They aren't growing any cotton commercially this year on the Ord—only one or two experimental crops have been planted. Yet a few years ago this area was producing a lot of cotton. Then insect pests got out of control.

At one time the stage looked set for a similar crisis in the cotton-growing areas of the Namoi Valley of New South Wales. But for the last two seasons things haven't been too bad there. Last summer it was Queensland's turn to be in trouble.

Everywhere the cause has been the same. The cotton bollworm *Heliothis armigera* has become resistant first to DDT, and then to more of the few insecticides that are effective against the pest. In the last year of commercial cotton-growing in the Ord, growers dumped a staggering 125 kg of insecticide

> Troubles aplenty in

> our cotton fields

that, regardless of its ethics, relying entirely on insecticides for pest control doesn't work in the long run.

And the run may not be very long. On the Ord it was 10 years from the beginning of cotton production to its closing down. Resistance to DDT appeared during the sixth growing season. In the Namoi Valley it took 11 years for DDT resistance to develop.

It may seem churlish to suggest that here in Australia we could have foreseen, even before production started, that highintensity cotton-cropping would come to have arisen. In every country, the insecticide-resistant pest species have been artificial in the sense that they weren't regarded as much of a nuisance before spraying started. Everywhere the created pest has been one or other species of the *Heliothis* moth—the bollworms and budworms.

Here in Australia, the most persistent species in all areas has been the cotton bollworn *Heliothis armigera*.

Both at the Ord and in the Namoi Valley the cotton bollworm remained comparatively uncommon until fairly recently. Instead another species, the native budworm *H. punctigera*, caused some damage, but this was easily controlled by spraying small quantities of DDT. Grubs of both species attack the developing buds and cotton bolls, thus reducing yields.

Relying entirely on insecticides for pest control doesn't work in the long run.

on each hectare of cotton. That's 1 cwt an acre-quite possibly a world record.

Not only is spraying these huge amounts of insecticide on a crop expensive for the farmer, it can also be dangerous. Nobody knows for certain what effects the chemicals have on nearby wildlife, livestock, and crops, and fortunately Australia has remained comparatively free of the human health problems that insecticide spraying can cause. Even so, in one week during February 1973, the Wee Waa hospital in the Namoi Valley admitted 17 people with insecticide poisoning.

This tale of woe is not unique to Australia, in fact it is par for the course. An almost identical train of events has happened again and again in the United States, and the countries of Central and South America. The lesson from the cotton-growing countries of the world is grief if it depended exclusively on insecticides. But by the time commercial cotton-growing began in the Namoi Valley in 1961, and on the Ord in 1963, disaster caused by *Heliothis* resistance to DDT had already struck in Peru, and resistance to DDT had already appeared in one or two other countries. By the mid 1960s in the Americas, the writing was well and truly on the wall. Yet here, we are only now beginning to study the alternatives to straight insecticide use.

Biological control, in which predatory insects are introduced to control insect pests in the cotton crop, may not prove to be sufficient on its own. However, there are glimmerings that using a multipronged attack may succeed, at least in the Namoi Valley.

Man-made pests

But first let's look at how the problems

The native budworm occurs only in Australia. It feeds on a number of native plants, but in the uncultivated situation natural enemies keep its numbers low. The cotton bollworm *H. armigera*, on the other hand, occurs in all continents except America, where you find the closely related *H. zea* instead. The cotton bollworm might have been introduced into Australia, since it feeds almost exclusively on crop plants like cotton, maize, sorghum, or sunflowers.

Things began to go wrong at the Ord during December 1970. Cotton-growers found that they needed to spray on much more DDT to control *Heliothis* in their crops. Mr Angus Wilson, an entomologist who is now with the CSIRO Division of Plant Industry, was stationed at Kununurra to investigate. His studies showed that the troublesome species was in fact the cotton bollworm, and not the previously common native budworm.

Suspecting that the bollworm had become resistant to DDT, Mr Wilson carried out laboratory tests. He collected bollworms from sprayed cotton crops on the Ord River, and from unsprayed sorghum crops at two other localities in the Kimberleys. He also collected native budworms either from unsprayed cotton crops in the Ord Valley or from weeds growing close by. He compared the lethal effects of DDT on the three bollworm samples with those on the native budworms.

Cotton bollworms collected on the Ord proved 92 times more resistant to DDT than the native budworm. These results suggested that resistance to DDT had developed. But the unsprayed bollworms from Dunham River Station 64 km to the south-west of Kununurra were still 14 times more resistant to DDT than the budworms, and those from Camballin about 560 km south-west $5\frac{1}{2}$ times. So the possibility that the cotton bollworm was naturally more resistant than its relative couldn't be ruled out.

Mr Wilson therefore collected a sample of bollworms near Toowoomba, Qld, from an area well away from where DDT had been used. This sample proved to be just as susceptible as the Ord River sample of the native budworm. So resistance to DDT really did appear to be the cause of the upsurge of the cotton bollworm in the Ord. Mr Wilson thinks that the increased resistance of the Dunham River and Camballin samples must have been caused by adult moths migrating from the Ord.

