are far more expensive to maintain and are easily damaged by water. Another source of dust is the water-atomizing humidifier, which provides a fine, rapidly evaporating spray which effectively increases the humidity, but distributes minerals from the water on near-by objects which, in time, constitute a definite dust problem.

Facilities for adequate storage of equipment and supplies are considered when the floor plan is designed. Interior finish of rooms is related to the size of the insects to be handled. Ledges around windows, fixtures, or ducts, can be eliminated by flush design. A smooth plaster finish painted with a glossy moisture-resistant paint coloured off-white (blue or green tint) greatly facilitates the collection of insects and enhances illumination within the room. Paints containing fungicides may be desirable, but paints having insecticidal properties should not be used. All paints used in culture rooms should be thoroughly tested for toxicity to beneficial insects. A convenient screening procedure involves placing in pint-size glass fruit jars a piece of wood or pressed board which has been painted with a sample of the paint to be used and allowed to air-cure for 30 days. Honey streaks are provided on the glass and parasites are added. Control insects from the same culture are placed in an empty glass jar with honey provided. Mortality counts at 24-hour intervals will reveal the needed information. In order to reduce variables, it is necessary to subject both test and control jars to equal conditions of light, temperature, and humidity during the test period.

Window lighting alone is of insufficient intensity for suitable plant growth. Artificial lighting usually will be required for this purpose. An even light gradient, i.e., north light in the northern hemisphere, may be helpful in certain handling procedures such as phototropic collection of hosts or emerging adult beneficial species which exhibit positive phototaxis. On sunny sides of the building's exterior, louvres may be used to achieve a similar result. In order to reduce thermal conductivity and to assure insect-tightness, windows should consist of a rigidly fixed inner pane which is of large dimension and free of cross bars (an aid in collection of insects by aspiration) and flush with interior wall surface, and a removable (for cleaning) but weather-tight outer pane. Approximately 2 inches of air space should separate the panes. If a quarantine area is a part of the insectary, an added degree of safety may be achieved when the outer panes consist of wire-reinforced glass. Improvements in artificial lighting, coupled with the known lack of control over, and inadequacy of, window light to produce healthy plants, have stimulated interest in windowless insectaries. Such a commercial insectary is advocated by DeBach and White (1960). Advantages of below-ground or windowless construction include increased insulation and controllable lighting. Of course, a dependable source of electrical power is a necessity if this type of structure is to be used.

Utilities

The number of ceiling light fixtures will depend on the proposed use. In general, natural lighting should be a secondary consideration mainly because of its unpredictability. Adequate light for growing plants can be achieved by portable racks

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containing 'cool white' fluorescent tubes, or by providing ceiling hooks from which lights can be suspended directly over growing plants. Figure 67 illustrates such fixtures in use at Albany and Riverside.

It is very important to provide sufficient numbers of electrical outlets. Usually such receptacles will be located just above table or work-bench heights and in the ceiling. A general rule is one double outlet per 8 linear feet of wall.

Where a relatively large installation is contemplated, it is desirable to have a separate power substation provided by the utilities organization which serves the area. By so doing, adequate electricity for the insectary is assured, and the increased line load will not affect other buildings in the immediate vicinity. Where electricity is a primary source of power, power failure can devastate the insectary effort, not only by disrupting air conditioning, but also by freeing several hundred thousand lepidopterous larvae which were confined by hot-wire barriers (see figure 55, chapter 11). Portable gasoline-powered generators can be utilized to maintain minimum operational requirements when such emergencies arise. This also emphasizes the importance of location, design, and insulation, for, if done properly, a building can withstand interruptions in utilities of several hours without suffering damage from fluctuations of temperature.

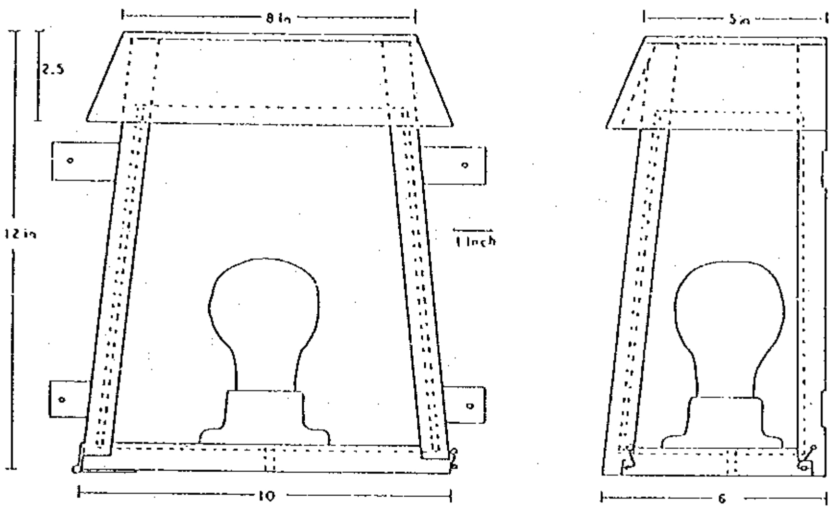
Related to the lighting problem is the placing of light traps in hallways, washrooms, and anterooms to attract and capture escaped natural enemies or hosts and thus reduce the contamination hazard in other rearing rooms. No matter how careful the insectary staff may be, there will be insects at large in the insectary either from cultures or coming in from out-of-doors. Since the hazard of contamination is ever present, it is imperative to reduce this free-living population to the lowest possible level. Chief requisites of construction for light traps are a light source and a baffle system that directs insects into the trap and prevents their leaving it. Light traps ordinarily are placed against or in walls (figure 68), and should be so located that they do not present a collision hazard to personnel or equipment passing near them. Since light traps operate constantly, they should be located away from doors or open windows to which insects out-of-doors may be attracted after dark and thereby gain entry to the insectary.

Domestic (potable) water at 40 to 60 pounds per square inch pressure should be available at all sinks and in all rooms. If possible, hot water should be available to personnel at all sinks.

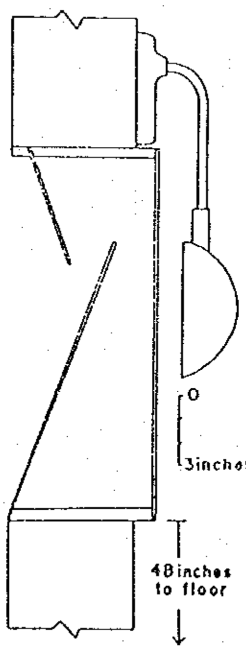
Distilled water is a necessity for preparing nutrient media for plants. Further, as a last rinse in washing glassware it greatly reduces hard-water film. During warm weather, distilled water can be collected from the cooling coils of refrigerative-type air conditioners. Such water is satisfactory for rinsing glassware but due mainly to a relatively high copper content it may not be used in nutrient media or in hydroponic solutions.

Natural or bottled gas may serve as fuel for the heating system and for conventional burners at laboratory tables. For reasons of safety, gas appliances should be vented to the outside of the building.

Air pressure at approximately 60 pounds per square inch in all propagation



A. This trap is designed for installation on walls or partitions with its top tight against the ceiling. The sloping sides and front are of window glass. The back, top, and bottom may be of wood or sheet metal. The 2½-inch baffle at the top is opaque and may be constructed of wood, pressed fibreboard, or sheet metal. Located at the ceiling-wall angle of corridors, it does not interfere with passing traffic.



B. This trap is located in the partition between the quarantine room and the anteroom at the Albany laboratory. The lamp is in the quarantine room. The sloping lower pane of glass is removable.

FIGURE 68.

rooms and at sinks will prove useful for drying washed fruit, for blowing debris out of corners of cages, for operation of certain types of temperature and humidity controls, and in water spray humidifiers.

Air vacuum at 10-inch minimum mercury for collectng insects may be more necessary than air pressure facilities, if there must be a choice between the two, because collection is one of the most time-consuming and necessary functions of insectary operation. An alternative method is to make use of available portable electric machines, which provide both positive and negative air pressures.

Floor drains appropriately located in propagation rooms and perhaps main hallways will facilitate sanitation. Such drains should have dirt-tight covers; otherwise, their traps will become clogged and become an additional item of maintenance. Toilets and lavatory facilities should be located away from the propagation rooms.

AIR CONDITIONING AND ENVIRONMENTAL CONTROL

It was emphasized earlier that air conditioning—temperature, humidity, and ventilation—is the most important single problem to be resolved. Only in certain insular locations is there little or no need for supplemental temperature control. Excessive build-up of humidities may be a problem here, but large airy cages usually permit adequate ventilation. Most of what is said here pertains to locations with climate considerably less amenable to insectary operation. Basically, there are two concepts of design involved, namely, a central system which consists of positive and negative pressure ducts radiating to and from all rooms from one or more heating and cooling units, and individual air conditioning for each room. The chief disadvantages of the conventional central system are: (1) lack of adequate control in individual rooms; (2) all the rooms are affected during periods of routine maintenance or breakdown; and (3) high initial cost. The main disadvantage of air conditioning rooms individually is the possibility of higher cost of maintenance per room, which may be compounded in time by unavailability of parts.

Since temperature fluctuations of 2° F and relative humidity fluctuations of 4 per cent are adequate for normal insectary work, moderately priced controls will satisfactorily operate either system. Also to be considered is the possible need of providing for fluctuating temperatures. In this regard, Stein (1960) indicated that *Trichogramma cacoeciae* Marchal propagated at fluctuating temperatures of 16° and 26° C was approximately ten times as effective against codling moth eggs when compared with parasites propagated at a constant temperature of 27° C.

Ventilation, or recirculation of air within insectary rooms, is a vital part of the air-conditioning problem. Munger (1955) demonstrated the need for fresh (filtered) air in the culture of citrus red mite, and the principle appears to have a bearing on the degree of success of culturing certain insects as well. The problem is considered of sufficient importance that a system with several complete air changes per hour with partial or complete recirculation passing air through spun glass and carbon filters to remove particulate and chemical pollutants, respectively, has been incorporated into the planning of the new addition to the Department of Biological Control insectary at Riverside. Such an arrangement calls for highly specialized temperature-control equipment, which would be too costly for other than large insectaries at research institutes.

