# *Heliothis*: a Global Problem

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**Abstract**

*The geographical distribution of the major pests,* Heliothis armigera, H. zea, *and* H. virescens, *and the crop losses caused by these are reviewed. Although it is generally considered that the destruction of natural enemies by pesticide use and changes in cropping patterns and management have promoted these insects to major pest status, there are areas where* H. armigera *is a serious pest, although traditional agriculture is still practiced, and no pesticides are used. The dangers of a further increase in losses to* Heliothis spp *by breeding more susceptible crops are described. There is a need for a more imaginative and holistic approach to research directed towards the management of these pests.*

**Résumé**

Heliothis, *un problème global: La communication fait le point sur la répartition géographique des ravageurs importants que sont* Heliothis armigera, H. zea *et* H. virescens, *ainsi que les pertes culturales qui leur sont dues. En général, on considère que la destruction des prédateurs naturels, due à une utilisation de pesticides et des changements dans les modes de culture et de gestion, a permis que ces insectes s'élèvent au rang de ravageurs importants. Cependant, on trouve des régions où l'on pratique une agriculture traditionnelle, sans application de pesticides, et où* H. armigera *pose de graves problèmes. Les dangers d'une augmentation éventuelle des dégâts imputables à* Heliothis spp, *suite à une sélection de plantes plus sensibles à cet insecte, sont décrits. Il faudrait adopter une approche plus imaginative et globale dans la recherche sur la lutte contre ces ravageurs.*

## The Pests and Their Distribution

Of the many recorded *Heliothis* spp (Todd 1978), only a few are of major importance as crop pests. However, the polyphagous nature and wide geographical spread of some of these (Hardwick 1965) merit their consideration at an international level.

Here at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), we are mainly concerned with *Heliothis armigera* (Hb.), a species that has been recorded as damaging 60 cultivated plant species and at least 67 other plant species in 39 families across Africa, Asia, and Australasia. It is likely that this recorded list of host plants is only a fraction of the total number of plants on which this insect can, and does, feed. A systematic study of the host range is long overdue, for this could give information concerning the chemical and physical attributes of plants that determine their attraction and edibility. The geographical range of *H. armigera* extends from the Cape Verde Islands in the Atlantic, through Africa, Asia, and Australasia, to the South Pacific Islands, and from Germany in the north to New Zealand in the south. It causes most damage in the semi-arid tropics, however, and so is of prime interest to ICRISAT.

Until the middle of this century, this insect had been considered to be identical to the cotton bollworm or corn earworm of the USA, which is now known as *Heliothis zea* (Boddie), thus accounting for the common name, American bollworm, that is still used to describe *H. armigera* through much of the Old World. Subsequently, however, Common (1953) working in Australia and Forbes (1954) in the USA, concluded that there were specific differences between these insects. It has been generally accepted that these two species, which are very similar in all aspects, between them circle the earth, with *H. zea* across the Americas and *H. armigera* stretching across all the other tropical

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and subtropical countries, with no geographic overlap.

This tidy and simple distribution has not gone unquestioned, however, and there have been many suggestions that there is subspecies differentiation, and even differences that merit the erection of species among what are now regarded populations of *H. armigera* across the wide geographical range. Here in India, Bhattacherjee and Gupta (1972) distinguished two species from within the commonly accepted *H. armigera*. They considered that collections from different plant hosts showed consistent differences in taxonomy that merited specific separation. Subsequently, Bhatnagar (ICRISAT 1976) studied the range of the cited taxonomic characters of insects collected from those host plants and concluded there was continuous variability within populations and no consistent differences associated with the collections from the different hosts. However, we frequently encounter puzzling differences in apparent host-plant preferences of *H. armigera* across and between areas and cannot rule out the existence of at least subspecific differences between populations. For example, in southern India, at Coimbatore, *H. armigera* seldom reaches pest status on cotton, but many moths of this species are caught in light traps through the cotton season, and this insect is a major pest on the legumes and other crops in this area. A few miles to the south and a few hundred miles to the north, *H. armigera* is a very damaging pest of cotton in most years.

