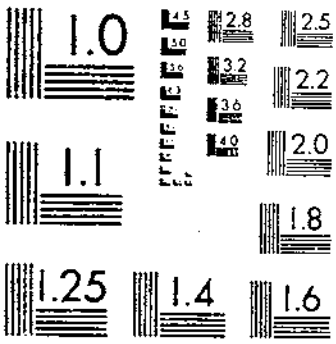

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CORN EARWORM REARING MECHANIZATION

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CORN EARWORM REARING MECHANIZATION

By A. N. Sparks and E. A. Harrell[1]

ABSTRACT

Corn earworm, *Heliothis zea* (Boddie), rearing at the Southern Grain Insects Research Laboratory advanced rapidly from 1968 through 1974. The ability to rear insects was increased from a few hundred per day to about 120,000 per day, primarily through mechanization. An inline form-fill-seal machine was obtained and modified for use in insect rearing. The station dies for forming and sealing were designed to produce individual rearing cells of one and one-sixteenth of an inch in diameter by 1 inch in depth, with a rounded bottom. Diet-filling and egg-infesting equipment was designed, built, and synchronized with the equipment. The diet-filling equipment metered between 5 and 10 milliliters of diet into each rearing cell. Eggs were placed into cavities between the cells because placing them on hot diet destroyed many of them. Upon hatching, the larvae crawl through an opening onto the diet in the cells. A pupae collection machine was also developed. The entire process was used to rear and collect over 6 million pupae from March 1972 to February 1974. Production efficiency (1972–74), measured as pupae produced per cells processed, averaged only 31.4% ($13.61 per 1,000 pupae, 1974 costs), but refinements should lead to at least a 75% production efficiency ($5.81 per 1,000 cells, 1974 costs). Six controlled tests run (1974) using equipment to mix, meter, and sterilize the diet, with a corn and soya blend diet or a substitute diet based on corn meal, soy flour, and milk solids, resulted in a production efficiency of 72.9%. **KEYWORDS: *Heliothis zea*, *Heliothis zea* rearing, insect diet filler, insect diet, insect rearing, insect rearing equipment, mechanization of *Heliothis zea* rearing.**

INTRODUCTION

The corn earworm, *Heliothis zea* (Boddie), has been cultured in the laboratory with varying degrees of success since as early as the first decade of this century, when lots of 10 to 20 larvae were reared on plant parts primarily to obtain life history data (*22*).[2] As a general rule, culturing of the earworm and other insects of agronomic importance continued much along the same line through the early 1960's (*2*, *11*), when researchers reported efforts to rear standardized colonies on artificial diets for laboratory studies (*3*, *23*).

The cannibalistic habit of the corn earworm is so well established that separation of the larvae has been the only solution for successful rearing (*1*). Disease has always been a major problem in mass rearing, even though the larvae are isolated (*20*). A third problem in rearing *H. zea* is the mating and oviposition of laboratory-reared adults (*11*). These problems have caused many failures in attempts to rear numerous species of insects, the corn earworm in particular.

Entomologists and agricultural engineers at the Southern Grain Insects Research Laboratory (SGIRL) have worked to mechanize the rearing of lepidopterous insects, with major

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[2] Italic numbers in parentheses refer to items in "Literature Cited," page 11.

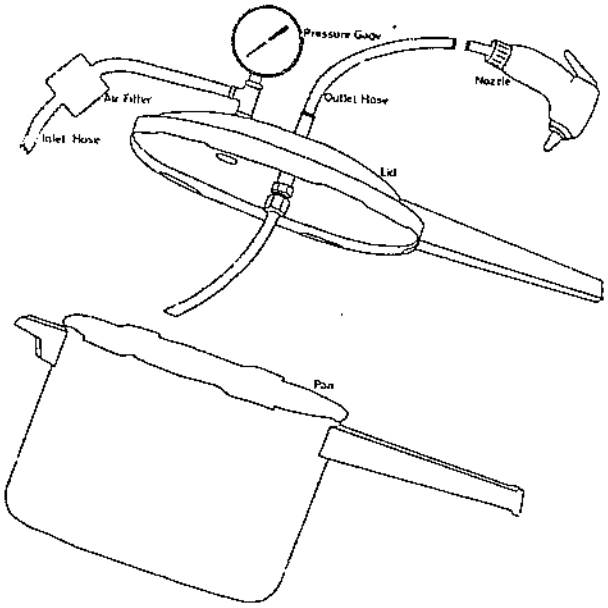

FIGURE 1.—Cooker fitted to dispense diet into shell-glass vials.

emphasis on the corn earworm, since the early 1960's. A summary of those efforts is presented here, as well as the most recently developed mechanized regime for rearing the corn earworm, which can be adapted to rear numerous other species of insects.

ADVANCES IN MECHANIZATION

After the routine use of artificial diets was accepted, two devices (*9*) were developed to speed up Berger's method (*3*) of rearing the corn earworm. A 6-quart, stainless-steel pressure cooker (fig. 1) was adapted (air filter, hoses, gage, and nozzle) to dispense diet into shell-glass vials, eliminating the use of polyethylene squeeze bottles and the problems of pouring hot (>120° F) diets. The second device isolated larvae into vials containing diet (fig. 2) to eliminate the lengthy process of isolating by means of the artist's brush method. At that time, the diet was prepared and dispensed into reusable shell vials and cooled. The larvae were then isolated, and the vials plugged with cotton and stored. Larvae were reared as individuals on artificial media in shell vials from 1964 to 1966. Although no exact costs have been calculated for this type of rearing, the labor required prohibits practical use of this method on a large scale. However, it is still effective when small numbers of insects are required.