'Heat pumps' which automatically control both heating and cooling are increasingly available on the American market. The 1960 cost (installed) is approximately $600 per ton cooling capacity for household units. In a temperate climate, a 3-ton unit of this type could be used to air-condition an insectary of 1,000 to 1,600 square feet, providing insulation and ceiling height were proper. Since this is a forced-air system, a certain amount of duct work is required. A return duct to the machine insures a degree of recirculation. Air filters and humidifiers can be supplied for 'heat pumps.' Only time will tell the story on maintenance costs and efficiency, but it appears that 'heat pumps' have much to offer in the area of packaged climate control.

A related matter is that of circulation within the individual rooms in addition to that provided by the main heating or cooling source. This becomes especially important if many large cages and tables occupy a room and as a consequence dead air spaces, or stratification, develop. Fans located in such a manner as to keep air moving at various levels will smooth out temperature and humidity gradients.

In general, methods used for achieving climate control will depend on the type and permanency of the insectary.

Temporary Facilities

Temporary facilities should conform to the general planning of a permanent installation and in practice should give several years' dependable service. For example, many existing laboratories have ceilings 8 feet or more in height. The construction of a false ceiling at the suggested 7-foot height will make air conditioning easier and more satisfactory. The false ceiling may be made of light-gauge gypsum board, $\frac{1}{4}$-inch plywood, or $\frac{1}{8}$-inch masonite nailed to the lower edges of properly spaced joists and furring strips. The seams can be covered with tape and the entire surface then painted. Additional mechanical features, such as wiring, plumbing and duct work can occupy the space above the false ceiling.

Heating may be achieved by household-type electric or gas heaters. If the latter are used, it is important to have them vented to the out-of-doors. At Riverside, one thermostatically controlled 1,200-watt electric heater with a built-in fan adequately heats a well-insulated 14 ft. × 30 ft. room with a 7-foot ceiling. Smaller rooms (12 ft. × 12 ft. × 7 ft.) can be heated with similar but smaller heater fans or by bare wire heat cones with a fan behind them. A simple wiring diagram for inclusion of thermostats with such heaters is shown in figure 69.

When considering cooling for small areas, the prevailing relative humidity out-of-doors must be known. Evaporative coolers are useful in arid climates, but are much less effective where the humidity is in excess of 50 per cent during hot weather. Air conditioners of the refrigerator type, although more costly, are effective regardless of existing outdoor humidities.

Relative humidity may be regulated by either reduction or increase to a desired level. The former may be accomplished by either a refrigerative cooler which locks free moisture as ice on its cooling coils, or an exhaust fan in the attic which can reduce relative humidity to the level of outside conditions by pulling air through the building.

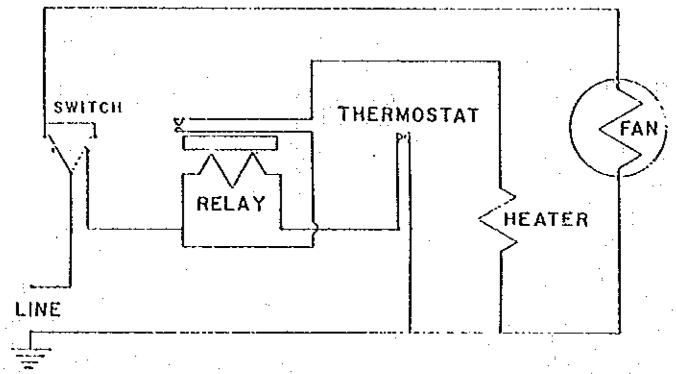


FIGURE 69. Wiring diagram for simple laboratory heaters. If assembled as indicated, the fan will operate continuously and the heating element will be energized only when the contact points of the thermostat close.

In arid climates it is relatively simple to increase humidity by using evaporative coolers housed completely within the building. Figure 70 shows a wiring diagram of such apparatus. Minor mechanical changes of the evaporative cooler allow the fan to operate constantly, and the recirculating water pump operates only when an increase in humidity is called for by a humidistat. Additionally, desirable features of both systems are increased air circulation and filtration of the air. A 2,000 CFM evaporative unit is considered adequate to humidify approximately 4,000 cubic feet, providing insulation and vapour sealing are adequate. As previously mentioned, circulation of air within rooms is necessary if stratification is to be prevented.

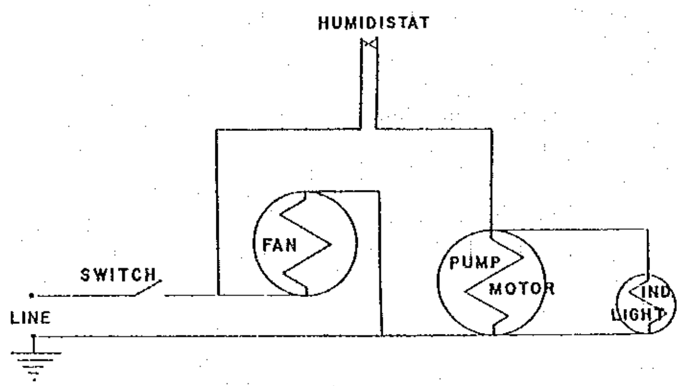


FIGURE 70. Diagram of evaporative cooler used indoors to increase relative humidity. If wired in this manner, the fan runs continuously. Water recirculation pump is activated by humidistat.

Recirculation may include or exclude outside air. If outside air is to be forced into the insectary, it is necessary to provide adequate filtration in order to prevent the entry of unwanted organisms or particulate matter. In arid areas, especially during periods of high temperature and low relative humidity, it may be necessary to exclude outside air and recirculate the air within the building in order to maintain the desired relative humidity unless air enters through an evaporative cooler. If evaporative coolers are used, it is necessary to provide filtered openings, such as partially opened windows or doors, in order to assure a flow of cooled air through the building. Otherwise, excessive humidities as well as heating will result.

Permanent Facilities

Larger permanent insectary installations may be provided either with central systems of climate control or with individual room air conditioners. If the insectary consists of more than one wing, or group of rooms, a 'heat pump' for each wing may be desirable. In the original insectary at Riverside a system of dampers in the supply and return ducts permits the recirculation of air solely within one wing or through the central humidifying and heating units.

At Riverside the recently completed insectary addition is equipped with a central steam-heating system and a central chilled-brine cooling system with individual rooms controllable $\pm 2°$ between 60° and 90° F and ± 4 per cent between 40 and 80 per cent R.H. Heated or cooled air and steam for humidity enter rooms through a common duct as thermostats or humidistats dictate. The central cooling system actually consists of two operating units each of which has two compressors. The designed capacity of the compressor is such that three of them will provide adequate cooling. The fourth compressor is a reserve or safety feature which guarantees continuous operation of the air-conditioning equipment if one unit becomes inoperative. Because of excessive summer heat, additional features include insulation of ducts and ceiling as well as a provision for cooled air to be continually blown through the attic space from a large evaporative cooler. The roof is covered with light-coloured crushed rock embedded in tar over four layers of asphalt-impregnated paper. In the older portion of the insectary the central evaporative cooling system failed to give adequate temperature control. Therefore, it was necessary to install household refrigerated room air conditioners in several of the existing rooms, and they have been quite satisfactory during the past five years.

Maintenance and Safety

The foregoing discussion of various types of rather specialized devices leads naturally to the problem of maintenance. Preventive maintenance needs to be planned and practised throughout the year, and it is highly desirable to have a person of varied mechanical interests on the insectary staff. Replacement of items of equipment and anticipated maintenance costs must be considered in projected budgets.

Because of the mechanical features pertinent to insectary operation, safety to personnel becomes an important consideration. To this end, all moving machinery should be well shielded. Indeed, the initial design should include all possible safety features, such as fire prevention, low electric-shock hazard, well-lighted stairwells and entrances, and non-opposing doors. Miscellaneous safety facilities include a well-stocked first-aid kit (all personnel should be well trained in emergency first-aid techniques), adequate fire extinguishers at appropriate locations, fire blankets, and mild alkaline solutions for neutralizing the effects of acid burns.

FURNISHINGS AND EQUIPMENT

Insectary furnishings include standard items such as work tables, storage cabinets, chairs, and basic office equipment. Specialized equipment items pertaining to specific quarantine or mass-culture problems are mentioned in chapters 10 and 11.

Mobility is a desirable feature for bulky items such as laboratory tables, large racks, and plant-growth lighting devices. Retractable wheels present added versatility for such equipment. For most efficient use of space, cages, racks, or tables should be designed in equal multiples of dimension. Figure 72 illustrates such portable equipment.

Peterson (1947) describes a great many insect-rearing aids. The present writing will touch mainly on technical aids of a general nature as utilized in biological control for the propagation of entomophagous insects.

Cages for housing insect cultures are perhaps the items most used in the insectary and range in complexity from those which can be made easily by laboratory personnel from such articles as glass jars, lamp chimneys, cellulose acetate, and a great miscellany of small cages for limited propagation, to those requiring the services of an experienced carpenter or cabinet maker. Examples of both general types are shown in figure 71.

Principles of Cage Design

In order to have assurance that an insect cage is escape-proof, particular care must be given to such matters as mortised and glued joints, glazing, properly attached cloth areas, and well-sealed doors. Door gaskets may consists of felt cloth or of light sponge rubber. Cloth and gasketing should be glued and stapled, or tacked to the cages. Ease of cleaning is important and is possible if the bottom of the door is flush with the floor of the cage.

An isolation or sleeved cage was developed for handling parasitic insects by workers in the U.S. Department of Agriculture in 1907 (Howard and Fiske 1911, plate IX, figure 2). S. E. Flanders, in 1934, redesigned this type of cage, and since then several modifications of it have been made, but this is the type most often used in insectary rearing programmes at the University of California. Figure 71 B shows some of these cages.

Worthy of further emphasis is the fact that when insects are propagated indoors, proper ventilation and filtration of air can be prime factors of success. This is true in open culture where an entire room serves as a cage (previously discussed under recirculation), as well as with conventional rearing cages, each with its own particular micro-environment. The size mesh of cloth or screening to be used is determined by the size of the smallest insect to be contained in or excluded from the cage. If the inclusion of growing plants causes excessive humidities or unfavourable odour concentrations, exhaust apparatus similar to that shown in figure 73 should provide the needed ventilation. In addition, it may be necessary to pass the air through activated carbon filters in order to get rid of chemical pollutants.

