Chapter 12

STATUS OF REARING TECHNOLOGY FOR COTTON INSECTS

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INTRODUCTION

Many insect pests of cotton can be cultured on synthetic diets in controlled environments to conduct research for development of advanced pest control concepts. Pest species with defined rearing procedures include: the boll weevil, *Anthonomus grandis grandis* Boheman (Coleoptera: Curculionidae); tobacco budworm, *Heliothis virescens* (F.) (Lepidoptera: Noctuidae); bollworm (corn earworm, tomato fruitworm), *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae); pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae); plant bugs, *Lygus* spp. (Heteroptera: Miridae); and armyworms, *Spodoptera* spp. (Lepidoptera: Noctuidae). Certain beneficial species also can be reared on a large scale.

Diet formulations and rearing methods (manual vs. mechanical) for insect propagation are variable depending on production levels needed. These methods are described in recent literature. King and Leppla (1984) discuss colony establishment and maintenance through genetic control, diets and containers, engineering requirements for facilities, sanitation and microbial controls, quality control testing, systems management and descriptions of rearing techniques for specific insects. Singh and Moore (1985a,b) developed a set of "cookbook-style" handbooks in which specific instructions are given in a step-by-step manner for each operation in a particular rearing procedure. A worldwide listing of arthropod species in culture was published by Edwards *et al.* (1987) who cited contacts for many research programs. This work may be helpful when seeking insects for studies or for starting a colony. Rearing equipment ranging from bioclimatic chambers to large-scale facilities also have been described (Leppla and Ashley, 1978). More recently, Fisher and Leppla (1985) emphasized multi-room facilities for rearing Lepidoptera.

The ability to rear large numbers of insects must be integrated with a strategy for maintaining production and product quality control. A strong quality control component is crucial to any rearing program to ensure production output is maintained and that test or release insects will perform effectively. Laboratory-reared insects may become so strongly adapted to artificial rearing conditions that the information gained from experiments may be meaningless. The goals of this chapter are to describe: (a) the status and increased potential for applied biological control programs due to new technology available for insect rearing; (b) challenges that face entomologists in developing and employing effective biological control programs (production/release); (c) field evaluation technology for laboratory-reared insects; and, (d) a system for transferring new methodology to other agencies, to industry or to other potential users. Much of the discussion for the latter three goals will relate to boll weevil production.

STATUS OF REARING FOR MAJOR PESTS

The composite effect of advanced technology in insect rearing by refinements of defined diets and applied field programs have fostered development of engineering systems capable of meeting the challenges of today's biological control programs. Biological control is used broadly here to include use of sterile insects, backcross hybrids, etc. Future insect control concepts must be effective, economical and environmentally safe. The technologies needed are well developed and available through commercial sources. The necessary support and operational expertise are needed to put them into use.

The thermoform tray preparation technique introduced by Ignoffo and Boening (1970) and advanced by Sparks and Harrell (1976), who used a flash sterilizing unit (Figure 1) to process and deliver sterile diet to a thermoforming packing unit (Figure 2), established a prototype system that is adaptable to production of many insect species. The USDA, Agricultural Research Service (ARS), Southern Insect Management Laboratory, Insect Rearing Research Unit is housed in the R. T. Gast Rearing Laboratory at Mississippi State, Mississippi. Personnel of the Insect Rearing Research Unit have refined the system. They developed accessory tray assembly equipment that can be sanitized to deliver sterile diets to specialized trayforms for filling with diet and eggs. The eggs can be introduced in liquid or dry media, and diluted or concentrated for delivery to feeding cavities in desired quantities.

The mechanized system offers advantages desirable for mass production programs. Major advantages include improved sanitation control, reduced labor and increased production output capability. Commercial engineering firms with expertise for packaging specialized food and drug items have developed the basic technology to meet specialized operational requirements. The advantages gained through mechanized industrial insect production open the door for advanced use of pathogen-free insects for suppression programs, production of carcasses for specific virus and bacterial propagation, and mass rearing of host/prey insect species to culture predators and parasites for control of target pest species. Mechanized systems offer potential for expanded