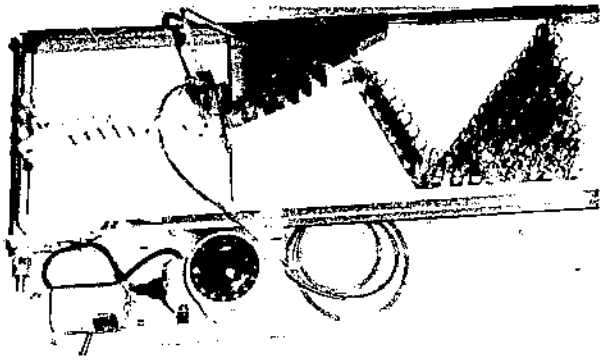

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FIGURE 2.—Equipment to isolate larvae into vials containing diet.

The need for large quantities of lepidopterous larvae at SGIRL led to the purchase and modification of a food-packaging machine (*7*) (fig. 3) and the development of a larval dispenser for use on the machine (*8*). The machine dispenses 1-ounce plastic cups, adds a metered amount of diet to each cup, dispenses larvae onto the diet, and caps each container in a continuous process at the rate of 2,000 to 4,500 containers per hour. The processed cups are placed in bundles of 200 (fig. 4) for storage in an environmentally controlled room. This process was satisfactory for rearing the fall armyworm, *Spodoptera frugiperda* (J. E. Smith), and SGIRL scientists used this insect for experimentation because techniques of rearing adequate numbers of corn earworms had not been developed at that time.

Problems with pesticides, along with economic losses from corn earworm attacks on

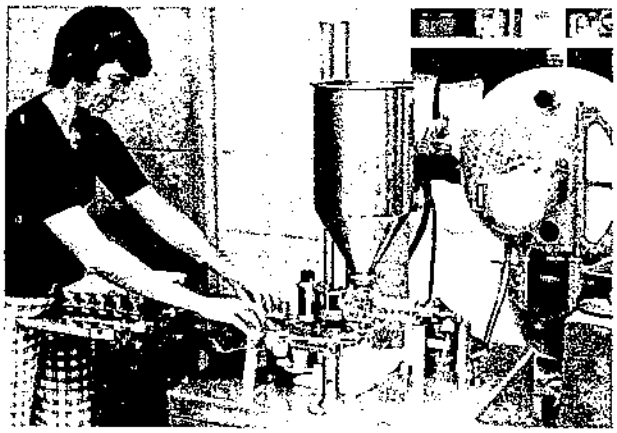

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FIGURE 3.—Food-packaging machine for dispensing, filling, and capping 1-ounce plastic cups used for rearing cells.

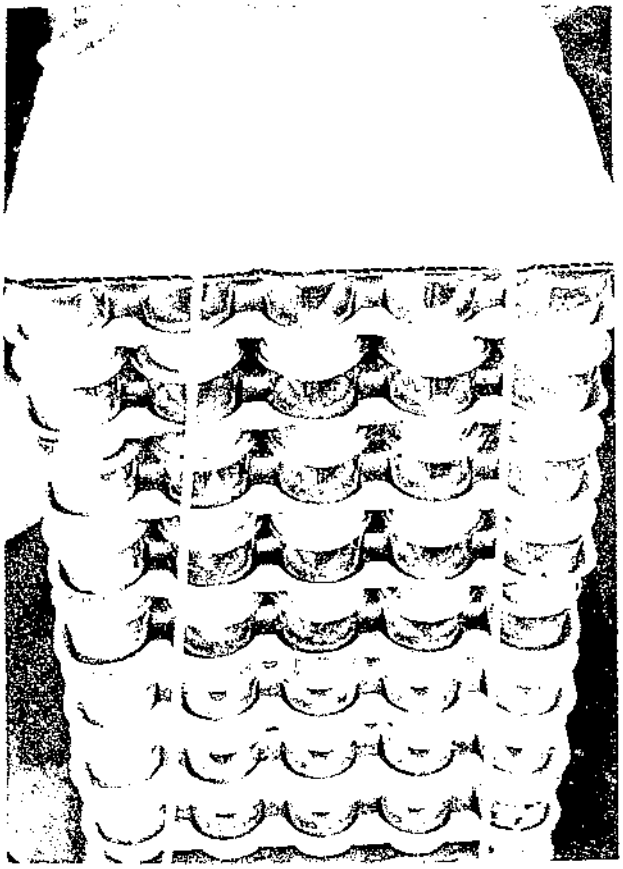

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FIGURE 4.—Processed 1-ounce rearing cells placed in a bundle for storage in an environmental room during the insect's larval stage.

numerous crops, made the corn earworm (CEW) a good choice for research on alternative methods of pest control; that is, the use of attractants, pathogens, sterile insect techniques, host plant resistance, and predators and parasites. In April 1967, special Entomology Research Division funds were allocated to SGIRL for mass rearing the corn earworm for identifying sex attractants and determining the suitability of St. Croix, U.S. Virgin Islands, as a site for a trial of the sterile-male technique as a means of eradicating the species from the island. Females were needed for the extraction of tips to determine the identity of the sex pheromone. Males were needed for basic feasibility studies on St. Croix, and an effective technique for mass rearing the corn earworm needed to be developed. On hand was the food-packaging machine. The primary need was a satisfactory method of placing eggs or larvae into the cups during the regular cycle of the

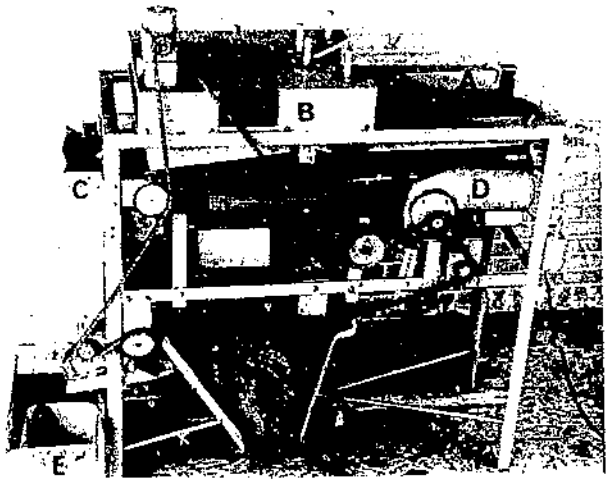

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FIGURE 5.—Equipment to collect corn earworm pupae from 1-ounce rearing cells. A, Cup conveyor section; B, cup crusher section; C, chute; D, drive motor; E, trash collector; F, pupae trough.