As was previously stressed with regard to paint for interior walls, paint for cages also should be thoroughly tested in the cured state for toxicity to insects. The same precaution should be exercised if insects contact raw wood, as may be the case with wooden nursery flats. As a general rule, no cages are used if any paint odour can be detected. Sizing or dyes in cloth, as well as various plastic materials, are suspect unless proved safe. Inasmuch as all insects do not react similarly to various toxicants, representative species should be tested. Experience at Riverside has shown that micro-Hymenoptera, such as species of *Aphytis* and *Coccophagus*, serve as good insects of such effects.

Because many adult and immature beneficial insects are quite small, certain optical aids, together with adequate illuminators, are necessary for efficient insectary procedure. Magnifications of 9× to 54×, as provided by conventional stereoscopic dissecting microscopes, are sufficient for most routine needs. Adequate extension supports provided with a rack and pinion focusing mechanism, and ball and socket swivel mounted for vertical and horizontal swinging give added usefulness to the instrument. Other optical aids that are useful are hand lens of 14× or 20×, head lens of 3× or 4×, a reading glass, and illuminated magnifiers. The research laboratory will, of course, have need of instruments of greater power. Basic optical aids are shown in figure 74.

COLLECTION, PACKAGING, SHIPPING, AND STORAGE EQUIPMENT

Certain specialized techniques and items of equipment have been developed regarding procedures for collection, packaging, and storage of beneficial insects pending shipment.

Collection in the insectary may be accomplished by three general methods used singly or in combination, namely: (1) utilization of insects' inherent behavioural taxes; (2) anaesthetization; and (3) aspiration.

Perhaps the most commonly used behavioural taxis utilized for insect collection is phototaxis. The first-instar, or crawler, stage of many scale insects as well as adult entomophagous insects exhibit strong positive phototaxis. The light source may be an even light gradient from a window or an artificial light. Figure 75 shows equipment and methods designed to collect insects by light attraction.

Because most adult beneficial insects are attracted to light, care must be taken in open culture to shield hot light bulbs with cloth or panes of glass to prevent parasites from contacting them.

Strong anemotaxis may be taken advantage of for concentrating large numbers of insects. Use of this response was utilized in the collection of *Aphytis* (Flanders 1951). In a different and novel application, artificial air currents were useful in obtaining large numbers of eggs of the moth, *Sitotroga* (Flanders 1934). Moving air pressed the females' abdomens against a wire screen and the resulting pressure stimulated egg deposition. Although currently not used, a collection technique which utilizes the chemo- and phototaxic responses of adult *Cryptolaemus montrouzieri* Muls. was developed by W. C. Beckley, manager of Associates Insectary at Santa Paula, California. The chemo-stimulant consisted of smoke from smouldering rags in a bee smoker which stimulated the beetles to fly to the nearest light source, in this case a cloth-covered window. A large, flat funnel is utilized to scoop them into plastic tubes (see figure 59 B, chapter 11).

Anaesthetization by combining CO_2 and ether was developed by Finney, Flanders, and Smith (1947) in connection with the mass production of *Macrocentrus ancylivorus* Roh. and its host, *Gnorimoschema operculella* (Zell.), the potato tuber moth. CO_2 used alone will anaesthetize insects for only short periods and is consequently of limited value in mass-production work. However, it is adequate and safe for handling small numbers of insects rapidly, for instance in making quick sex-ratio counts or for removing contaminant organisms. Ether used alone may weaken or kill insects and when used repeatedly or in quantity in a poorly ventilated room constitutes a definite explosion and fire hazard. Mixing the two gases by means shown in figure 76 greatly extends the anaesthetization period as compared with CO_2 used alone and minimizes the danger of explosion.

Collection by aspiration may be by simple mouth aspiration or by utilizing mechanical suction such as that provided by household vacuum sweepers, portable devices designed for laboratory use, or piped-in vacuum. Collection by use of a modified hair dryer is illustrated in figure 77. Mouth-operated aspirators should be equipped with filters in order to protect the operator from inhaling fine debris. Several types of aspirator collectors are shown in figure 78.

In mass-culture work, large numbers of a beneficial species can be collected by anaesthetization in a closed unit (figure 58, chapter 11), measured (counted), and placed in storage containers during one continuous operation. Volumetric counting of parasites or predators is convenient and accurate but can be used only when size and sex ratio are uniform. Some counting devices are shown in figure 59, chapter 11. In a technique developed by Bedford (1956) for the collecting, counting, and packaging of *Chelonus texanus* Cress. (see figure 59, chapter 11), the parasites were attracted by a double light source directly into the shipping container, and were easily counted as they passed through slots in cork on the way.

After insects are counted they are placed in containers for transportation to colonization sites. Choice of container depends on the mode of transport. Insulation against lethal temperatures extremes and an available food supply for the insects while in transit are prime considerations. Convenient storage containers are small, heavy paper cartons of one-half-pint or one-pint size. Glass or plastic tubes and vials can be used for small numbers of beneficial species. Containers must be supplied with streaks of honey or honey-agar as food for the insects as well as bits of shredded wood or paper for resting sites. Paper or shredded wood which have been impregnated with honey may be used satisfactorily to provide both food and resting surface (B. R. Bartlett, unpublished notes). Such containers may be packed in sturdy boxes or cartons for shipment (figure 79).

Most adult entomophagous insects may be satisfactorily stored at 50° to 60° F and at approximately 75 per cent relative humidity. At this temperature they are relatively inactive and consume little food. Conventional household refrigerators equipped with modified thermostats are usually adequate for this purpose. If it is necessary to accumulate collections for several days or, in some cases, weeks before shipping the insects or taking them to the field for colonization, they will remain in good condition if the containers are removed two or three times weekly from 60° F and warmed to approximately 80° F for 20 or 30 minutes. During this time the insects become active, feed, and defecate. With this procedure it is always important to provide a supply of food and moisture. Otherwise, loss of vigour and increased mortality may follow. Honey seems to provide both requirements.

Packing and shipping of entomophagous insects from an established insectary for the purpose of intrastate colonization will constitute the major portion of the following discussion. Techniques of shipping natural enemies to the home insectary as utilized by collectors in foreign areas are discussed in chapter 9.

Typically, shipments from insectaries will be for direct release at the destination. Because of the hazards inherent in such procedure, the matter of proper quarantine handling enters the picture. Although immature parasites may survive adverse conditions better than adults, detection of potentially harmful species is most accurately performed by screening the latter. Shipments of parasitized hosts can be safe under closely controlled conditions as in mailing cards to which are attached eggs of *Sitotroga* parasitized by *Trichogramma*. It is presumed that collections of beneficial species will be thoroughly checked by the shipper and only pure cultures of the beneficial form included. As an added precaution, such material, prior to field release, should be re-examined at the destination for the presence and removal of unwanted species.

The problems of shipping are concerned with local transportation which may involve insectary, institutional, or local growers' vehicles, and utilization of public or governmental transportation facilities. Prevailing weather has a profound influence on the chosen mode of shipment, particularly when extremes of temperature prevail.

Since containers in which parasites or predators are collected and stored in the insectary will usually be too fragile to serve as shipping containers, local shipment of beneficial species requiring not over 8 hours in transit may be satisfactorily accomplished by placing the containers of insects in a small, insulated, prechilled chest. The addition of a frozen gel packet will prolong the effectiveness. In order to avoid subjecting the insects to lethal or weakeningly low temperatures, some sort of insulation between the insect containers and the frozen gels or ice should be provided. This technique was developed by Brennan and Mail (1954), who made mites can have an equally devitalizing effect on their insect hosts. Fine dust from poor-quality concrete floors or from free-spraying humidifiers can settle on host material and greatly reduce activity of parasites. This subject is elaborated upon under 'contaminants' in chapter II and is re-emphasized here because of its profound importance.

Facilities and equipment which will improve sanitation for the building are vacuum cleaners, brushes, brooms, sweeping compounds, mops, buckets, antiseptics, such as aqueous solutions of formalin or chlorine, and also adequate storage space for these items. The best sterilization method for glassware is autoclaving. Next best are deep sinks or trays wherein glassware and plastic cages can be immersed in antiseptic solutions.

Waste disposal presents a special problem. A safe procedure to prevent living insects leaving the environs of the insectary is burning or fumigating host-plant material used in the culture programme. Arrangements for regular removal of trash should be made with local agencies.

SUBSIDIARY FACILITIES

Greenhouse

Greenhouse facilities may be necessary for culturing host plants. In general, however, a plant propagation greenhouse does not provide an ideal environment for the mass culture of entomophagous insects because of factors which are largely beyond the control of the insectary operator, namely: (1) light and humidity conditions cannot be economically standardized; (2) contaminant species of phytophagous insects will invade the plants; and (3) predators or secondary parasites cannot be excluded. Specially designed greenhouses for the quarantine handling of imported weed-feeding insects would overcome the disadvantages just mentioned, but the cost probably would prevent their being used for commercial production of entomophagous insects.

Storage

STORAGE OF EQUIPMENT. Storage of equipment has been mentioned previously and is here re-emphasized for it is a most necessary facility both within the insectary in the form of reasonably dust-proof cabinets or drawers for storage of cloth and glassware, and outside as weather-proof sheds or buildings for unused cages, certain host material, and tools.

STORAGE OF HOST MATERIAL. Storage of host material may require considerable space and is usually provided independently of the insectary building. A commercial insectary may require several hundred square feet for such purposes. Because of the necessity for maintaining several insect species simultaneously, a research insectary also may require relatively spacious facilities for storage of a variety of host-plant materials such as banana squash, melons, potatoes, citrus fruits, and grains, and, in addition, lath house or greenhouse space for leafy plants.

Seasonally available host materials such as melons and other cucurbits require mites can have an equally devitalizing effect on their insect hosts. Fine dust from poor-quality concrete floors or from free-spraying humidifiers can settle on host material and greatly reduce activity of parasites. This subject is elaborated upon under 'contaminants' in chapter 11 and is re-emphasized here because of its profound importance.

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Seasonally available host materials such as melons and other cucurbits require dry storage. Ordinarily, an open shed with a water-tight roof provides adequate protection. Material of this sort is safest when placed in layers one or two deep on sturdy, airy racks. Thorough screening will minimize rodent damage.

Grains and cereal products should be fumigated upon receipt and then placed in insect-proof containers for storage.

In warm regions certain host materials such as potatoes and citrus fruits do not keep well without refrigeration. Refrigerated rooms will be required to maintain the necessary 38° to 42° F.

