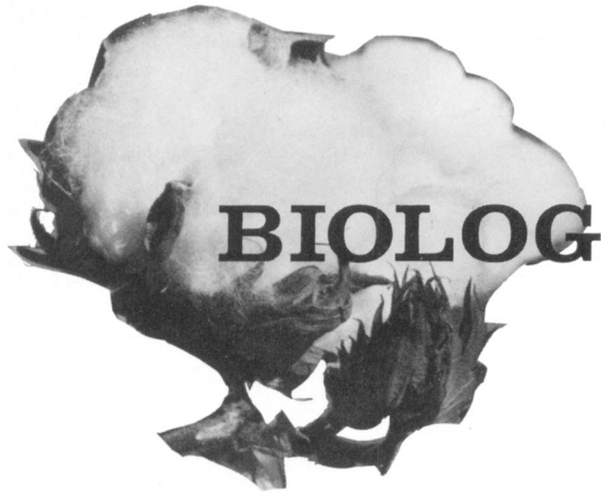

A progress report . . .

BIOLOGICAL CONTROL OF

B. R. BARTLETT • D. GONZALEZ

SINCE THE INVASION of Southern California desert cotton-growing areas by the pink bollworm in 1965, attempts at its eradication have been unsuccessful. In Arizona (with a longer history of permanently established infestations of this pest) its severity under similar desert growing conditions has resulted in losses estimated at from $50–$75 per acre. In both states, available chemical materials have proven very costly and less effective than hoped for—and they have prompted outbreaks of several secondary pests.

The pink bollworm problem has been fairly well handled in most of the cotton-producing countries of the world through enforcement of a shortened cotton-growing season, and early destruction of post-harvest plants and attendant bolls. However, such a long cotton-free season under desert conditions is viewed by many growers as imposing a serious threat to economic production of the crop.

The University of California Agricultural Experiment Station has now initiated a biological control program against this pest. Whereas, there are obvious difficulties in the biological control of a pest which spends most of its existence deeply imbedded in a cotton boll where it appears inaccessible to parasites and predators, there are still some weak spots in its defense which make the prospects for successful biological control more promising than they might at first appear.

Current research program

This article points out the particular strategies being used in the prospective natural enemy importation program to exploit some of the pest's weak spots, and the procedures to be used in testing the parasites, predators, or pathogens expected to be found in foreign countries.

A preparatory program for receipt and culture of imported parasites, predators, and pathogens was initiated at Riverside in November 1968. Pink bollworm larvae were collected from field-infested cotton bolls by various procedures to establish laboratory stocks and to study the patterns of inception, and duration of its diapause, under insectary conditions. Diapause and pupation sites were examined in the fields to see to what comparative degree of overwintering took place in the bolls, and in the trash and soil where they have different exposures to natural enemy attack. Native natural enemies which had accommodated to the new host were sought in the various habitats. Procedures were developed for producing diapausing larvae and getting them to enter special clear plastic corrugated strips which could be placed in the field as traps for parasites and predators attacking this stage. Various procedures for getting adult moths to lay eggs on various materials were examined so that the eggs might be exposed in the field to trap any parasites and predators attracted to them.

Food support

A variety of natural and synthetic foods were tested to see which might best serve for supporting parasitized pink bollworm larvae to be shipped to Riverside from areas too remote for survival of the adult parasite stages. Prospective procedures for testing certain parasite species after their arrival at Riverside for their ability to diapause in synchronization with this particular host were examined. Continuous cultures of the pink bollworm, the potato tuber moth and other possible substitute hosts suitable for parasite and predator laboratory rearing were established. These detailed studies were in addition to a general familiarization with the field problem, particularly as it related to prospects for parasite and predator release sites where pesticides dangerous to their initial survival could be avoided. Literature surveys were also made on the worldwide records of natural enemies found on this pest over the past 100 or more years; on the most likely countries of origin of this species and its close taxonomic relatives; and data were acquired on various plant hosts attacked in different countries.

Current progress

Cultures of the pink bollworm have been established at Riverside to the extent of rearing about 1000 moths per day. The laborious and relatively expensive methods currently in use for rearing these cannibalistic pests were modified to shape them toward the particular needs. Methods had to serve the dual purposes of providing ways of feeding and handling pink bollworm larvae in remote foreign areas without modern facilities; getting them back to Riverside; and finally to serve for their mass propagation for release in California cotton fields. While small bolls in sealed containers can be used for transporting larvae with about 25% survival, the most suitable method was found to be the use of a synthetic medium in stapled plastic straws which offered better survival and permitted storage of food for reasonably long periods before use.