machine. The larvae were too fragile to dispense on grits (*7*), and the heat and the microbial inhibitor components of the diet rendered the eggs inviable. Despite much research, the problem was not solved during this mass-rearing trial. It was necessary to dispense the cups, put in the diet, allow the diet to cool, and then hand-infest and hand-cap the containers (*5*). This process required a great amount of labor and increased the probability of contamination.

Lack of adequate holding facilities for the rearing cells during larval growth allowed an excessive number of larvae to escape by chewing out of the cells. Optimum temperature and humidity conditions were not available. An air tunnel with a fan was used but found inadequate.

A second attempt was made to mass-rear the corn earworm in 1968. From June 25 to September 8, an average of 3,322 male pupae per day were reared and shipped to the island of St. Croix for an eradication project. Again, the majority of the females were kept in Tifton for the sex attractant project. Although a pupae collector (fig. 5) had been designed and constructed (*14*), hand labor was still necessary for infesting and capping the cups. The program was halted in September because the native population of earworms on St. Croix had reached an unmanageable level and because a combination of cytoplasmic and nuclear polyhedrosis viruses (NPV) had riddled the colony. The major rearing problems were inadequate

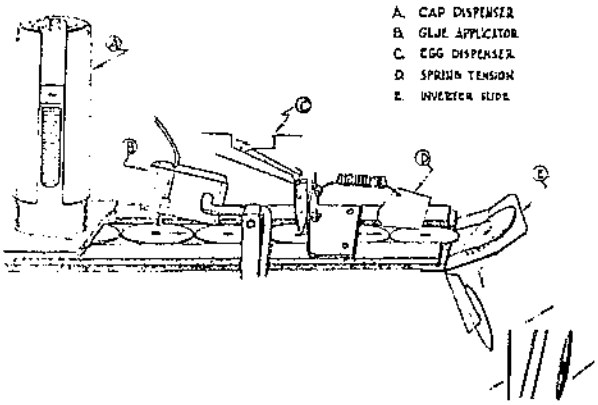

FIGURE 6.—Schematic of machine to place corn earworm eggs in a pickout in the center of cardboard caps.

larval rearing facilities, disease, and quantity of hand labor required to infest and cap the cups used as rearing containers.

In 1969, another attempt to eradicate the corn earworm from St. Croix was planned. Equipment was developed to allow mechanical infestation and capping of cups used for rearing cells (*15*). This equipment (fig. 6) individually dispensed cardboard caps (0.045 inch thick by 1.50 inches in diameter), placed a minute amount of glue into a depression (pickout) 0.030 inch deep by 0.25 inch in diameter in the center of the cap, and put six to eight *H. zea* eggs onto the glue in the pickout. The machine then inverted the caps and restacked them for repackaging in their original container. The caps with the eggs were mechanically placed on the cups after they were filled with hot diet. The eggs hatched after the diet had cooled, permitting the larvae to fall safely onto the diet. The need for hand labor was, therefore, eliminated in yet another step of the rearing process.

However, the 1969 attempt to mass-rear the corn earworm reemphasized the magnitude of previous problems. Again, inadequate larval-holding facilities and disease greatly decimated the culture. From April 12 to July 19 some 1,100,000 pupae were reared, the males and a portion of the females being shipped to St. Croix for native insect control projects. The remaining females were used as before. The microsporidian *Nosema heliothidis* invaded a portion of the colony, resulting in a cycle of extremely low egg production. This infestation in the colony, coupled with high native populations of the earworm on St. Croix, made it necessary to abandon the experiment.

Diets required to mass-rear corn earworms have been widely studied (*5, 6, 10, 21*). The development of the corn, soya, and milk (CSM) base diet (*6*) and of the wheat and soya blend (WSB) base diet (*10*) reduced the cost of diet ingredients to about 13 cents per liter, compared to 25 cents per liter for the modified pinto bean diet and about 50 cents per liter for the casein and wheat germ diet (*23*). The estimated cost per liter for the pinto bean diet and the CSM diets in 1975 was 49 cents and 28 cents, respectively. Continued inflation makes the search for cheaper diet ingredients a necessity.

Disease was the major obstacle to successful mass rearing in 1967, 1968, and 1969. The surface sterilization of eggs (*5*) and rearing in individual containers reduced the incidence of contamination by NPV and cytoplasmic viruses to nonsignificant levels. After elimination of *Nosema heliothidis* (*12*) from the culture, techniques for developing and maintaining a laboratory colony of the corn earworm were researched (*24*) and used to develop an improved strain of earworms for release on St. Croix (*25*). In both cases, wild males were used to add exotic genetic material to the laboratory stock, a practice which increased the overall efficiency of the colonies and avoided contamination by micro-organisms. These processes alleviated known disease problems, but additional research is needed to develop techniques to rear disease-free, competitive insects in quality and quantity.

Finally, the cost of containers for individually rearing the earworm has grown from a low

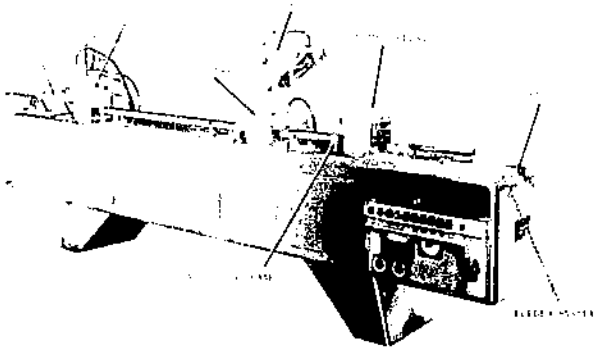

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FIGURE 7.—Inline form-fill-seal machine adapted for insect rearing at SGIRL.