We have much to learn from such puzzles, through the discovery of the reasons why *Heliothis* is not a pest on some crops and in some areas. Unfortunately, we concentrate all of our efforts on crops and areas where *Heliothis* is a major problem and await a brave, farseeing research supervisor who will direct his staff and funding to do otherwise!

The third most important species is *Heliothis virescens* (F.), which burst into prominence as a major pest on cotton in the Americas in the middle of this century. Its common names, tobacco budworm and tomato budworm, reflect the crops on which it caused most concern in both North America and the West Indies in the early part of this century. Although this species had been recorded on cotton in the Virgin Islands by Wilson (1923) it did not merit concern on this crop until the 1930s, when it was recognized as having become a major pest of cotton in some areas of South America, particularly in Peru (Wille 1940). Hambleton (1944) reviewed the pest status of this insect and noted the association of the use of arsenical dusts and the increased attacks by this pest. He recorded that in 1942-43 a general recommendation to farmers not to dust their cotton led to a sharp decline of this pest, largely through the resultant increase of its natural enemies, particularly in an area with a wide range of host plants.

The spectacular rise to infamy of *H. virescens* in North America is so well known that we need not devote much time to this. *Heliothis virescens* had been recorded as a pest of cotton in Louisiana in the mid-1930s (Folsom 1936), but it was the widespread use of DDT and other chemical pesticides from 1950 to 1970, primarily to control *Anthonomis grandis* Boheman, the boll weevil on cotton, that forced *H. virescens* into prominence (Adkisson 1971). The elimination of its natural enemies and the resistance of the pest to all available pesticides allowed it to cause so much destruction that it closed down cotton growing in very large areas and so caused enormous economic upheaval. The publicity given to these events induced a widespread realization that chemical insecticides could not be relied upon to insulate farmers from insect pests, gave a tremendous boost to integrated pest management, and so led Adkisson to comment that *H. virescens* had become a beneficial insect!

In addition to the "big three" *Heliothis* spp, there are others of localized or of minor-crop importance. *Heliothis punctigera* (Wallengren) is a pest of a wide range of crops in Australia. *Heliothis peltigera* (Schiff) is widely distributed across Europe, Africa, and Asia, causing some damage to cotton and safflower. *Heliothis assulta* (Guenee) is widespread through Asia and Australasia, with a different subspecies occurring in Africa (Hardwick 1965), and causes some damage to solanaceous crops. *Heliothis viriplaca* (Hfn.), which earlier featured in the literature as *H. dipsacea*, merits pest status on several crops, including cotton and several legumes, from southwest Asia well into USSR.

## Losses Caused by *Heliothis* Spp

As with many other pests, there are few well-researched estimates of losses caused by the *Heliothis* spp. It has been generally assumed that the losses are greatest on cotton, for it is on this crop that these pests have received most attention. On cotton and other crops, *Heliothis* spp form only a part, but often a major part, of the pest complex, and so it is difficult to apportion the losses, even where the total losses are known. Losses to *H. zea* in the United States have been estimated to reach "hundreds of millions of dollars," and the losses to *H. virescens* through the 1960s and into the 1970s must have reached similar sums. The cost of chemicals used on cotton to suppress *Heliothis* spp were estimated by Ignoffo (1973) to be in excess of $50 million per year.

In Australia, Alcock and Twine (1980) estimated that *Heliothis* spp cost over $16 million in the state of Queensland alone each year, with major losses on sorghum, cotton, tomatoes, tobacco, and safflower, and with substantial losses on 11 other crops. These estimates included both the cost of protection designed to reduce crop loss and the residual losses. Elsewhere in Australia, the destruction of natural enemies and resistance of *Heliothis* spp to insecticides (Wilson 1974) led to a situation in the Ord scheme where the pests could no longer be controlled, and cotton-growing had to be discontinued, so leading to large losses and the need for a substitute crop that was not susceptible to *Heliothis* and could be grown profitably. In Africa, there appear to be no recent estimates of losses in cash terms. It is not difficult to estimate, however, that the loss of cotton to *H. armigera* in Tanzania alone must amount to more than $20 million in most years, a loss that may appear small in the developed countries, but is a massive sum when related to the economy of that developing nation. In Sudan, this pest is now costing the Gezira and other cotton schemes enormous sums both in yield losses and in pesticide costs.