Fumigation

Fumigation facilities are necessary if proper sanitation and prevention of contamination by insects are to be achieved. Nicotine and HCN fumigation chambers can be easily and economically constructed. For example, a large box or framework enclosed by a plastic tarpaulin will suffice. Injury to potted plants from methyl bromide usually can be averted if relative humidity in the fumigation chamber does not fall below 80 per cent. A general-purpose fumigation chamber used at Riverside is shown in figure 82.

Persons who conduct fumigation must be thoroughly conversant with the dangers of the materials used and the necessary antidotes, and must understand what constitutes adequate fumigation for the particular material being tested. Except for the occasional necessary fumigation of insectary rooms, fumigation should be performed well outside of the insectary. If a permanent fumigator is contemplated, it should be located downwind of the main building and equipped with an exhaust stack high enough so that discharged fumes will not endanger personnel or cultures in the insectary or near-by installations.

Workshop

If research is to be a major insectary function, facilities for construction and repair of cages and other paraphernalia are necessary. Power tools such as table saw, grinders and sanders, jointer, bandsaw, and drill press require the services of someone trained in their uses. A collection of conventional hand tools such as hammers, saws, chisels, planes, screwdrivers, wrenches, brace, bits, and clamps of various sizes will suffice for most repairs. Electrical and plumbing facilities also will need occasional attention. In addition, painting supplies will be needed, and safe storage is required for flammable materials. In short, the insectary programme will greatly benefit from the services of a skilled handyman.

Specialized Research Equipment for Controlled Environment Studies

BIOCLIMATIC CABINET. Of proved value for determining biological potentials of insects is the bioclimatic cabinet (figure 83). The following description is taken from Messenger and Flitters (1957, pp. 119–127): 'Each chamber is similar to a walk-in refrigerator, being fitted with two doors separated by a 4-foot vestibule, and having an inner work space providing floor area 6 feet by 6 feet for conducting experiments. Attached to the chamber are various air-conditioning controls and devices that permit the air circulating within the chamber to be heated, humidified, cooled, or dried, as desired. A major feature of these chambers lies in their capability of controlling temperatures and humidities in smoothly varying patterns such as occur naturally. Temperatures may be controlled to within plus or minus one degree Fahrenheit over the range from $-5°$ to $+125°$. Humidities, within this same temperature range, may be controlled to within plus or minus 3 per cent relative humidity over the range 20 per cent to 98 per cent. At temperatures above freezing, humidities may be controlled to as low as 10 per cent. Lights within the chambers are automatically turned off and on by means of time clocks, and the settings of these clocks are periodically varied in order to duplicate the variations in photoperiod as these occur naturally.'

Detailed descriptions of mechanical features are given in Flitters, Messenger, and Husman (1956). Three bioclimatic cabinets are at present located at the University of California, Department of Biological Control laboratory at Albany, California.

Biotrone (*Bio=life; trone=balance*). In order to study the plant-insect complex under a wide range of combinations of sunlight, temperature, and humidity, this highly specialized greenhouse was conceived by S. E. Flanders and C. A. Fleschner. Although this useful research facility has been mentioned in scientific literature (Clausen 1954*a*) and popularly in various trade journals, no detailed description has appeared since it was placed in use in mid-1953. The following description was provided by C. A. Fleschner:

'The biotrone is a 12 ft. × 12 ft. glasshouse covered by a cubical lath-house consisting of 165 interlocking aluminium louvres. The main purpose of the louvres is to prevent excessive direct solar radiation, and they may be opened and closed automatically in three ways, namely, by direct solar radiation, by a combination of direct solar radiation and temperature within the glasshouse, or by a time clock. As a means of heat conservation all louvres are closed at sunset and opened at sunrise the year around by the time clock which is self synchronizing for seasonal change in length of day. In addition, the clock energizes a remote bulb thermostat circuit which contains three separately located thermostats. These thermostats are located on the tops of the lath house and shielded to face east, south, and west. When a thermostat is closed by solar radiation in excess of a predetermined intensity, only the louvres controlled by that thermostat are closed. The east thermostat controls the east side and the easterly half of the top. The south thermostat controls the south side and the entire top. The west thermostat controls the west side and the westerly half of the top. The north, or entry, side is opened and closed by the clock and stays open all day.

'Heating or cooling within the glasshouse is accomplished by a thermostatically controlled electric heater and a refrigerative cooler. A humidistat adds humidification by means of fog-nozzles.

'Fluorescent and incandescent lights within the glasshouse provide simulated sunlight should the need arise.'

The biotrone is located at the University of California, Department of Biological Control, in Riverside.

INSECTARIES OF THE WORLD

The following listing (table 5) does not include all known insectaries and the final date of compilation was December 1960. The intention here is to present a well-distributed selection of biological control insectaries in several countries. Installations having known quarantine facilities are indicated by an asterisk. Those which produce material mainly for insecticide screening are not included. Presented elsewhere in this chapter are photographs and diagrammed floor plans of insectaries which, in our opinion, cover a wide range of design and therefore demonstrate methods used to cope with a variety of problems.

This information was derived mainly from answers to questionnaires sent to the institutions listed. Co-operation of all correspondents is hereby gratefully acknowledged. It is regrettable that information regarding biological control insectaries in China was not received in time for inclusion in this listing. The practical use of insectaries in Russia was reported by Dr. Carl B. Huffaker of this department. In 1959 he visited certain Russian agricultural research institutes and he stated (department files) that there is considerable production of *Trichogramma* on collective farms in the Ukraine with the reported result of a complete saving of winter wheat from cutworm attack.

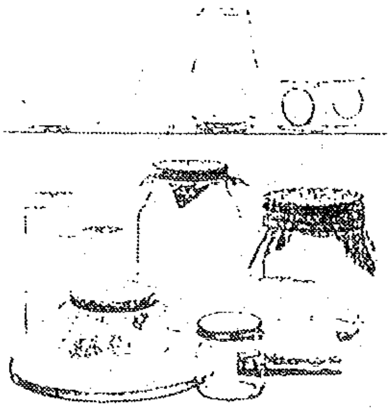
Because rearing programmes change we chose not to indicate the organisms being propagated but rather the listing is intended to illustrate that Biological Control is of world-wide interest and has been supported by government and private funds for a considerable period. A listing of national (state and private) organizations which includes brief summaries of the scope of their works is given in the admirable work by Franz (1961*a*).

A list of selected propagation programmes is given in the closing section of chapter 11.

TABLE 5

A partial list of biological control insectaries

Country	*Sponsoring organization*	*Date founded*	*Full-time personnel*
Argentina	Instituto National de Tecnologia Agropecuaria, Buenos Aires	1935	22
Australia	Queensland Dept. of Lands, Brisbane,* Qld.	1924	7
	CSIRO,		
	Canberra,* A.C.T.	1927	7
	Samford,* Qld.	1958	3
	Sydney,* N.S.W.	1953	3
Canada	Canada Dept. of Agr. Res. Branch, Belleville,* Ont.	1928	79
Chile	Ministerio de Agricultura, La Cruz	1937	20



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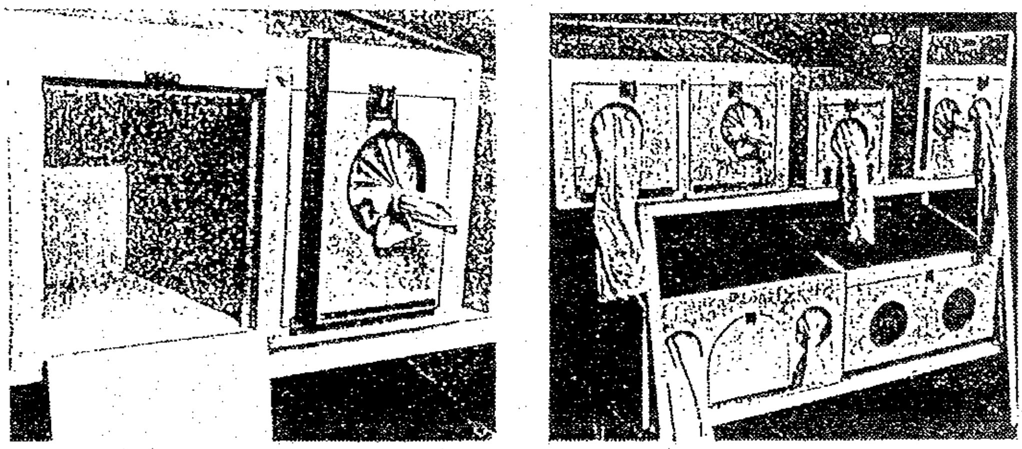
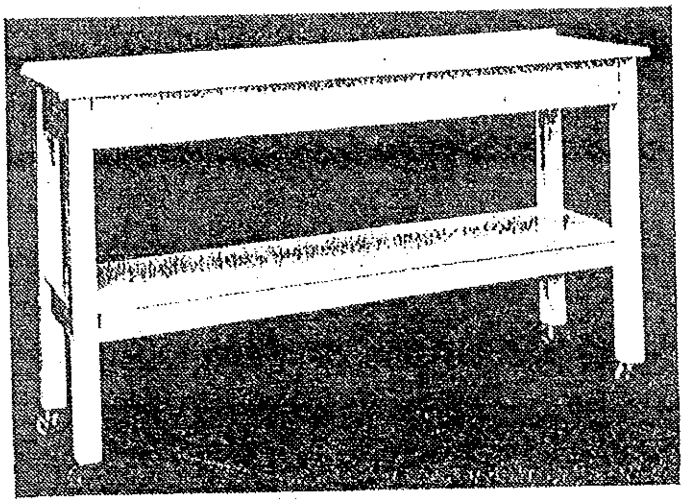


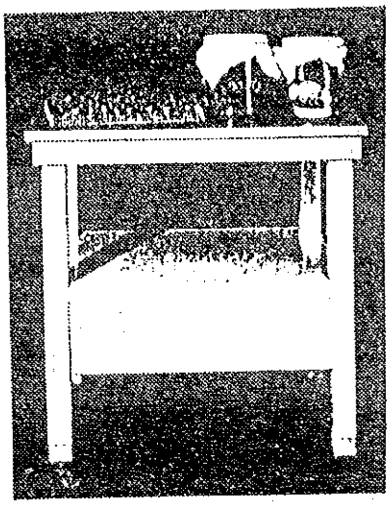
B

FIGURE 71. General types of cages.