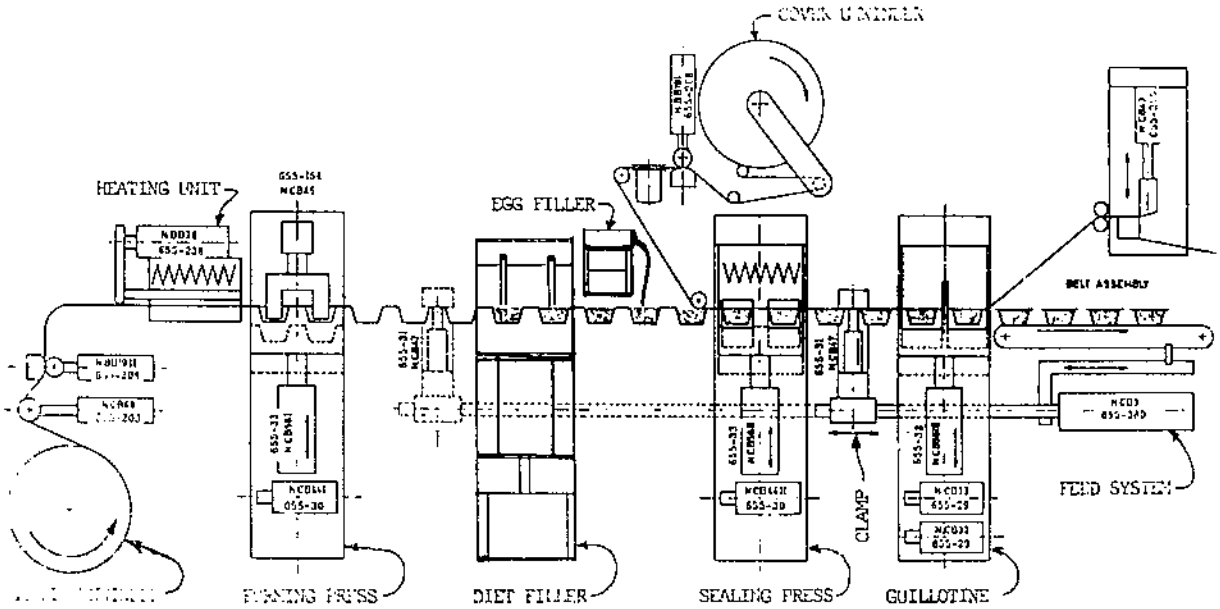

FIGURE 8.—Schematic of inline form-fill-seal machine adapted for use in insect rearing at SGIRL.

of $1.17 per 1,000 ($3.25 for cups, 92 cents for caps) in 1967–68 to a current price (1975) of $9.35 ($7.55 for cups, $1.80 for caps). These containers became too expensive for mass-rearing after the 1967 program.

DEVELOPMENT OF THE INLINE FORM-FILL-SEAL REARING REGIME

In October 1971, an inline, form-fill-seal machine—Anderson Brothers model B (655)—was purchased by SGIRL (fig. 7). The machine is about 15 feet long, 2.5 feet wide, and 5 feet high. It was received as shown except that a guillotine was substituted for the trimming press. Powered electrically and pneumatically, the machine forms plastic into a continuous web of cells of a desired shape and size, heat-seals a cover material over the formed cells, and shears the web into desired lengths. The machine is synchronized to carry out simultaneous operations at the forming, sealing, and shearing stations at a maximum of 17 strokes per minute. We designed, fabricated, and synchronized the diet-filling and egg-infesting stations to make a continuous automated process (fig. 8).

The forming- and sealing-station dies were made to our specifications. The forming die produces cells 1 1/16 inches in diameter and 1 inch deep, with a rounded bottom a half an inch in radius. The cells were arranged in a 4 by 8 pattern to yield 32 cells per stroke (fig. 9). The forming station is equipped with a solid shaft (plug) with a rounded end mounted over each cell. This adjustable plug moves down into the forming die on each stroke, controlling the thickness of the sides and the bottom of the cells. During operation the forming die moves up and is locked into position, the plug moves down, and pressurized air is released around the plug to force the preheated (300° F) plastic into the die. The forced air also cools the plastic sufficiently for it to retain the shape of the die. The die and plug return to their original position to complete the stroke at that station.

The sealing head was designed to fit snugly around the formed cells, forcing them uniformly against the top die to seal the cover material to the web. The cover material is sealed to the web in a pattern one eighth inch wide around the edge of the web, between each cell across the web, and between alternating cells lengthwise of the web. Sealing temperature and time are adjustable.

The guillotine, which can cut the web into any length from 1 to 999 strokes of the machine, was set to shear the web after the fourth stroke to accommodate carts used for storage in a larval-holding room. The standard webs,