Internal parasite

Some trials were run on an internal parasite, *Chelonus curvimaculatus* Cameron, from East Africa which lays eggs in the eggs of the pink bollworm with the parasite eventually emerging from the mature larvae of the host. Stocks of this parasite are being propagated at the University and by the Vitova Insectary laboratories of Riverside. From these stocks has come some expertise on handling this type of parasite—which we assume will be least likely to suffer from the long pest protection period afforded while the bollworm is inside a boll. With this parasite, pink bollworm eggs laid on dacron cloth

were exposed to attack and then transferred manually as newly hatched larvae to a synthetic media (wheat germ base). From these full-grown larvae the parasites eventually emerge. Other tests are soon to be undertaken with another parasite of East African origin, *Bracon kirkpatricki* (Wilkinson), a hymenopterous parasite made available to us through courtesy of the U.S.D.A. laboratories in Arizona. Screening tests are also being run on the efficiency of a number of general predators in killing eggs and newly hatched larvae; and the attack upon pink bollworm by a number of different kinds of egg parasites of the genus *Trichogramma* is being examined.

Four species

To date, four species of native parasites have been taken from pink bollworm in California. All are known species with a wide array of other hosts, upon none of which they are every effective. A continuous check on these and other possible change-over parasites is being conducted. Some 90 other parasites and three or four general predators are recorded in the world literature as having, at one time or another, attacked pink bollworm. Almost without exception these are known to have little specificity, and in a majority of cases are believed to have a very casual or overflow relationship with the pink bollworm.

Foreign exploration

The development of strategies for a foreign parasite, predator, and pathogen search were vital to proper implementation of this effort. The search is generally concentrated in the native home of the pest where there will have evolved, along with the host, certain natural enemies which keep it sparse by preying upon it, but which have failed to follow the pest in its migration to new lands. Unfortunately, some of the best clues usually available for determining the origin of a pest were not available with the pink bollworm. The ancestors of cotton seem to have had too many different potential points of origin. Actually, it is not certain even that cotton is the preferred or native host of the pink bollworm because there is fair evidence that in some habitats *Hibiscus* or other Malvales may support it reasonably well under natural conditions.

Clue to origin

One useful clue to the origin of the pink bollworm arises from the fairly well documented dates on its introduction to most countries, almost invariably from adjoining areas—eventually leading back to India where the pest was first reported in 1847. For this and for some less prominent reasons, about 90 per cent of the speculation centers around the Indian subcontinent as the origin of this species.

Another commonly used clue regarding the nativity of a pest is the abundance of closely related species usually found in the place of origin. In this case, the relatives of pink bollworm have been poorly studied, and hence are controversial among the few taxonomic authorities on this group. Information available points toward Northwestern Australia, or possibly the Mediterranean basin or the high plains of Northeast Africa, as the native home. Another clue sometimes available is the native presence of parasites which have developed a high degree of specificity toward the pest. There is presently little sound basis for judging this possibility, but most of the recorded parasites have been reported from the Far East, and though their biologies are unknown some may be specific.

Scarcity of pest

Scarcity of the pest in areas appearing as most suitable climatically often afford some evidence as to a pest's origin, since this may possibly be due to suppression by natural enemies. In this case, however, there has been little interest in areas of low incidence of the pest and hence no worthwhile evidence accumulated in this regard as to the likely origin of the pink bollworm. In fact, very few features of the life history of this pest give any suggestion as to its native home, and even those that do provide only evidence pointing toward the elimination of some suspected lands of origin.

Diapausing instinct

The strong diapausing instinct of the insect, largely dependent upon cold and aridity for its expression, substantially indicates that it could not well have originated in a tropical climate. This habit, along with the unusually high temperature optimum for the insect, indicates that it is particularly adapted to hot summer areas with dry cold winters and with a first rainfall period coinciding with the period of cotton flowering and fruiting.

On the basis of this very circumstantial evidence just presented, and the thesis that over 90 per cent of the authorities are not too likely to be misled, the first search is being directed toward the more northerly and arid areas of India, Pakistan, and Afghanistan.

Important feature

An important feature of the plan will be to concentrate the search in and near areas with climates close to that of the California desert, and in areas where the pest, though present, is not abundant. This should select out the most effective natural enemies with the best adaptation to California cotton-producing areas. The parasite search will be particularly directed toward cotton, on the premise that an initial attraction to this host plant may be a vital instrument in effectiveness

of the parasites in finding their host on cotton.