In India, there are no published estimates of losses caused by *H. armigera,* but calculations based upon ICRISAT surveys of farmers' fields indicate that the annual loss of the two major pulses, chickpea and pigeonpea, may exceed $300 million per year, and losses in other legumes, cotton, cereals, and other crops must add substantially to that total. Such estimates certainly justify the increased research attention that is now being paid to this pest.

## What Promotes *Heliothis* Spp to Pest Status?

The *H. virescens* saga in the USA convinced some scientists that the pest status of *Heliothis* spp has been almost entirely pesticide-induced. Consequently all *Heliothis* spp have recently been regarded as "upset pests" that can be easily relegated to minor status by measures—including a reduction in pesticide use—that will allow the natural control elements to decimate the populations. This simplistic approach has undoubted merit in some cases, particularly in relation to *H. virescens,* but certainly not in the case of *H. armigera* in many of its endemic areas.

*Heliothis zea* was a major pest of several crops, including maize and cotton, well before the widespread use of pesticides. At the turn of the century it was considered to be of sufficient importance to merit a 149-page USDA Bulletin (Quaintance and Brues 1905), and Hyslop (1927) considered this to be the third most destructive pest in the USA.

*Heliothis armigera* has been the dominant and primary pest of cotton in some countries of Africa, including Tanzania, both before and after pesticides became widely used. In India it is the dominant pest on cotton in some areas and on several other crops, particularly pigeonpea and chickpea, in most areas. On both the major pulse crops, *H. armigera* commonly destroys more than half the yield, yet even now less than 10% of the farmers use any pesticides on these or other crops on which this pest is particularly damaging. In such circumstances, the pest status cannot be attributed to man's misuse of pesticides and the answer is certainly not a reduction of pesticide use.

It is commonly considered that *Heliothis* spp are becoming an increasing problem, this being associated with improving agriculture. Quantitative evidence of increasing intensity or extension of the areas of attack is available from only a few areas, however, for there are usually no base data of quantitative records of populations or losses.

There is little doubt that *Heliothis* spp increased in importance in the United States largely because of pesticide use, but partly also because of a general improvement in cropping, leading to higher yields through the use of inputs such as fertilizer and irrigation. We know that *H. armigera* has increased in importance in Sudan and Egypt, apparently for similar reasons. In northern Nigeria, *H. armigera* was a rarity in the late 1950s, but has since become a pest; this increase was perhaps associated with the introduction of maize and tomatoes in irrigated schemes. In India, the pest populations are at present greatly reduced each year by the hot dry summers in the south and the cold winters in the north. We fear that an increase in the use of irrigation in the south is leading to an increase in the availability of plant hosts through the dry season and a subsequent increase in pest populations. We also suspect that there are substantial long-range migrations of the moths, so the north may face increasing populations as a result of developments in the south.

Scientists in the USA have demonstrated that the factors regulating populations of *H. zea* are fairly well understood, for computer programs combining these factors now permit the forecasting of populations across areas with reasonable accuracy (Hartstack et al. 1976). For *H. armigera*, however, our knowledge of what promotes differing populations across areas and years is woefully inadequate.

Perhaps the most important observation towards understanding *H. armigera* populations was made by Coaker (1959), while working in southern Uganda. He noted that *H. armigera* was not a serious pest of cotton in that area, but within 200 miles, both to the north in Uganda and to the south in Tanzania, this pest was severe on cotton. He concluded that in southern Uganda, the insect did not achieve pest status because the climate allowed both the insect and its natural enemies to thrive throughout the year. In northern Uganda and in Tanzania, however, there are prolonged dry seasons during which few host plants provide food for the insects, so populations of the pest and its natural enemies are reduced to very low levels each year. In the rainy season, *H. armigera* population increases outpace those of its natural enemies. By the time the natural enemy populations build up to influential levels, the damage to crops has already been done.