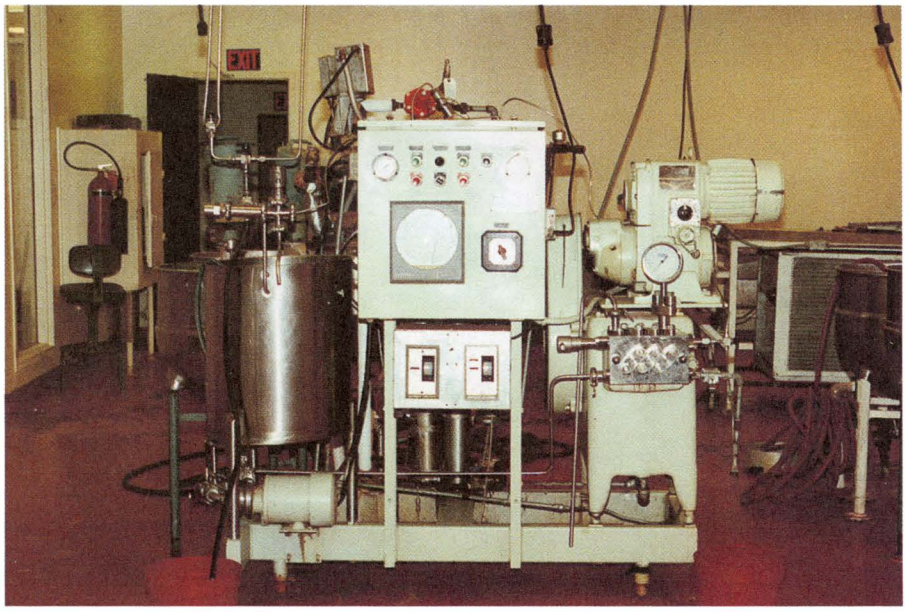

Figure 1. Flash sterilizer for diet processing.

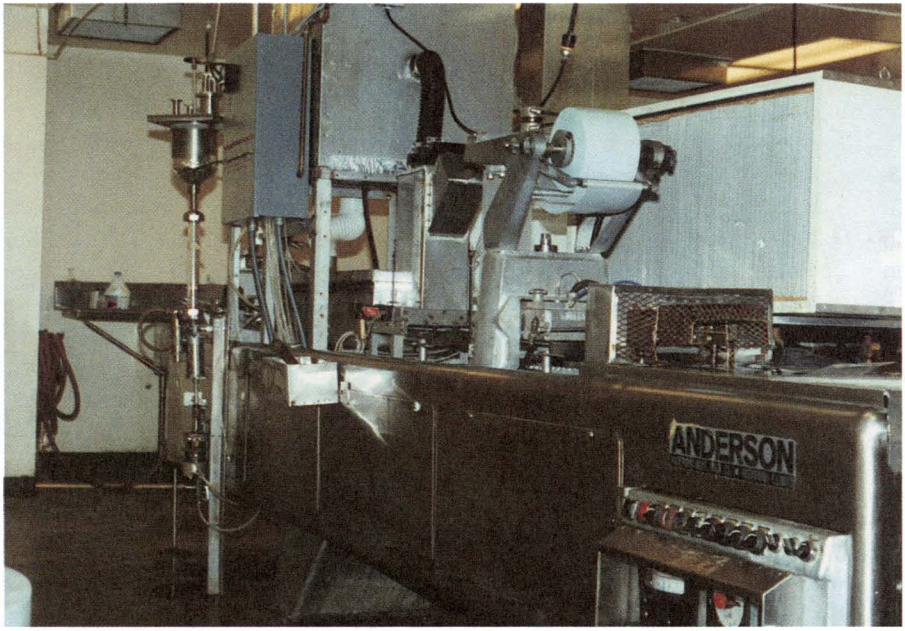

Figure 2. Thermoforming packaging unit to form and assemble rearing trays.

production with minimal stresses to personnel conducting program operations, compared to stress with expansion of rearing processes that require a high level of manual procedures.

Rearing procedures and equipment are available for mechanized production of the boll weevil, tobacco budworm, bollworm and the parasite *Microplitis croceipes* (Cresson) (Hymenoptera: Braconidae). A methods development program is in progress to adapt pink bollworm rearing operations to a mechanized process using flash sterilization and thermoform packaging units to meet the increasing needs for sterile release programs in California. The technical advancements gained by adapting insect rearing to packaging systems that can be managed sanitarily with a minimal labor force has advanced biological control concepts to the threshold of a new era. In order to better utilize and implement these technologies, personnel involved in research and field applications must review traditional problems with consideration of the changing times and advantages that different approaches to problems could yield. We must realize that mass production of insects is rational and presents a realistic solution to the complex problems introduced to today's agriculture.

BOLL WEEVIL REARING

In 1966, Gast and Davich described boll weevil colonization adapted to mass production processes, and technological advances continue to be made by USDA's, Insect Rearing Research Unit at Mississippi State, Mississippi. The Gast Laboratory opened in May, 1972 and produced 2.7 million sterile male boll weevils in 1973 for release in the Pilot Boll Weevil Eradication Experiment (Lindig, 1976). Major problems were encountered with microbial contamination of the diet and production costs due to intense labor requirements, especially in sexing the laboratory-reared weevils. In 1975, an Anderson 18-B Thermoforming packaging unit with prototype equipment designed for assembly of boll weevil trays was transferred from the USDA, ARS, Insect Migration/Dispersal Research Unit. In 1976, the first large-scale rearing program using the thermoforming packaging equipment was conducted. Production was 600,000 weevils per day for a six-week period. They were used as one of the technology components being tested in support of the proposed Boll Weevil Eradication Program. In 1977, a more ambitious program was conducted. Production averaged approximately 850,000 adults per day for a nine-week period. A fractionated pupal irradiation sterilization process was evaluated. During this period, problems were confronted concerning low egg production and microbial contamination of rearing trays.