A. Adaptations of glass and plastic containers. Upper row, left to right: Three conventional lamp chimneys and one hard plastic box (holes may be punched out by using a heated tin can, cloth is attached with a soluble plastic cement, such as DuCo Household Cement). Lower row, left to right: Four glass tubes with cloth glued on one end; one-gallon pickle jars are used entire, or cut and placed on a pad of cellucotton, cotton, and cloth. Positioning the rubber bands as shown on the battery jar at the right permits a tight fit of the cloth top. Other items shown are a household one-pint fruit jar, and a section of glass cylinder on a padded board.

B. Cages requiring services of skilled cabinet makers. Left: Sleeved cages showing modifications. The longer types can be used in a vertical position to accommodate potted plants. Right: By starting a culture in one side of this duplex cage, it can later be given additional space by removing the centre partition, thereby avoiding a possibly disturbing move. The ruler is in inches.





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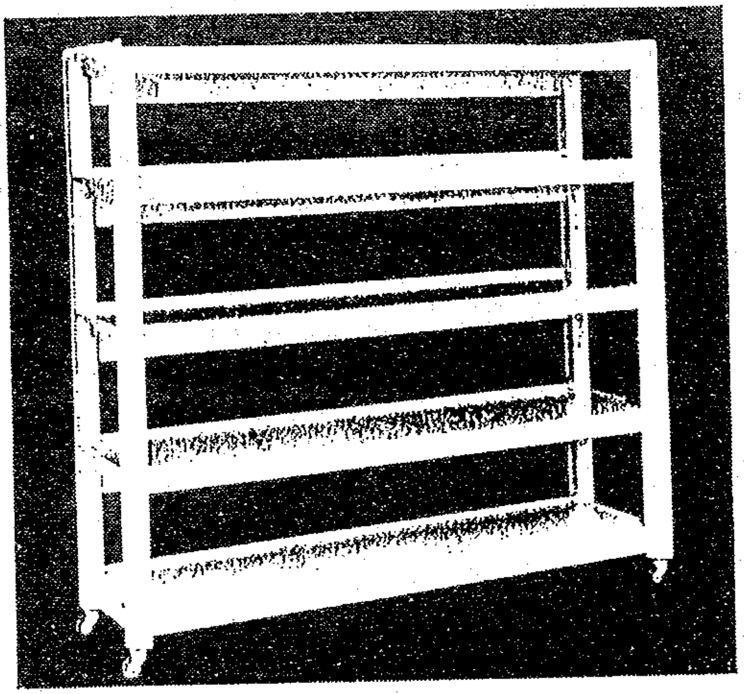
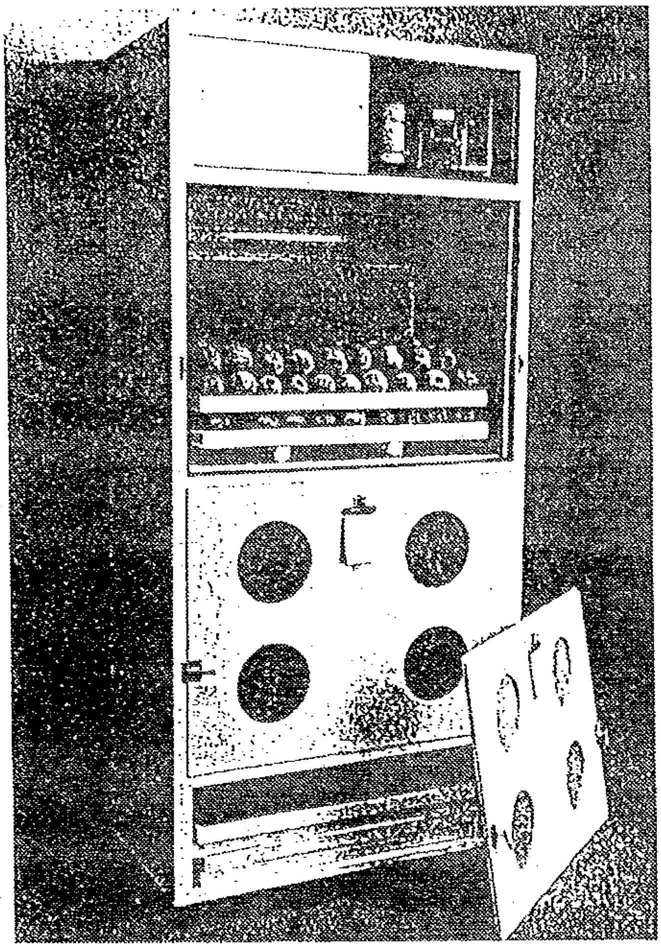




B

FIGURE 72. Portable equipment designed to allow for maximum use of available floor space.

A. Upper: Rolling laboratory tables of counter height. Lower: The tall rolling rack was designed for battery jars of one- or two-gallon capacity.

B. Combination propagation cage and storage for glassware, cloth, and other supplies.

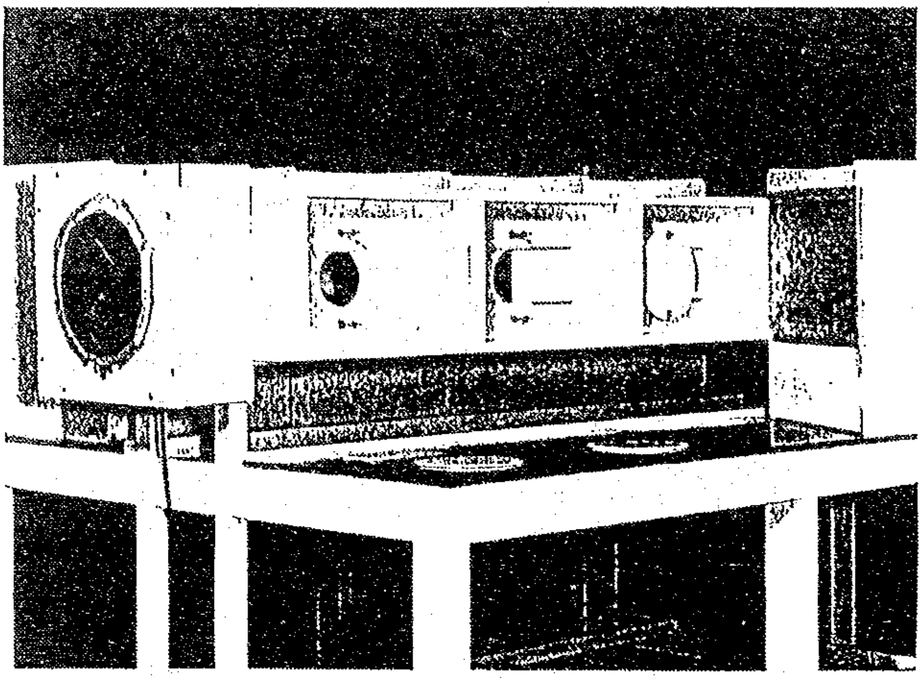
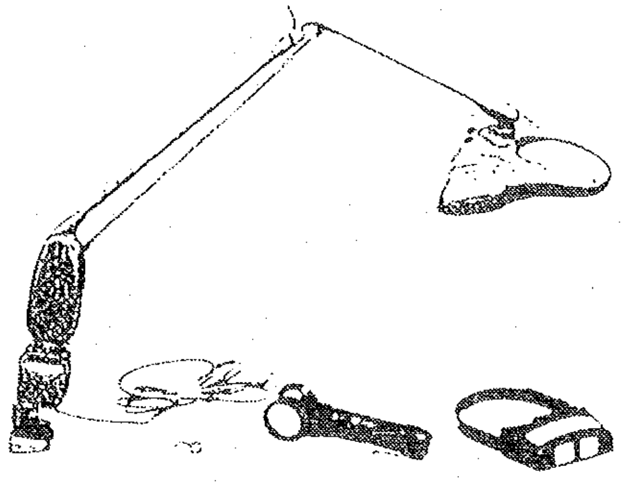


FIGURE 73. Apparatus used for ventilation of sleeved cages. The fan creates a negative pressure in the common duct with the result that air is pulled through the cages which are placed with their cloth backs against the ports. It is doubtful if aphids or mites can be continuously propagated indoors in numbers sufficient for economical insectary procedure without providing adequate ventilation (Finney 1960).



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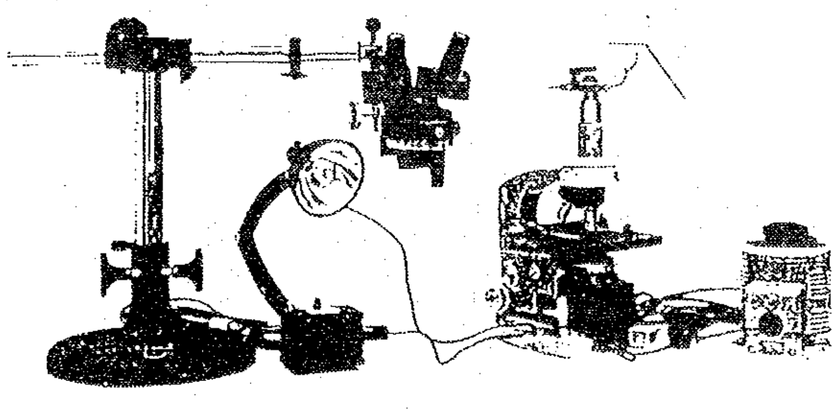
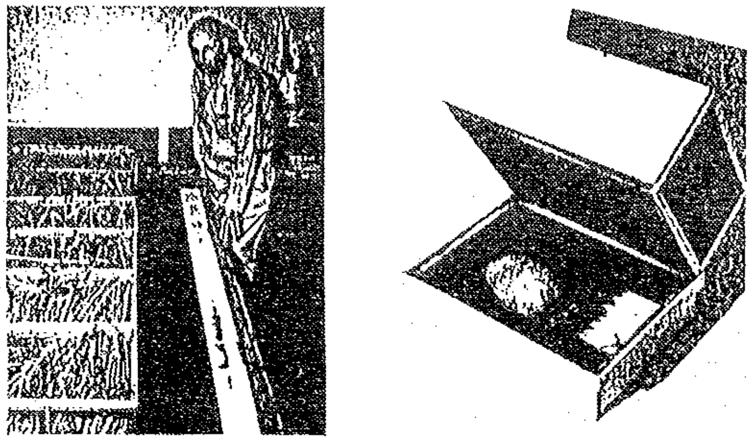


B

FIGURE 74. Basic optical aids necessary for efficient insectary work.