Given such evidence, we may be totally wrong in fearing that an increase in the availability of hosts through the dry season may give India increasing *Heliothis* spp problems. Here at ICRISAT we insist upon a closed season during which no crops may be grown, in an attempt to control some pests, including *Atherigona soccata*, the sorghum shoot fly. There is at least a possibility that such closed seasons could lead to an increase in *H. armigera* populations as a result of a reduction of the natural enemies. We may be providing a disruption of the natural control and so promoting the pest, just as pesticide use has done. We now have to consider whether we can find evidence that will determine whether a closed season is beneficial or harmful to the pest status of *H. armigera* in any area. It is unlikely that we will be able to contrive a replicated experiment that will allow us to test this in our fields, so we may have to rely upon computer simulations, if we can determine the meaningful inputs, including the incidence and extent of moth migration.

Disruption of the natural control elements of *H. armigera* can also occur during migrations from area to area and during shifts from one host to another in the same area. This latter effect has been clearly shown (Bhatnagar et al.: these Proceedings) in the case of sorghum and pigeonpea, for on these crops the pest transfers from one to the other, but many of the natural enemies do not.

Although most blame for increases in *Heliothis* problems has been attributed to the destruction of natural control by pesticides, there is some evidence that plant breeders have also contributed. Progress in breeding for resistance to *Heliothis* in the major host crops has been slow, and there are few instances of new cultivars particularly selected for their resistance or tolerance to *Heliothis* being released to farmers. Most breeding and subsequent testing of *Heliothis*-susceptible crops, particularly in the developing countries, are carried out in pesticide-protected fields, with yield as the main selection criterion. We have some evidence from trials at ICRISAT that such selection is likely to lead to increased losses to *Heliothis* and other pests. Good examples of this are (1) the determinate type pigeonpeas, which can yield well under pesticide protection but yield virtually nothing in unprotected fields in southern India, and (2) the tight-head sorghums, which do well under protected conditions but are much more severely attacked by *Heliothis* and other pests than the open-head types of sorghum in farmers' fields (Doggett 1954). Here at ICRISAT we appear to be unique among research stations in retaining large areas of land that are pesticide-free, and these are being increasingly utilized not only by the entomologists but also by our breeders and other scientists.

## The Future

In the past, a great deal of research effort was expended upon *Heliothis* spp, but usually on single crops, particularly cotton, and within small areas sometimes within research station boundaries Much of the research has been directed towards single elements of pest management and the literature is rich in such information. In spite of all this work, however, we have little to offer farmers in the semi-arid tropics of the developing countries in the way of practical reduction of *Heliothis*-caused losses on their crops, other than to advise them to use one or two pesticide applications. We ar nowhere near a situation where we can provide practical integrated pest management on a national, area, or even field basis, that can compete with the immediate economic advantage of using DDT

Our failure may be a result of the restriction of most research to individual crops or fields We need a more holistic approach, with emphasis upon *Heliothis* populations over areas and over time ICRISAT is ideally placed to encourage such research across India and has already embarked upon this in cooperation with scientists of the Indian Council for Agricultural Research and those working in other national and state institutes. In Australia, there is a team in Queensland that has been concentrating upon *Heliothis* management and their work may well act as a model for other areas In Africa, there appears to be no well-funded or multidisciplinary team effort to fight *Heliothis*, except in the Sudan In the United States there have been some magnificent individual contributions to the understanding and management of *Heliothis* spp, but even there greater progress could have been made if there had been integration of effort on an area, rather than on a crop, basis

We hope that this workshop will promote not only the interchange of information and ideas between scientists working on different aspects, on different crops, and in different countries, but will also stimulate a reappraisal of research policies that will result in more coordination of individual and localized research If such a reappraisal is not made, there is a danger that there will be another workshop 80 years in the future, discussing similar problems and prospects Those who have studied Quaintance and Brues' (1905) report will realize that much of the *Heliothis* research today is doing little more than rediscovering what was reported at the beginning of this century!

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