Large-scale operation rearing procedures were critiqued during this period for procedural improvements and labor reduction. As a result, the following major modifications were implemented: (a) installation of High Efficiency Particulate Air (HEPA) filters in holding-room areas and within the chilling tunnel of the tray-forming unit; (b) use of sterile sand-corncob mix with antibiotics and fungicide for rearing trays; (c) modification of egg spray equipment for improved spray pattern on rearing trays; (d) change of glue formulation on Tyvek® lidding for improved seal; (e) improved environmental controls in holding room areas; (f) emergence of adults from trays to light

traps for collection; (g) feed-out of preirradiated adults in mosquito net bags; and, (h) use of rackveyors for holding rearing trays. The rearing procedures introduced from 1976-1979 were expected to improve field performance of sterile weevils by extending their longevity and improve the likelihood of eradicating low density field populations of weevils.

Photographs and descriptions of the facility and production equipment were detailed by Griffin (1984). The historical development of boll weevil diets was traced by Lindig (1984), and phases of laboratory rearing by Roberson (1984); microbial contamination was described by Sikorowski (1984).

Field data did not indicate increased pest control effectiveness that was anticipated from sterile weevils that were produced with the improved rearing methods. In 1984, survey tests were conducted at the rearing laboratory to observe weevil behavior (flight, walk, mating, etc.) following standard irradiation treatment processes. Investigations conducted in 1984 to 1985 by personnel at the Insect Rearing Research Unit and the USDA, ARS Boll Weevil Research Laboratory, Mississippi State, Mississippi (Roberson and Villavaso, 1986) observed high weevil mortality when aerial releases of weevils were made on soil surface temperatures reaching 120F (49C) and higher. Losses were also high if packaged weevils were stored for two or more days before release.

Studies in cooperation with USDA's, Animal and Plant Health Inspection Service (APHIS), Aircraft Operations Center, Mission, Texas, led to design and construction of paper tube loading equipment (Figure 3) to package irradiated weevils in paper cylinders for aerial dispersal. The improved handling and packing processes were evaluated in field releases in North Carolina in 1985 and in Alabama in 1987 and 1988. Noticeable improvement in the condition of shipped adult weevils resulted from use of the modified handling procedures. However, results obtained did not indicate sufficient control to justify incorporation of the sterile weevil concept in the ongoing Boll Weevil Eradication Program. The survey did provide valuable insight into essential considerations for future insect control programs. Shipping, holding and release methods employed for insects were recognized as being essential considerations. They are prime factors that determine establishment of released insects in the field, thus, the ultimate success of biologically-based control. This action (delivery) is analogous to proper application of insecticide in order to obtain expected field results. The same principle holds true with application of insects as insecticides—if released insects are not established in the field for any reason (poor quality, release technique), then control of target pests cannot be expected.

Present rearing capabilities at the Insect Rearing Research Unit were demonstrated during the 1987 and 1988 Alabama Sterile Boll Weevil Release Test (Powell *et al.*, 1988; Powell and Roberson, 1989). Powell *et al.* (1988) reported improved production capabilities resulted from: (a) adding beta-carotene to the diet; (b) collecting adult weevils in a chilled environment [54 to 59F (12 to 15C)]; (c) using large cages for adult feed-out; (d) using a diflubenzuron (Dimilin®) water dip treatment; and, (e) careful handling of packaged weevils in aerial release processes.

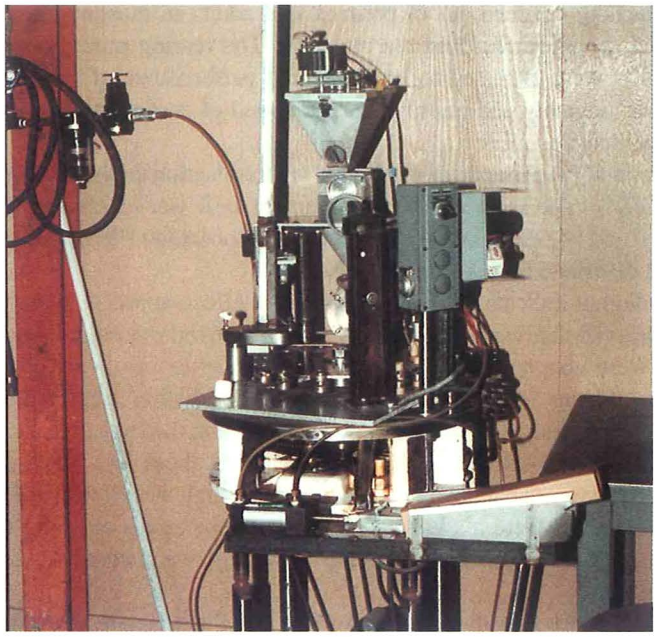

Figure 3. Boll weevil tube loader.