A. Low-power magnifiers used in routine mass culture. Left to right: Illuminated magnifier (fixed), hand lens, portable self-illuminating magnifier, and head loupe.

B. Higher power magnifiers used in research insectaries. Left to right: Stereoscopic dissecting microscope gives 9× to approximately 100× magnification; the supporting mount permits adjustment in three planes; flood lamp illuminator with variable transformer control. At the right is a compound microscope with its substage illuminator. Shown attached are a card for converting ocular micrometer readings to microns and a camera lucida. The variable transformer can be used for adjusting light intensity which is of particular value when working with the latter.



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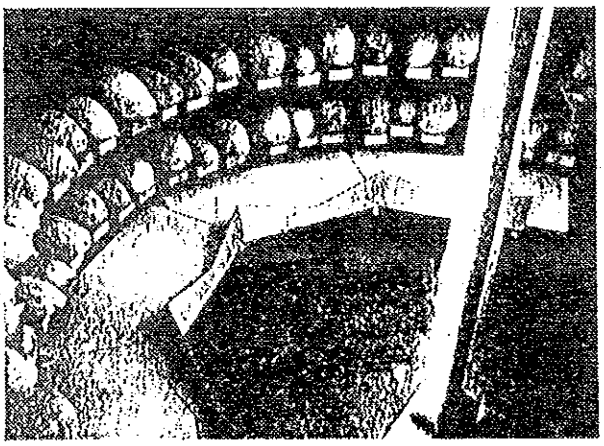


B

C

FIGURE 75. Phototaxic collection of insects.

A. Left: Shadow collection of black scale crawlers (Fillmore Citrus Protective District Insectary, Fillmore). Crawlers leave the drying twigs and collect below the light at the shadow line. Right: Shadow box used for collection of smaller numbers of lecaniine crawlers. When the double-walled cover is in place ventilation is provided through cloth-covered holes in the interior wall. Crawlers move towards light which enters through the glass or celluloid front and collect at the V-shaped shadow. The interior is painted with non-reflective black paint.

B. Amphitheatre—oleander scale crawlers (University of California). Crawlers are attracted towards the vertical fluorescent tube and collect in windrows at the shadow line case by broad V's of cardboard.

C. Leptomastix (Associates Insectary, Santa Paula). The demountable box is at floor level. When the slide is removed, the parasites which are positively geotaxic (and therefore on the floor) and positively phototaxic move into it. When a predetermined number of parasites have entered the box, the metal sliding covers are replaced. The box is then removed and taken to mealybug-infested citrus groves where the parasites are released.

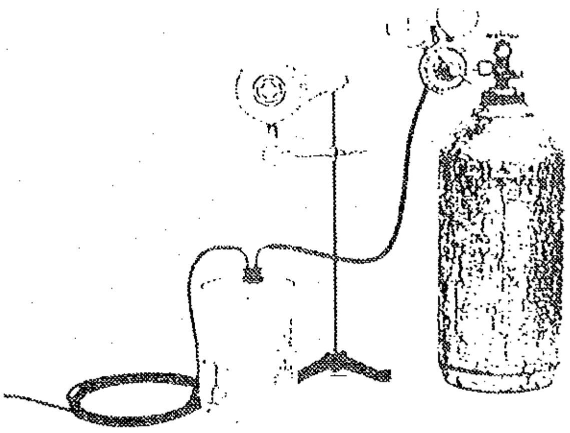
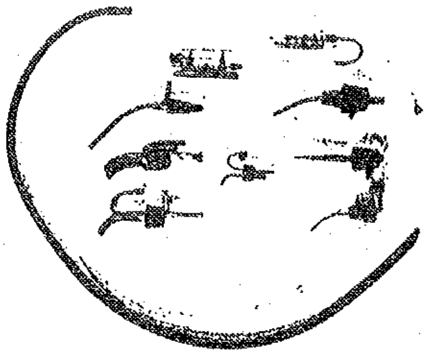


FIGURE 76. Apparatus for blending CO_2 and ether for anaesthetizing parasites. From right to left: CO_2 cylinder with pressure regulator, warm air source to prevent pressure regulator from freezing up during prolonged use, flask of ether in water bath at room temperature (80 degrees), tubing in the rubber stopper of the ether flask. CO_2 does not bubble through the liquid ether, but passes in and out of the flask, picking up sufficient ether to produce the desired effect.

FIGURE 77. Modified hair dryer used to collect parasites directly into a carton for storage prior to shipment (U.S.D.A., Moorestown).



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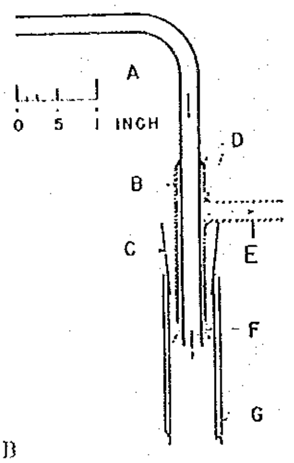

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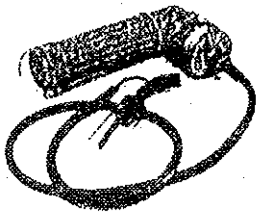


C

FIGURE 78.

A. Collecting devices utilizing air flow. At the top is a glass tube with the end narrowed. The hose holds a bit of fine mesh cloth over the opposite end of the tube. Just below is the collecting device developed by A. J. Nicholson (C.S.I.R.O., Div. of Ent., Canberra, Australia) in conjunction with population studies utilizing blow flies as test animals. Air pressure only is needed as direction of air flow can be controlled by the two-way valve arrangement beneath the major tube either to suck insects in or blow them out. The other devices are made from copper tubing of various sizes and they fit into standard straight-sided shell vials. The three at the right were designed for collecting predaceous mites. The small one in the centre fits into a 1½-dram shell vial.

B. Diagram of aspirator. A construction diagram of the uppermost aspirator in the group on the left in figure 84 A.

Legend: A Intake tube
B External shell of suction line
C Stopper
D Bead of solder around tube
E Suction line
F Cloth or 100-mesh screen
G Receptacle

C. Portable collector. This portable collector is made from a clothing vacuum cleaner. Two size-D flashlight batteries provide power to run the tiny rotary fan. This collector is very useful in the insectary as well as in the field.

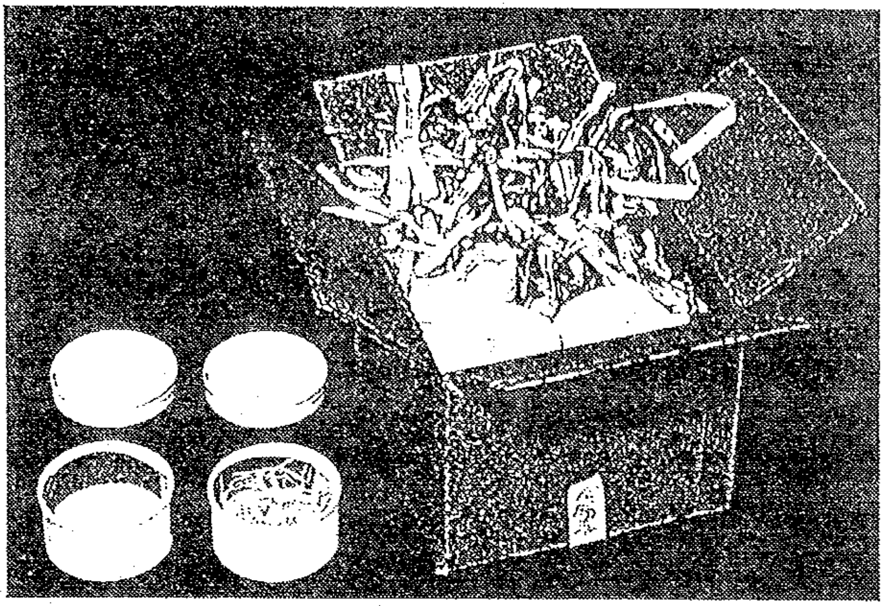


FIGURE 79. Containers for storage and shipment of beneficial insects pending field colonization. Cartons of various sizes can be utilized. They should contain a lining of waxed paper streaked with honey for food and shredded wood to provide added resting surface during storage and in transit.

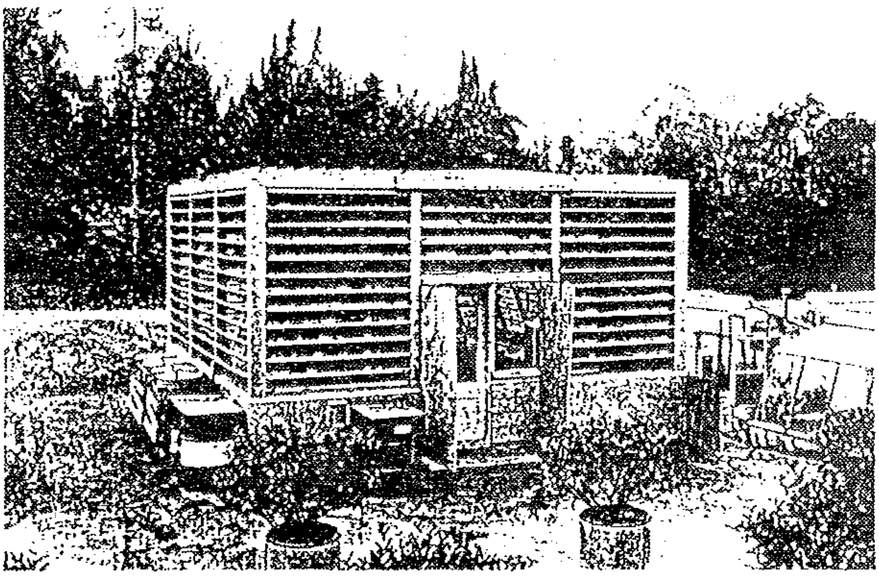
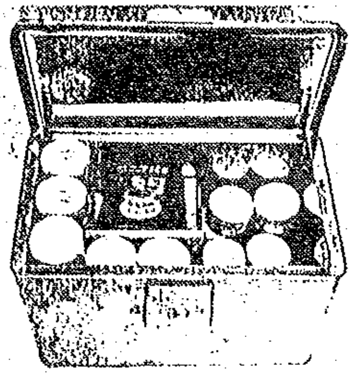


FIGURE 80. Biotrone.