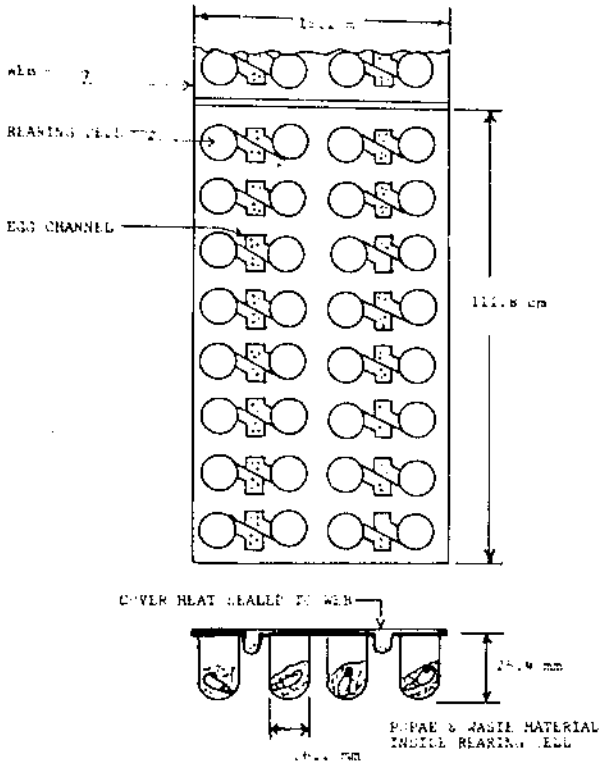

FIGURE 9.—Schematic of plastic web processed on the form-fill-seal equipment at SGIRL.

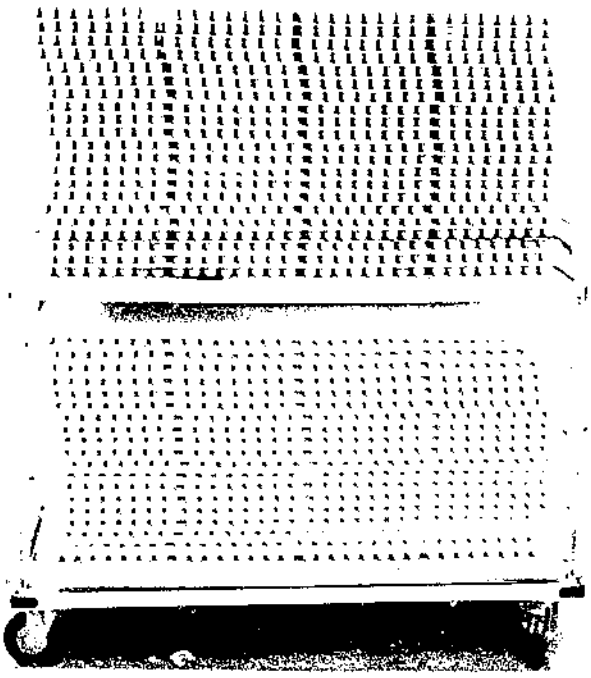

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FIGURE 10.—Cart loaded with 20,480 processed corn earworm rearing cells.

44 inches long with 128 cells, are stacked 4 across up to 20 high in 2 layers of each cart. Each cart may contain up to 20,480 rearing cells (fig. 10). Screen wire (14- by 16-mesh) separates layers of cells to reduce escapes and improve water and air exchange from the cells.

Equipment and methods (fig. 11) were devised to store, meter, mix, sterilize, and transport the insect diet to the diet-filling station at a rate up to 68 gallons per hour (*16*). We designed, built, and synchronized a diet-filling machine (*18*) to meter 5 to 10 milliliters of sterile diet into each of the 32 rearing cells formed two strokes previously at the forming station (figs. 12 and 13).

Experience had shown that corn earworm eggs could not be placed on the surface of hot diet, and so the effects of heat on egg hatch were investigated (*13*). We solved this problem by modifying the forming die to make a channel between each two cells and designing equipment to place eggs in these cavities (*19*) (figs. 14 and 15). Upon hatching, first instar larvae crawl through an opening 0.8 millimeter by 1.59 centimeters into the diet-laden rearing cells.

This new equipment and these new techniques required the development of a machine to collect pupae (*17*) (figs. 16 and 17). The entire process was used to rear and collect over 6 million pupae from March 1972 to February 1974 for the St. Croix program.

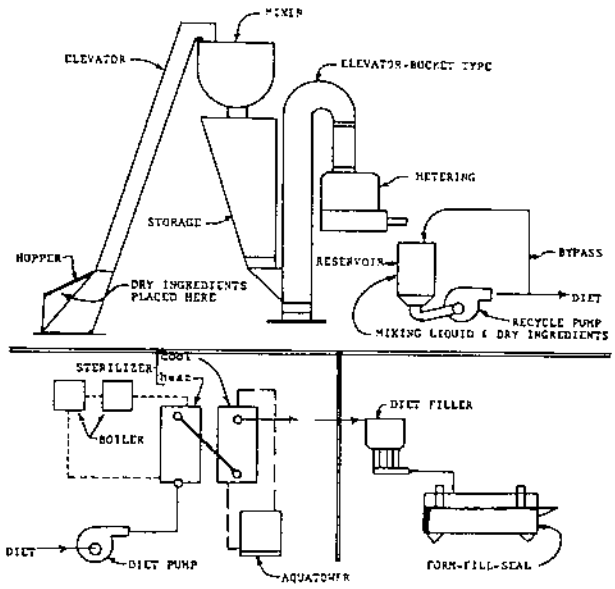

FIGURE 11.—Schematic of equipment assembled at SGIRL to process insect diet for mass rearing.

RESULTS AND DISCUSSION

Table 1 summarizes several attempts to mass-rear the corn earworm at SGIRL. Prior to 1964, plant parts, purchased or collected, were used as food for larvae reared in small plastic boxes. Contamination, disease, and the large amount of hand labor required resulted in inefficiency and extremely high costs. Cultures handled in this manner, could not be counted on to supply the demands of research projects in peak seasons and generally became defunct in the winter. The development of an artificial diet to replace plant parts reduced the cost of producing corn earworms and increased output, but did not do these enough to warrant production on a large scale.