Powell and Roberson (1989) reported that 21.2 million weevils were produced in 1988 with 13.5 million irradiated for release. They also reported production output, operational requirements of materials and labor, and cost per 1,000-weevil rearing unit. More recently, data indicate that irradiation of emerging weevils in rearing trays (Figure 4) can significantly increase longevity of sterile weevils and reduce production costs by approximately 50 percent. The process utilizes the flash sterilizer/tray packaging system for mass production of microbe-free insects. The emerging weevils then are irradiated in the rearing trays and these trays are shipped directly to the field for release. This substantially reduces handling work operations of adult collection and packaging. Also, shipment of treated weevils in rearing trays that contain diet in moist conditions reduces critical stress encountered with previous shipping methods. The mechanized process offers advantages for each phase of the operational system and proposes a basic prototype that can be adapted to other insect species.

More recently, boll weevil mass rearing has been utilized to provide host food (Figure 5) for propagation of *Catolaccus grandis* (Burks) an ectoparasite that attacks third instar boll weevil larvae infesting cotton squares. Such rearing technology is a critical component of research development and field assessment.

Boll weevils are reared at other locations using various techniques. However, through a program organized by and operated through The Cotton Foundation, many public and private groups obtain weevils for testing purposes from the Gast Laboratory.

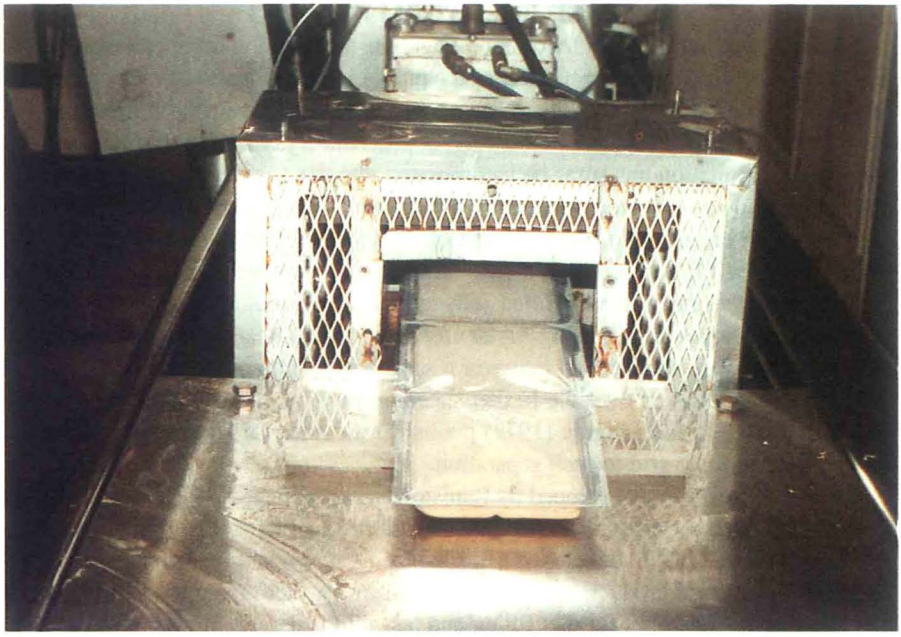

Figure 4. Boll weevil rearing trays.