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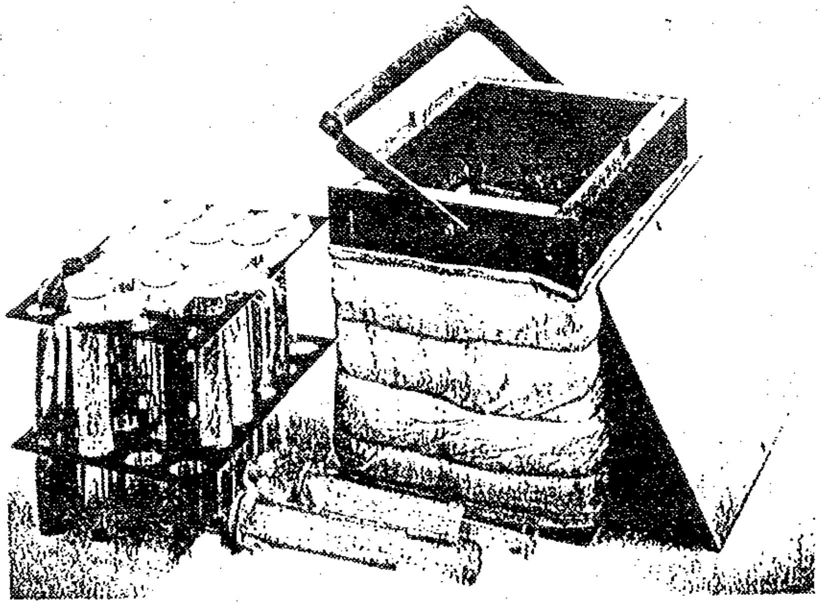


B

FIGURE 81. Methods for counteracting lethal high temperature during local shipment of parasites.

A. Prechilled chest and frozen gel packet utilized in shipments requiring added protection from excessive heat. Note buffer between frozen gel and containers of insects.

B. Carrying case which cools by evaporation. The plastic hose is used for jarring the insects out of the tubes at the release site.

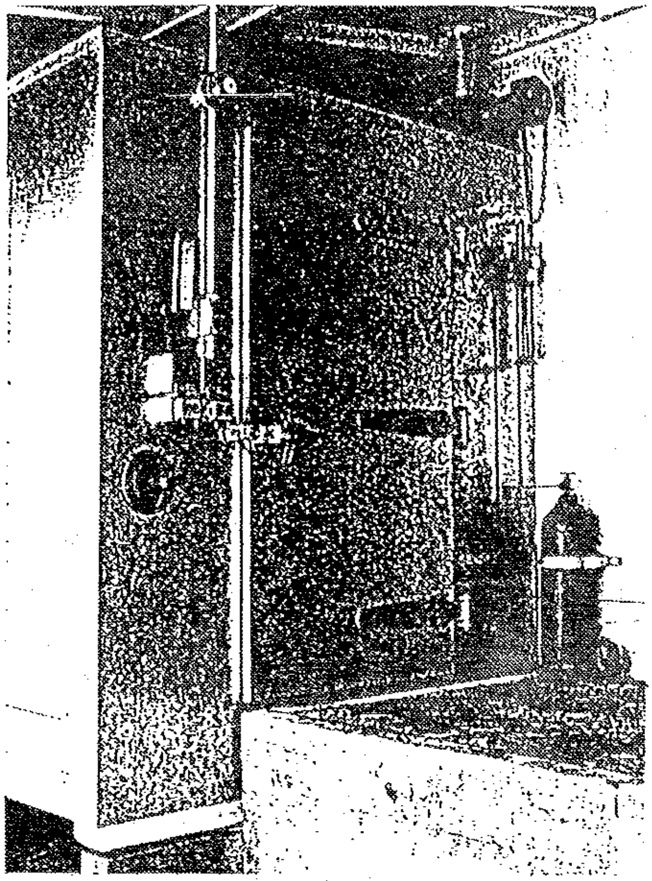
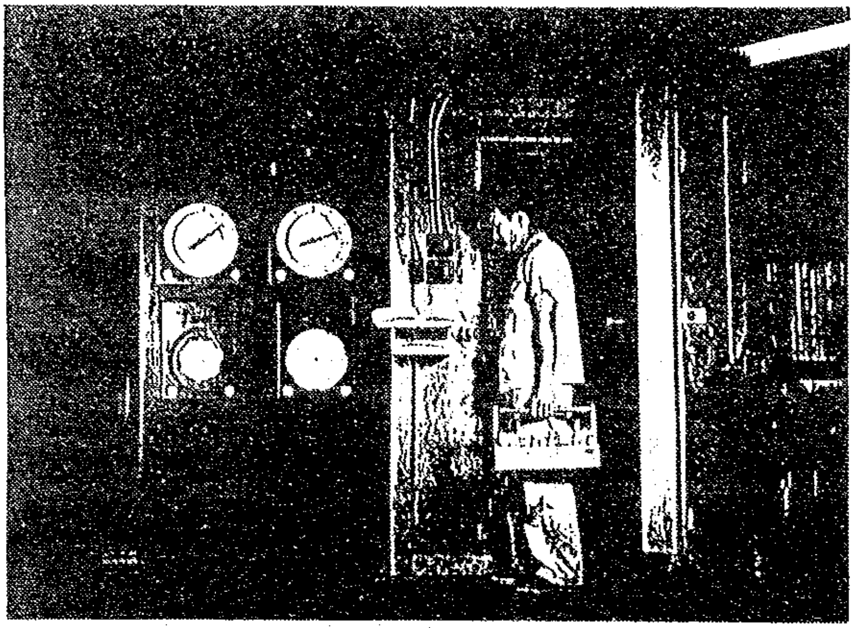


FIGURE 82. Fumigation chamber. The interior volume of this double-walled and insulated box is 250 cubic feet. The interior is lined with galvanized steel and all seams are soldered. The door is double gasketed. The exhaust valve at the upper right and air intake valve at lower left are gas tight. Air within is circulated past a thermostatically controlled electric strip heater. A perforated false floor permits the fumigant to completely surround the material. Methyl bromide is admitted via a coiled copper tube which is immersed in a one-gallon size warm water bath. The arrangement assures accelerated volatility of the fumigant and a relative humidity adequate to prevent plant damage. Safety features include interior lighting, an alarm bell, a padlock on the door, and a tall exhaust stack. The exhaust fan and its motor are located on top of the corrugated roof which covers the fumigation chamber.



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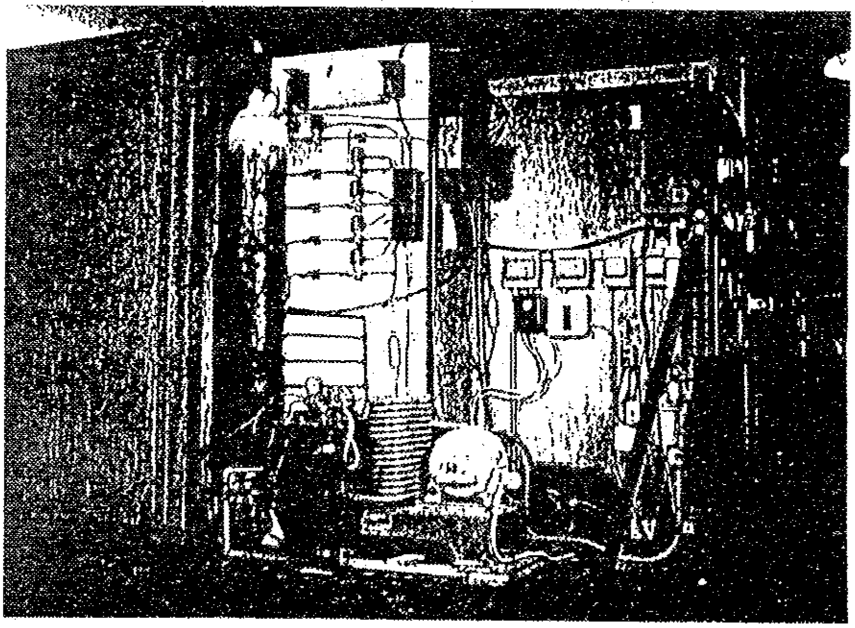

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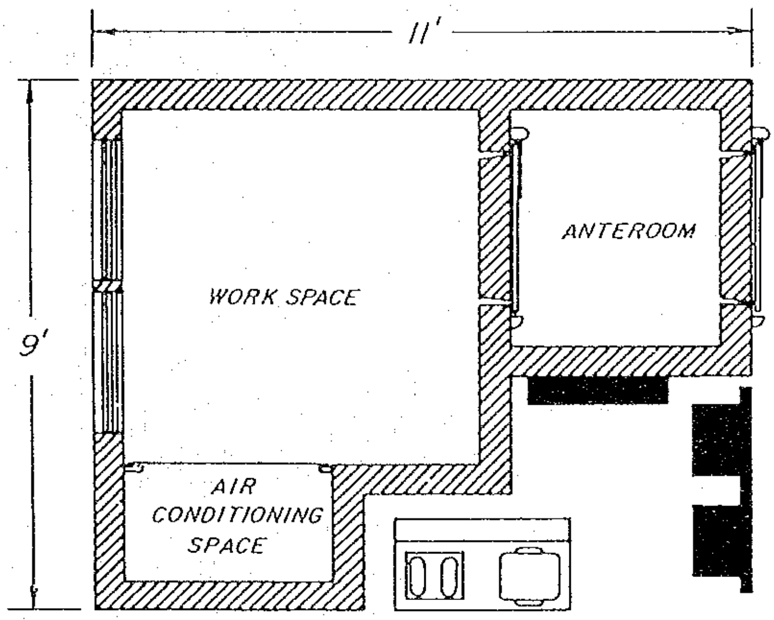

C

FIGURE 83. Bioclimatic cabinet (Albany, California).

A. Front view of bioclimatic cabinet, showing main control panel at left, and outer door opening into air-lock vestibule. The switches at centre control the ultra-violet, infra-red, and ordinary tungsten lights within the cabinet.

B. Side view of bioclimatic cabinet showing control panel at far right, motor and power switches at centre, chimney coil, solenoids and relays at left, and freon refrigerator pumps below.