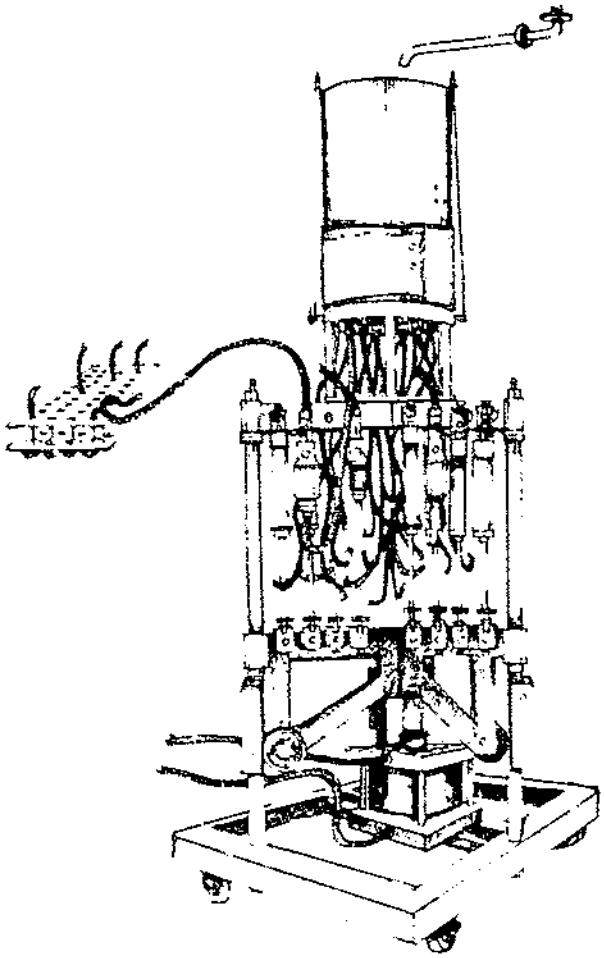

FIGURE 12.—Pictorial view of diet-filling machine designed for use with the form-fill-seal equipment.

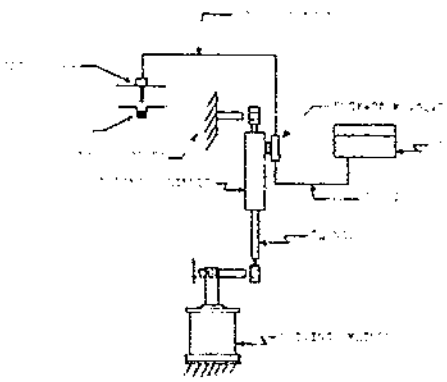

FIGURE 13.—Schematic of diet-filling machine designed for use with the form-fill-seal equipment.

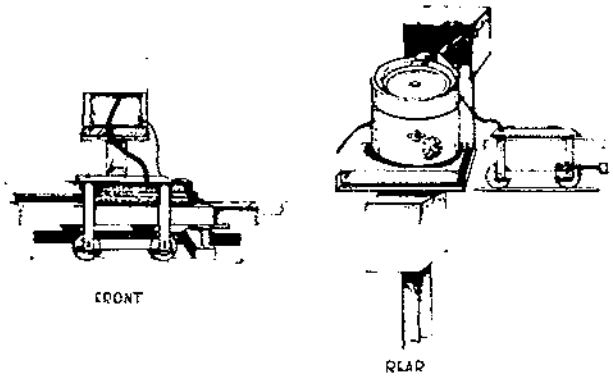

FIGURE 14.—Pictorial view of equipment to place corn earworm eggs into cavities on web near rearing cells.

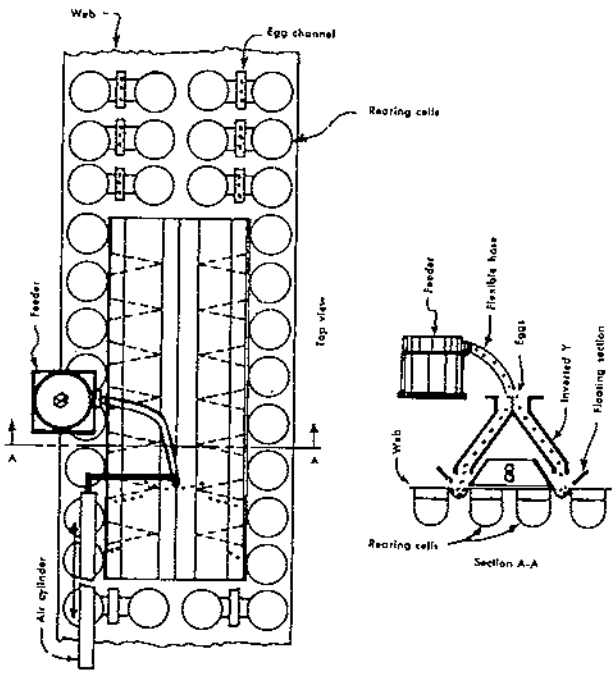

FIGURE 15.—Schematic of equipment to place corn earworm eggs into cavities on web near rearing cells.

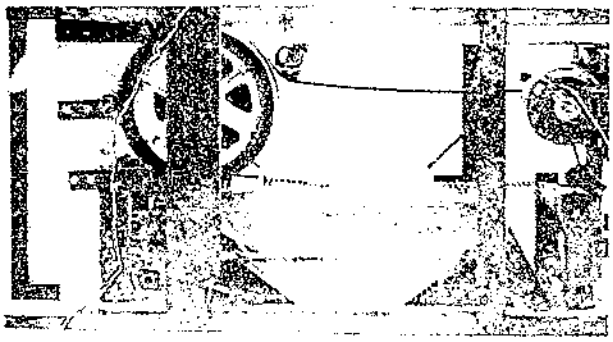

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FIGURE 16.—Equipment designed to aid corn earworm pupae collection from cells in a plastic web.