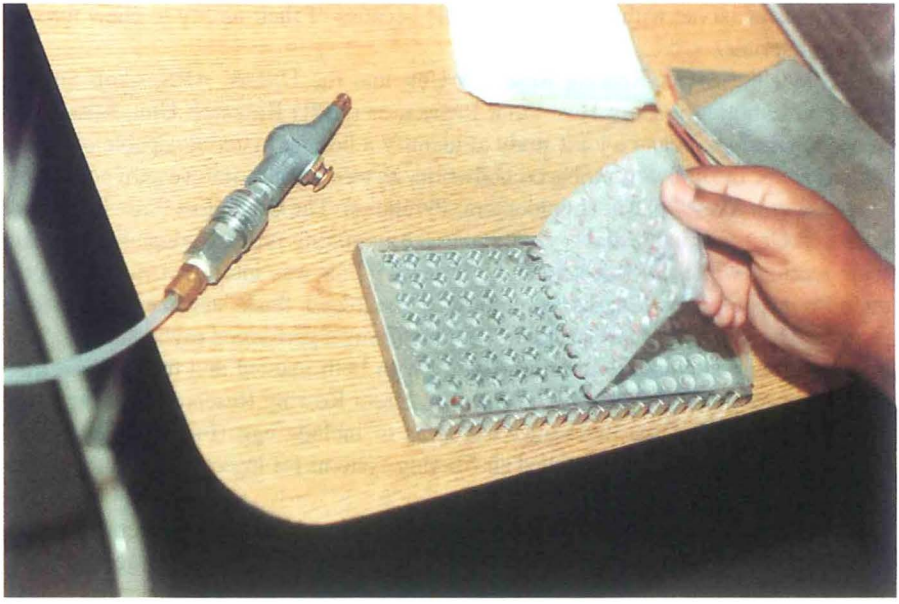

Figure 5. Boll weevil larvae encapsulated in parafilm cavities for *Catolaccus grandis* (Burks) parasite production.

TOBACCO BUDWORM AND BOLLWORM REARING

Tobacco budworm and bollworm propagation historically have presented challenges to insect rearing research. Most of the problems encountered have been focused on cannibalistic behavior and susceptibility to virus. Because of the difficulties that these problems have presented, earlier rearing procedures demanded that intense labor and extreme sanitation measures be incorporated into the operational procedures.

Early procedures involved inoculation of larvae into vials or cups to rear specimens individually (Berger, 1963). Burton and Cox (1966) modified a jelly-filling machine to mechanically fill cups with diet, and introduce eggs/larvae held in a corncob grit medium into the mechanically filled jelly cups. A tray method was developed by Roberson and Noble (1968) using Mylar Hexcel to inoculate eggs into 0.75 inch (1.9 cm) cells that were sandwiched between a sand base containing fungicide. A gelled diet slab was positioned over the hexcel sheeting, thereby encapsulating eggs within each cell. Raulston and Lingren (1972) published methods for large scale production using a light diffuser grid for cell separation.

The light diffuser tray developed by Raulston was modified by Hartley *et al.* (1982) by replacing cloth covers with an autoclavable plastic air filter for ease in preparation. Sparks and Harrell (1976) developed a mechanized tray production format for the bollworm. They adapted production to a flash sterilizer for diet preparation that pumped diet to a tray-forming unit for diet filling and larval inoculation. Studies also included development of pupal harvesting equipment. This mechanized system presented many advantages. However, problems were encountered when attempts were made to retain later stages of larvae within the rearing cells because of their ability to chew through strong materials.

In 1984, the Insect Rearing Research Unit and the USDA, ARS, Crop Science Research Laboratory, Corn Host Plant Resistance (HPR) Research Unit, Mississippi State, Mississippi, began a joint study to identify a lidding material capable of retaining larvae for the bollworm/tobacco budworm, as well as the southwestern corn borer, *Diatraea grandiosella* Dyar (Lepidoptera: Pyralidae). The Corn Host Plant Resistance Research Unit was interested in developing a tray rearing process adaptable to small-scale rearing, while the Insect Rearing Research Unit was interested in refining the methods proposed by Sparks to employ a combined flash sterilizer thermoform process. The joint study was successful in identifying a perforated mylar sheeting with hot-melt glue that could be used effectively with both manual and mechanized tray-assembly processes (Davis *et al.*, 1990). The Insect Rearing Research Unit then continued refinement of the mechanized process to include egg (Figure 6) and pupal (Figure 7) harvesting with improved air filtering systems for insect scales in the oviposition room (Roberson *et al.*, 1989).

Considering the difficulties encountered with disease and labor requirements, mass production of the tobacco budworm/bollworm complex in support of large-scale field release programs has been very successful. The tobacco budworm backcross experiment in St. Croix (U.S. Virgin Islands) demanded production of 10 million pupae during the period 1977-1980 (Proshold *et al.*, 1982). Operations were necessary to