C. Plan of bioclimatic cabinet.

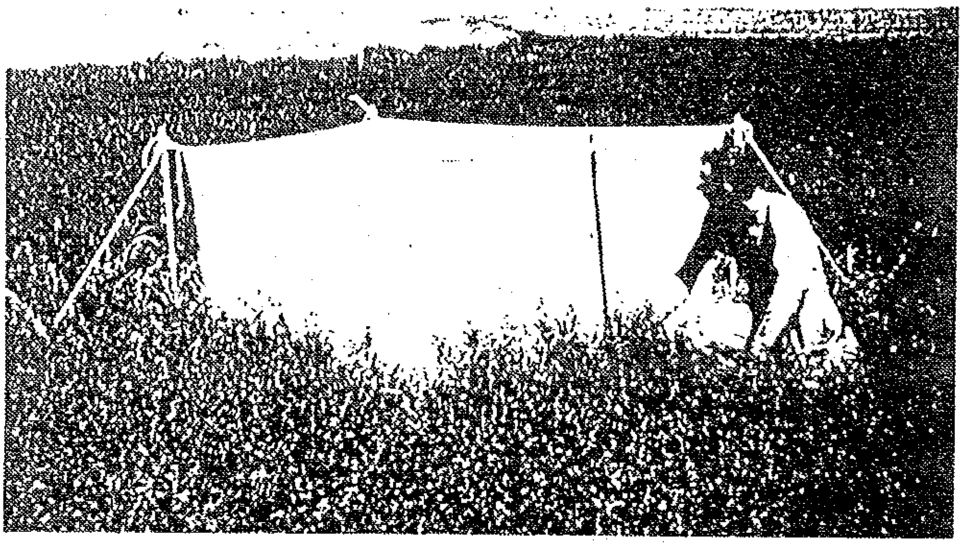

FIGURE 84. An easily transportable, large organdie-cloth colonization cage used in field colonization of natural enemies of pests of vegetable and field crops. A vacuum machine collector is utilized to remove all insects from the plants within the caged area. The organdie cage is then fastened to a board base and soil is used to close the space between the boards and the ground. Host insects are then introduced into the cage. Natural enemies may be colonized at the same time or at any later date. The best results are obtained if a sequence of several releases are made to ensure all stages of the parasites or predators being present in the colony. One or several generations of the host and natural enemy may be reared before removal of the colonization cage.

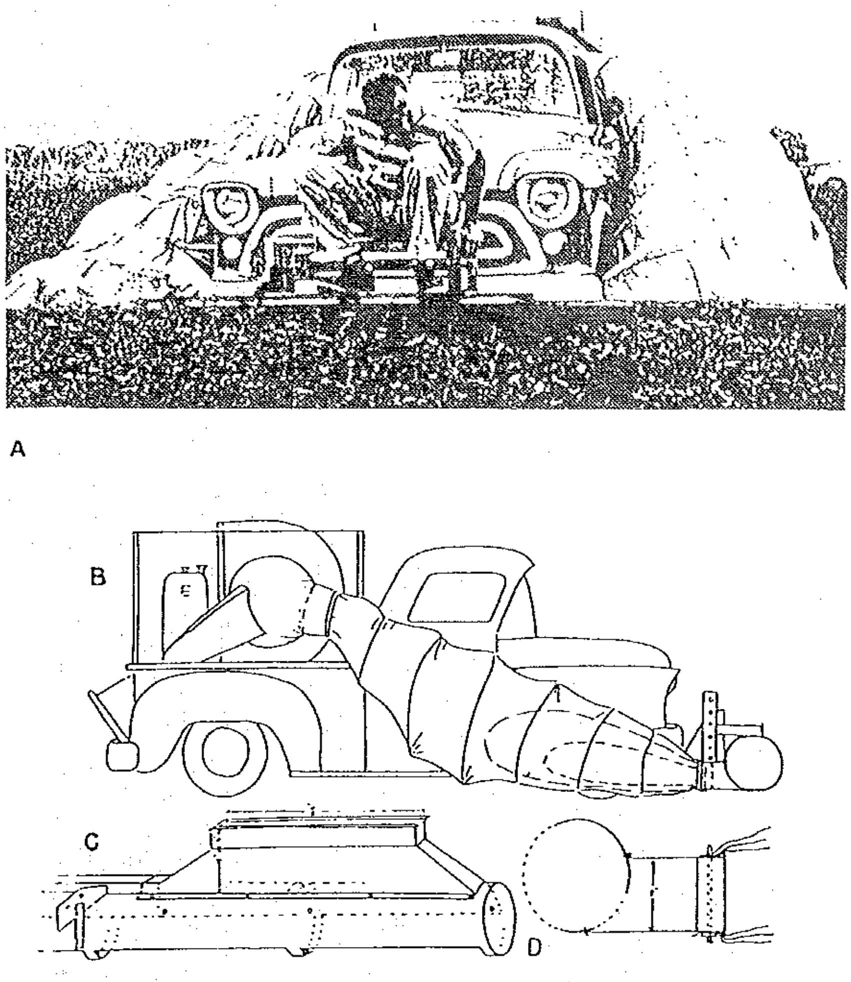

FIGURE 85. Mechanical collector developed for large-scale field collection of imported parasites of the spotted alfalfa aphid: (A) collector in operation; (B) diagrammatic side view of collector—broken line invaginations in air duct indicate positions of collecting sacks; (C) diagram of one side of 'scoop' showing the adaptive collar with which it is connected to air duct; (D) lateral view of 'scoop'—note anterior opening (broken line) for entry of insect material and posterior opening through which material is drawn via adaptive collar into collecting sacks in air duct (van den Bosch *et al.*, 1959).

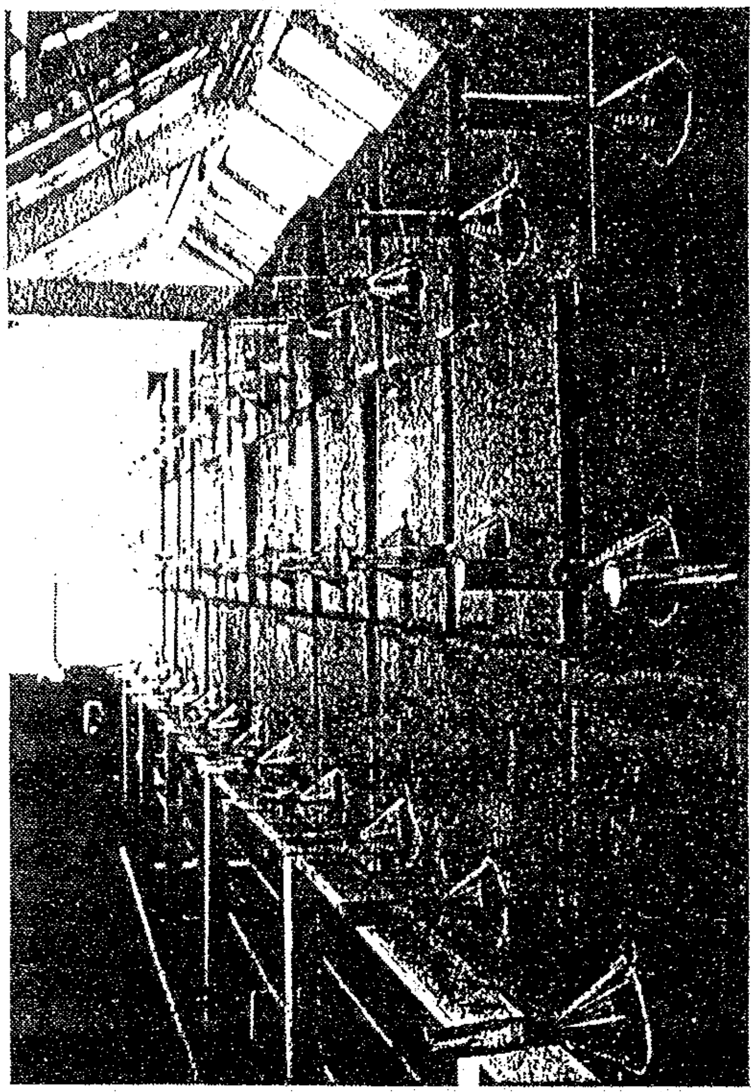

FIGURE 86. Emergence cages for recovery of natural enemies from samples of parasitized host material. The containers are made from corrugated cardboard cartons with a false floor sloping to the lip of the funnel. Adult parasites attracted to the light source collect in the removable glass vials. (Courtesy of E. C. G. Bedford, Union of South Africa, Division of Entomology Parasite Laboratories.)

Country	*Sponsoring organization*	*Date founded*	*Full-time personnel*
France	USDA, ARS, Nanterre, Seine	1919	7
	Ministère de l'Agriculture, La Minière, S. et O.	1957	5
	Institut National de la Recherche, Agronomique Antibes (A.-M.)	1917	7
Germany	Institut für Biologische Schädlings-bekämpfung, Darmstadt	1953	18
	Landesanstalt für Pflanzenschutz, Stuttgart*	1951	2
India	CIBC, Bangalore	1956	2
	Indian Agricultural Research Institute, New Delhi	1938	11
Israel	Citrus Marketing Board, Rehovot	1960	2
Japan	Faculty of Agriculture, Kyushu University, Fukuoka	1920	—
Kenya	Dept. of Agr., Nairobi	1941	—
Mauritius	Dept. of Agr., Reduit	1924	—
New Zealand	Dept. of Scientific and Industrial Research, Ent. Div., Nelson*	1956	29
Pakistan (West)	CIBC, Rawalpindi	1957	8
Peru	Estacion Experimental Agricola de la Molina, Lima	1935	3
Switzerland	Swiss Federal Agr. Exp. Sta., Nyon, Changins	1960	4
Trinidad	CIBC, St. Augustine	1945	5
Turkey	Zirsi Mucadele Enstitudu Parazit, Laboratuari Diyarbakir	1956	4
Union of South Africa	Dept. of Agr. Tech. Serv., Div. of Ent., Pretoria	1957	6
Union of Soviet Socialist Republics	Ministry of Agriculture, Tashkent*	1947	8
	Pyatigorsk*	1958	6
	Batumi*	1947	5
United States	Univ. of California, Albany*	1943	33
	Riverside*	1929	27
	Associates Insectary, Santa Paula, California	1928	3
	Fillmore Citrus Protective District, Fillmore, California	1924	3
	USDA, Moorestown*, New Jersey	1928	3
	CIBC, Fontana, California	1949	2
	Bd. of Agr. & Forestry, Honolulu*, Hawaii	1913	7
Yugoslavia	Inst. for Plant Protection, Beograd (Zeman)	1954	6

* Has known quarantine facilities.

16—I.P.W.