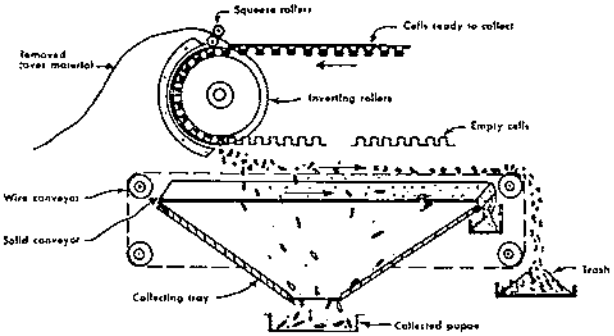

FIGURE 17.—Schematic of equipment designed to aid corn earworm pupae collection from cells in a plastic web.

Engineers and entomologists at SGIRL developed a good regime for rearing lepidopterous insects in individual 1-ounce rearing cells. The regime is excellent for maintaining a laboratory colony or supplying a few thousand insects up to a maximum of about 30,000 per day. However, costs of cups, caps, and labor are limiting factors.

During development of this regime the percentage of pupal return from processed cups was increased from 40.5 in 1967 to 65 in 1969. We reared 405,000 insects in 1967 at a cost of $84.72 per 1,000 pupae. Labor costs were $52.67 per 1,000 pupae. Had we been able to increase production efficiency, that is, raise pupae production from infested containers to a theoretical 100 percent, we could have reared the corn earworm for $34.31 per 1,000. We therefore looked at areas in the regime that were most expensive and that could be improved by mechanization or development of new techniques. As a result, in 1968 we reared twice as many corn earworms at about half the cost of the 1967 rearing. Labor costs were reduced about half by means of the pupae collector. Developmental techniques were continued, and in 1969 we reared over a million corn earworms at $22.52 per 1,000 pupae. In about 2 years we had reduced the actual costs of rearing corn

TABLE 1.—*Summary of* Heliothis zea *rearing programs conducted at the Southern Grain Insects Research Laboratory, Tifton, Ga.*

Type of rearing	Duration of test	Pupae reared		Larvae produced per infested container (%)	Cost per 1,000 pupae		
		Avg. per day	Total		Labor	Total	Theoretical[1]
Plant parts in plastic boxes (before 1964).	Continuous	200	...	...	...	...	...
Artificial diet in shell vials (1964-66).	Continuous	500	...	...	...	...	...
Food-packaging machine[2] (1967).	Mar. 6-Oct. 4	2,000	405,000	40.5	$52.67	$84.72	$34.31
Food-packaging machine[3] (1968).	June 25-Sept. 8	11,800	885,000	60	27.44	43.29	25.64
Food-packaging machine[4] (1969).	Apr. 12-July 10	12,200	1,100,000	65	12.27	22.52	14.57

[1] Theoretical costs are based on 100% return of pupae from infested containers.
[2] Hand-infested, hand-capped, and hand-collected. Funds allowed for trial were depleted.
[3] Hand-infested and hand-capped. Cytoplasmic NPV viruses eliminated culture.
[4] *Nosema heliothidis* invaded a portion of the colony.

earworms to about one-fourth of the original cost. Had we been able to increase production efficiency to 100 percent, the cost in 1969 would have been $14.57 per 1,000 pupae.

Labor and container costs, along with the increasing demand for large numbers of insects, prompted us to research alternative methods of rearing corn earworms. Labor costs per hour have more than doubled in the last few years, and the cost of cups and caps increased from $4.17 in 1967 to $9.35 per 1,000 in 1974. We calculated that we could increase output capacity, reduce the number of persons required to produce 1,000 corn earworms, and reduce container costs from $4.17 to $1.25 by using an inline form-fill-seal machine. The amount of diet was reduced from 10 to 7 milliliters per insect without detrimental results. The cost to form, fill with diet, infest with eggs, and seal 1,000 cells was $4.36. Theoretically, we could produce corn earworms for $4.36 per 1,000, provided we were 100 percent efficient.

Whereas the capacity of the 1-ounce cup rearing regime is about 30,000 cells per 8-hour day, the form-fill-seal unit has a maximum speed of 17 strokes per minute, yielding 261,120 cells per 8-hour day. Most equipment, however, will not operate at maximum speed for extended periods. For corn earworm rearing, 20 mil, high-impact polystyrene is required to make cells thick enough to prevent escapes. With this relatively thick plastic, the optimum speed for our equipment is between 10 and 12 strokes per minute. Allowing 1 hour per day for maintenance and cleanup, we could easily process 160,000 cells per 8-hour day in a continuous operation.

The form-fill-seal machine with a diet and egg filler was put into operation for the 1972–74 program. It was used part of the day, 6 days per week during this period. Production efficiency, measured as pupae produced in relation to cells infested, averaged 31.4 percent at a cost of $13.61 per 1,000 pupae (table 2). This is a low efficiency, and we knew so during the operation, but were unable to conduct the research required to increase efficiency. Production received top priority.

The feasibility of obtaining 100 percent efficiency in corn earworm rearing is poor. We plan for 90 percent efficiency, but realize that a production efficiency of 75 percent would be more in line with what should be expected from our equipment. At 75 percent efficiency, our cost would have been $5.81 per 1,000 cells. Since the close of this project in 1974, the cost of diet ingredients and container materials has grown tremendously. From 1974 to 1975, the cost of high-impact polystryrene increased from 37 cents to 55 cents per pound, cover material (Tyvek) increased from $22.85 to $33.92 per 1,000 feet, and diet ingredients increased from 13 cents to 28 cents per liter. In 1975, at 75 percent efficiency, 1,000 pupae would cost $9.58,

TABLE 2.—*Estimated cost of producing corn earworms when operating at full capacity (160,000 per 8 hours), at varying efficiencies*

[Per 1,000 cells]

Materials	1972–74 efficiency percentage					1975 efficiency percentage			
	100	90	75	50	32	100	90	75	50
Plastic[1]	$0.59	$0.66	$0.79	$1.18	$ 1.84	$0.88	$0.98	$1.17	$ 1.76
Cover[2]	.66	.73	.88	1.32	2.06	.98	1.09	1.31	1.96
Diet[3]	.91	1.01	1.21	1.82	2.84	1.96	2.18	2.61	3.92
Labor[4]	1.45	1.61	1.93	2.90	4.53	1.87	2.08	2.49	3.74
Miscellaneous	.75	.83	1.00	1.50	2.34	1.50	1.67	2.00	3.00
Total	4.36	4.84	5.81	8.72	13.61	7.19	8.00	9.58	14.38

[1] Plastic costs per pound (1.57 pounds of 20 mil plastic forms 1,000 cells): 1971–74, $0.37; 1975, $0.55.