A particular effort will also be made to seek the egg-larval parasites which are not impeded by the protected location of the pink bollworm larvae deep in a cotton boll. Another strongly sought feature will be to obtain a parasite with a diapause synchronized to that of the host. A polyphagous parasite (i.e. one attacking many host species) without diapause itself might, of course, find other suitable carryover host species during the period of diapause of the pink bollworm so we cannot eliminate these types without field trials.

Search analysis

This search analysis and projection, as presented, offers guidelines for emphasis of effort with individual species of parasites of pink bollworm. The projected program also includes a concentrated search for general predators. It is only in the past one or two decades that the enormous potential of general predators for controlling certain pests like that of the ordinary cotton bollworm (*Heliothia zea*) has been clearly recognized. This is particularly true in southern California desert areas where the general predators alone frequently show a capacity to handle this potentially serious pest. Some very circumstantial evidence at present indicates that the influence of general predators upon the pink bollworm may also be underestimated, and many researchers believe that this is an area of search that deserves considerable attention. The goal of importation and establishment of outstanding general predators from foreign countries is one believed likely to be rewarding against the pink bollworm and simultaneously against many other important California pests.

The importation of pink bollworm disease organisms has never been explored, but also offers considerable promise, and this prospect will be actively pursued in the future.

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Effects of . . . delayed

KAY RYUGO · D. E. KESTER

ONE OF THE MORE SERIOUS cultural problems in the growing of almonds in California is the poor set caused by the lack of cross-pollination during certain climatic conditions. This is especially true in some years when bloom periods do not overlap much. Since almonds bloom early, spring frosts (to which open flowers are susceptible) may also reduce fruit set. To explore the possibility of controlling the time of flower opening, preliminary trials where made in 1966 with the synthetic growth retardant, Alar. (Alar is not registered for commercial use on almonds.) These trials indicated that this compound not only reduces shoot elongation, but also extends the winter dormancy in almonds, thus delaying the opening of the blossoms.

In 1967, more extensive trials on several almond varieties growing in Davis and in the Manteca-Ripon area confirmed earlier findings that Alar reduces shoot length in young trees as shown in photo 1. On large, mature trees sprayed with Alar at 2,000 and 4,000 ppm in June, the average nut and kernel weights were reduced (table 1) causing a reduction in total yields (table 2). It is not known whether this reduction was a direct effect of the

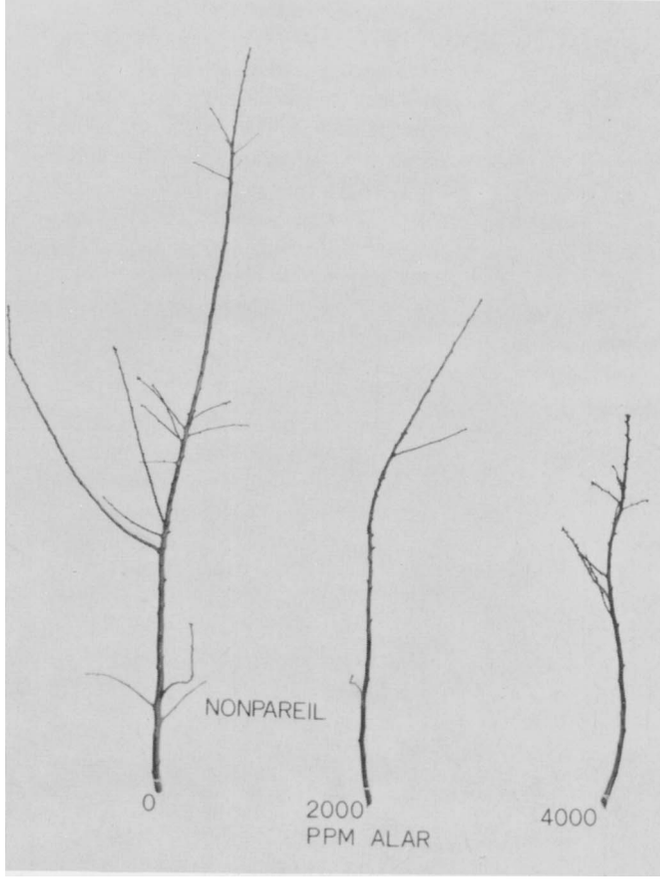

Photo 1. Shoot from control Nonpareil tree (left) and two that were sprayed in June with Alar (right). Photographed January, 1968.