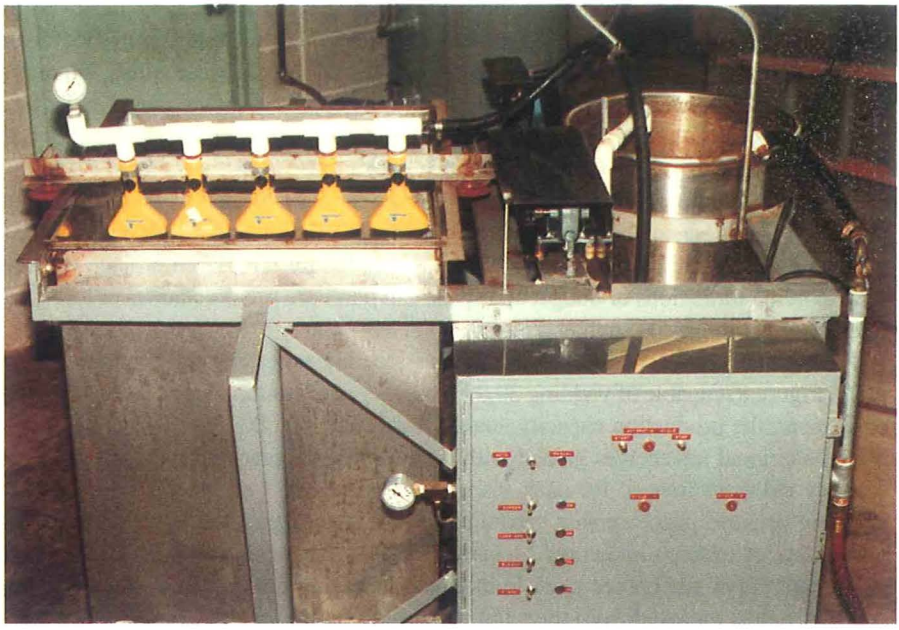

Figure 6. Bollworm egg harvester.

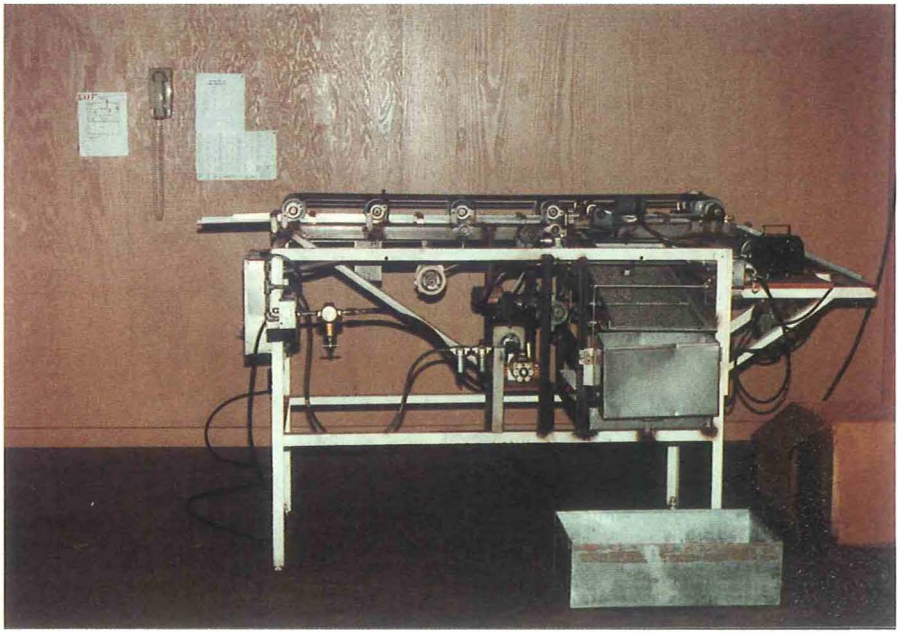

Figure 7. Bollworm pupae harvester.

produce, package and ship delicate pupae from the United States laboratories to St. Croix, then to effect placement in the field for emergence and flight from the release station. Field results indicate that the laboratory-reared insects successfully interacted with the feral (wild) moth population. Laboratory-reared females mated with wild males; males from their progeny were sterile and females transmitted the sterility trait to the next generation (see Chapter XVI, this book).

Review of rearing research programs illustrate the variable methods of production processes that are available for research projects. For the most part, propagation procedures used depend on the number of insects needed for a research project. Projects with extreme limitations of budget and space can purchase premixed diets or test specimens from commercial sources as needed.

Technologies developed in support of mass-rearing programs can produce rearing trays (Figure 8) capable of yielding 30,000 insects per operational hour. With advanced equipment, the production capacity could probably be 50,000 insects per operational hour. Additional advantages gained with the mechanized rearing procedure in which separate cells are formed for each insect reduce the stress of manual handling and shipping because pupae remain separated in self-formed pupation sites. Field emergence data of tobacco budworm backcross moths (Laster and Roberson, 1990) note significant pupal emergence rates from pupae emerging directly from trays (95 percent) vs. pupae removed from trays (56 percent).

As with boll weevil rearing technology, the status of mass-rearing technology for

Figure 8. Bollworm multiple cell rearing tray.

the tobacco budworm and bollworm is well advanced. The technology developed is adaptable to mass production for sterility control concepts, carcass production for pathogen production or host/prey supply for parasite and predator production. The historical problems relating to lack of specimen supply source due to unstable production for these insects should not impede progressive development of new biologically-based pest control concepts. The technologies developed are stable and, when properly administered, can be relied upon to support advanced research.