[2] Cover (Tyvek) costs per 1,000 feet (28.65 feet covers 1,000 cells): 1971–74, $22.85; 1975, $33.92.

[3] Diet costs per liter (7.0 liters fills 1,000 cells): 1971–74, $0.13; 1975, $0.28.

[4] Labor costs per hour: 3 workers, 1971–74, at $2.95; 1975, at $3.47; 1 worker, 1971–74, at $3.11; 1975, at $3.90; 1 worker, 1971–74, at $5.89; 1975, at $7.94; 1 worker, 1971–74, at 8.10; 1975, at $11.19.

TABLE 3.—*Efficiency of form-fill-seal rearing regime with controlled larval holding and rearing equipment*

Diet	Duration of test (1974)	Total cells	RH[1]	Pupae: Total	Pupae: Production efficiency[2] (%)	Larvae: Large (%)	Larvae: Small (%)	Dead pupae and larvae (%)	Blanks (%)	Missing (%)
Substitute	July 23–Aug. 13	8,960	60	7,130	79.6	3.7	1.4	6.0	6.5	2.8
Do	July 23–Aug. 13	8,960	50	5,017	56.0	2.1	3.9	17.7	8.5	11.8
Do	Aug. 20–Sept. 10	9,728	60	8,561	88	2	1	6	2	1
Do	Aug. 20–Sept. 10	10,240	50	8,397	82	1	3	9	2	3
Corn and soya blend	Aug. 19–Sept. 10	19,456	60	13,500	69.4	6.9	3.5	15.0	2.9	2.3
Do	Aug. 19–Sept. 10	20,992	50	15,109	72.0	5.9	4.0	14.1	2.0	2.0
	Total	78,336	...	57,714	73.68	...	...	...	...	...

[1] At 60% relative humidity, total cells were 38,144, pupae were 29,191, for a 76.5% efficiency. At 50% relative humidity, total cells were 40,192, pupae were 28,523, for a 71.0% efficiency. Temperature for all tests was 85° F.
[2] Normal pupae reared per cells infested.

which is about $3.77 more than they would have cost a year earlier (1974).

At the conclusion of the 1972–74 program, research was begun to improve production efficiency (table 3) and to test-run the equipment for metering, mixing, and sterilizing the diet. A corn and soya blend (CSB) diet—a variation of the CSM diet without milk solids—used in the 1972–74 operation was mixed in the laboratory in an 8-gallon blender. Controlled runs on 2 tests of 5,120 cells each yielded 7,116 pupae, for an average of 69 percent. Additional tests were run using the CSB diet and a diet, formulated at SGIRL, based on corn meal, soy flour, milk solids, and labeled a substitute diet (SD). These diets were mixed and sterilized with the new equipment and labeled as the mechanical equipment diet (MED). A total of 88,576 cells were processed, and they returned 64,600 pupae for a 72.9 percent production efficiency. There were 4.4 percent blank cells and 3.9 percent escapes. The percentage of dead pupae and larvae (9.0) is unexplainable so far, but research should result in reducing this loss. However, the life cycle and habits of the corn earworm are not conducive to mechanized rearing to the extent that the percentage of larvae remaining in the cells at pupa collection time can be reduced substantially. The standard rearing unit contains 128 cells that are harvested as a unit 21 days after infestation. The larvae simply do not mature and pupate uniformly enough to prevent some loss. Equipment designed to accurately control relative humidity and temperature in properly designed larval holding and rearing facilities will keep these losses at a minimum.

Schemes for the suppression or eradication of an insect population which require large numbers of insects, predators, or parasites depend upon an efficient rearing technology. Before such a control program is undertaken, the capacity to rear the chosen insect economically must be developed. Economical insect production requires a mechanized regime. The degree of mechanization now available (1975) reduces the costs of rearing the corn earworm $8.91 per 1,000 over previously used methods at SGIRL. Should a program require large numbers of corn earworms (more than 160,000 per day), mechanization would be essential. A production rate of 100,000 per day would result in a savings of about $891 per day. Savings from a 200-day operation would equip a rearing facility.

An excellent, basic insect-rearing regime has been assembled at the SGIRL. With proper support it could be expanded economically into a major insect-rearing facility. This equipment is not limited to rearing corn earworms and fall armyworms: the forming dies can be redesigned for making containers of many other shapes and sizes. Many other diets can be handled efficiently with this equipment. Some other lepidopterous insects requiring habitats similar to that of the corn earworm can be reared with this equipment with only minor modifications. Other insects, such as the boll

weevil, *Anthonomus grandis* Boheman, require more elaborate changes. Work is underway on the boll weevil. The dies have been changed to form two cells per stroke. However, the characteristics of the diet and techniques for infesting the cells, have slowed the equipment to six strokes per minute. At this speed the output is equivalent to the processing of 1,800 petri dishes per hour. Should we be able to produce 75 weevils in a petri dish equivalent, we could have a potential output of 135,000 weevils per hour. Additional mechanization and new techniques could further increase this production. Discussions are also underway for using similar equipment and techniques for rearing some forest insects, for example, the gypsy moth, *Porthetria dispar* (Linnaeus).

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