A manually oriented rearing process using reusable rearing trays is conducted within the USDA, ARS Southern Insect Management Laboratory at Stoneville, Mississippi. King and Hartley (1985) outlined methods for the tobacco budworm in which multicellular rearing trays were used to separate the cannibalistic larvae. This same technique was used for the bollworm and for the tobacco budworm sterile hybrid (Hartley *et al.*, 1982; King *et al.*, 1985). Yet another method for these pests uses dry diet flakes to separate larvae on trays of diet (Patana, 1985).

A few of the many earlier papers on bollworm/tobacco budworm rearing include: Barber (1936); Callahan (1962); Vanderzant *et al.* (1962); Berger (1963); Roberson and Noble (1968); Raulston and Lingren (1969); and, Young *et al.* (1976). Chauthani and Adkisson (1965) compared two artificial diets to determine effects on the biology of the bollworm or its response to insecticides. *Helicoverpa punctiger* (Wallengren), a serious pest of cotton in Australia, has been reared by Teakle and Jensen (1985).

As with the boll weevil, USDA-reared bollworms/tobacco budworms are made available for research purposes to public and private groups through a cooperative program with the Cotton Foundation.

PINK BOLLWORM REARING

The pink bollworm rearing and sterilization operations conducted by USDA's Animal and Plant Health Inspection Service in Phoenix, Arizona, stand as a model of advanced technology for stable insect rearing and sterilization. The program is scheduled to operate seven days per week and produce five million adults per day for a 150-day release period. To date, the program has been judged an effective tool for management of the pink bollworm, especially in keeping the pink bollworm from becoming a major cotton pest in the San Joaquin Valley in California. The USDA is currently conducting an extensive methods-development program to increase mechanization of the rearing operations. The rearing/sterilization operations and pink bollworm management programs are supported substantially by cotton producers in California.

Laboratory culturing studies were conducted at the USDA Pink Bollworm Research Laboratory, Brownsville, Texas. Larvae were inoculated in small vials with artificial medium and stoppered with cotton (Noble, 1969). The rearing procedures were modified by cubing the diet and layering hatched larvae/diet cubes/cotton in 9-ounce (265 ml) Dixie® cups to facilitate increased production needs (Noble, 1969). The inoculated cups were sealed with a plastic lid and layered in a standard 3-gallon egg collection container. As larvae developed to the last instar, they would chew through the paper

sidewall of the cups and pupate in shredded paper placed in the egg container bottom. Adults were collected by turning the lights off to cause flight of the emerged moths to a cone screen trap positioned on the lid of the container.

In 1966, the USDA, Methods Development section of APHIS, Plant Protection and Quarantine assumed rearing responsibilities to supply the sterile moths needed for release in the California San Joaquin Valley cooperative pink bollworm management program. In 1968, construction was initiated at the Phoenix, Arizona, production facility, with eventual expansion to rented warehouse space to facilitate increasing field demands for sterile pink bollworm moths. Serious difficulties in controlling microbial contaminants and viruses were encountered during the first years of expansion pressure. Technology was developed and implemented to improve egg treatment for cytoplasmic polyhedrosis virus (Stewart, 1984) and to develop mass-handling processes (i.e., larval cutout in hexcel, pupal collection and adult emergence). This enabled establishment and maintenance of large-scale, stable production.

Mass-rearing of the pink bollworm at the USDA facility in Phoenix, Arizona functions to supply competitive sterile moths in an effort to control this pest in California (Stewart, 1984). A discussion is provided on quality control and identified sources of contamination. In addition, a description of method and diet are given, along with information of quality control and life cycle data (Bartlett and Wolf, 1985).

PLANT BUG REARING

A proven method of rearing the western lygus bug, *Lygus hesperus* Knight, on artificial diet has been developed and used for many years (DeBolt and Patana, 1985). The method utilizes parafilm packets (Patana, 1982) of artificial diet (Debolt, 1982) for feeding and oviposition, and allows continuous rearing.

Oviposition in tissue paper has enhanced rearing methodology for the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois) (Snodgrass and McWilliams, 1992). They found that plant bugs preferred to oviposit in moist tissue paper wrapped around a green bean rather than in a green bean. Traditionally, green beans have been used both as a food source and as an oviposition site in rearing. Disadvantages of oviposition in green beans include desiccation of beans, not knowing how many eggs have been laid, not being able to monitor development, and growth of mold or bacteria that can reduce egg hatch and survival of young nymphs. The new technique for extracting eggs and storing at a cold temperature for 15 days offers greater flexibility to rearing and research programs.

The tarnished plant bug has also been reared successfully on sprouting potatoes (Slaymaker and Tugwell, 1982) and lettuce (Stevenson and Roberts, 1973), but survival on artificial diet was poor (Vanderzant, 1967).

ARMYWORM REARING

Rearing methods for the beet armyworm, *Spodoptera exigua* (Hübner), have been described by Hartley (1990) and by Patana (1985). Hartley's (1990) method is similar to that used for tobacco budworm and bollworm rearing referred to earlier in this chap-

ter (Hartley *et al.*, 1982; King and Hartley, 1985; and King *et al.*, 1985). Rearing methods also have been reported for the Egyptian cotton leafworm, *Spodoptera littoralis* (Boisduval) (Navon, 1985), and for the Southern armyworm, *Spodoptera eridania* (Cramer) (Wright, 1985).

APHID REARING

Forbes *et al.* (1985) described rearing techniques for the green peach aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae). Their methods can be applied to many species by changing the host plant and the timing. The cotton aphid, *Aphis gossypii* Glover, can become a serious pest of cotton, thereby necessitating a rearing program for testing.

QUALITY CONTROL STRATEGIES

Production quality control is used to monitor egg treatment, microbial contaminants, developmental rates, egg to adult yields, etc. The data collected provide critical insights to facilitate management to meet both quantity and quality of insects needed for use. Proper execution of established operational and sanitation procedures is the first step in maintaining production of high quality insects.

The importance of product quality control in insect mass production is recognized, as is evidenced by the attention given it in the literature. Chambers (1977), Chambers and Ashley (1984), Moore *et al.* (1985) and Leppla and Ashley (1989) represent only a small portion of the literature. In any progressive rearing program, changes are made continually in an effort to stabilize or improve production efficiency and insect quality. Unfortunately, many underfunded research programs can provide only minimal quality control support to rearing operations. As a result, marginal attention is given to sanitation, inbreeding or quality control standards for insect performance. Tabashnik and Slansky (1987) may give researchers insight into aspects of nutritional ecology that may enhance rearing of cotton insects. Maintenance of genetic diversity also contributes to improved insect quality; guidelines are discussed by Bartlett (1985).

RESPONSIBILITY FOR FIELD EVALUATION

Successful delivery and establishment in the field are essential for insect management effectiveness. Transportation and field dispersal of mass reared insects demand great attention to insure rapid release of healthy insects. Because of the intense operational demands of large insect release control tests and labor shortages for working closely with release operations, field dispersal of live organisms can be untimely and insect vitality decreased. Delays and mishandling during sterility treatments, packaging, transport, storage and field release may render an effective insect ineffective in the field.

To acquire the full benefit of a released insect, a strong effort must be directed to recognize and establish acceptable field release procedures. To release healthy insects, establishment and monitoring of handling procedures from the rearing facility to the

field is imperative. Handling operations involving extreme temperatures, extensive holding periods or harmful field release conditions can lower the vigor of shipped insects. These conditions can affect their ability to become established in the field and result in low survival of the insects during release operations.

Close communication between laboratory production and field release personnel is essential to synchronize insect development with desired time of release. Considering the financial investment of insect production and field release operations, a ground crew should be maintained to monitor field release conditions and to coordinate field dispersal personnel to improve the chance of successful establishment of field-released insects.

TECHNOLOGY TRANSFER

Most large scale rearing operations are developed by mechanizing small scale rearing procedures. Without mechanization, the quantity of insects required by massive field release programs could not be met. Major modifications from research to production therefore must be incorporated into the rearing methodology to meet production demands. This transition must be smooth, organized and timely, and current research systems organized for greatest efficiency. USDA research groups in the Agricultural Research Service and the Animal and Plant Health Inspection Service should be organized with compatible equipment and increased interaction of line personnel. This will maximize production and improve technology transfer. The Animal and Plant Health Inspection Service will benefit by gaining trained personnel and equipment to advance directly into mass production status. The Agricultural Research Service must continue to work closely with the Animal and Plant Health Inspection Service in directing full attention to deficient technology. Although few USDA insect rearing programs have interested commercial investors, their participation as suppliers or contractors for insects can fill pest control voids created by restrictions in pesticide use.

The need exists for a process to guide programs from research to development, with subsequent field testing and commercial employment. This will facilitate continuing progress and addressing new problems by rearing research groups. Although the organization to manage newly developed technologies is difficult, such a system is feasible. The requirements are that: (a) insect rearing technology be designed for cost effectiveness and adaptability to commercial application; (b) a legal protocol be established to advertise and to promote transfer of technology; and (c) actions be initiated to establish acceptable quality control and field evaluation standards. Further, government and industry must cooperate to establish an equitable system for identifying research needs, level of technology needed and a protocol for technology transfer.

SUMMARY

Many insects associated with cotton can be mass-reared using automated equipment. As this technology is developed, transfer to an action agency or to private industry is necessary for expanded use in applied operational programs. Research in insect rearing must be supported for production of high quality insects that are competitive and effective in the field. Insects must be reared for parasite development, production of pathogens, sterile release technology, hybrid sterility programs and other specialized uses.