During 1971, growers did what many others had done before them in the Americas—they changed to spraying DDT-Toxaphene mixture. To begin with this did the trick, but by June 1973, the bollworm had already become nine times more resistant to this mixture than the budworm. Growers then turned to trying to control the pest with a number of much more expensive and less effective organophosphate insecticides.

The Namoi too

Events in the Namoi Valley have followed a similar pattern. All went well for 11 years, during which time the region produced some of the highest yields per hectare recorded anywhere. Then in January 1973 growers began to complain of reduced *Heliothis* control using DDT. Mr Wilson visited the area late that month and collected *Heliothis* pupae from the crop. His sample contained mainly native budworms, but about one-third consisted of bollworms. However, when eggs collected in the crop from this generation of insects hatched and produced adults in February, nearly all were bollworms. So the spraying was killing only the budworms.

This discovery coincided with alarm among local growers, and the March generation had just about every insecticide in the book thrown at it. Spray costs doubled—to about \$185 per hectare. Nevertheless, the next generation caused heavy losses of buds and bolls, and estimated losses in lint production averaged about \$245 per ha. In one year the cotton bollworm had become as much of a pest in the Namoi Valley as it had after 3 years on the Ord.

Laboratory tests, which were carried out by Mr Wilson in collaboration with the New South Wales Department of Agriculture, revealed the increasing resistance. They compared the resistance of

In one year the cotton bollworm had become as much of a pest in the Namoi Valley as it had after 3 years on the Ord.

succeeding bollworm generations with a reference strain of the same insect collected from an unsprayed sunflower crop at Bathurst, some 500 km south of the Namoi Valley.

Compared with the susceptible strain from Bathurst, the cotton bollworms of the Namoi Valley were 21 times more resistant to DDT in January 1973, 103 times more resistant in February, and more than 280 times more resistant to DDT in March the same year. Resistance to DDT-Toxaphene showed a somewhat similar trend, the Namoi bollworms being 9 times more resistant to this mixture than the susceptible Bathurst strain in January 1973, and 43 times more so in March 1974. It looked as though disaster was about to strike.

Reprieve

But the disaster hasn't happened. The particularly wet summer of January 1974 caused major flooding in the Namoi Valley. The flooding ravaged the cotton crop, but it also won the growers a reprieve from the cotton bollworm, since it drowned much of the bollworm population. The insect never really recovered that year, so the growers didn't have to spray very much. As a result, insecticide resistance didn't build up any further, and, following a cool summer, resistance to DDT-Toxaphene in March this year was slightly down—to about 40 times that of the susceptible Bathurst strain.

In the meantime resistance to DDT and DDT-Toxaphene appeared for the first time last summer in the irrigated cotton at St. George, west of the Darling Downs in Queensland.

Incidentally, cotton bollworms collected from the Ord in March 1974 proved to be no less than 200 times as resistant to DDT-Toxaphene as the Bathurst strain.

The problem for the cotton-growers is what should they do next? A program using the idea of integrated pest management seems to be the only long-term hope if cotton production is to continue. Such a program is also desirable if we are to keep our environment clean. The United States, and most countries of Central and South America, are now busily setting up integrated pest management schemes for their cotton-growing areas, but few have been going long enough for them to be completely successful.

Peru, possibly, is the exception. It introduced a system of biological and integrated control way back in 1957, and the Peruvians claim it has proved very successful ever since. However, their system may not be directly applicable to Australia.

Peruvian cotton is probably unique in that it grows in irrigated valleys isolated by surrounding desert. The Peruvians also grow a different type of cotton.

In Australia, as well as in the United States, we grow very high-yielding strains of the species Gossypium hirsutum. Our cotton-growers must get very high vields to make machine-picking economic. Unfortunately these strains are also very vulnerable to insect attack. The Peruvians use the lower-yielding Tanguis strain of G. barbadense. This produces very highquality fibre, and it is much more resistant to insect attack. The Peruvians hand-pick their cotton, so they can tolerate lower yields. In addition, because of the desert climate, they can probably time their plantings to avoid the ideal time for Heliothis populations to build up.

Working with the climate

And possibly herein lies hope for the cotton-growers of the Namoi Valley as



Heliothis caterpillar beside its hole in a developing cotton boll.

well. This area is about as far south as the crop can grow; further south the growing season becomes too short. As it happens the climate is getting a bit cool for the cotton bollworm too. The pest has to survive the winter as dormant pupae in the soil beneath the dead plant trash remaining from the previous season. Mr Wilson has found that the adults do not emerge until the soil temperature rises above 18°C.

In years with a cool spring (1974 for example) this may not happen until early December, so the population cannot start to build up till then.

The fact that the pupae remain dormant in the ground for 5–6 months makes them vulnerable to attack. Cultivating the cotton residues into the soil in autumn should kill the great majority of the pupae—thus greatly slowing down the speed of build-up of large and damaging populations the following season.

In the short term it should be possible to hold the cotton bollworm at bay by doing this. Small amounts of insecticide may have to be applied too. And deft management, particularly of irrigation and nitrogen fertilizer, can make sure that the cotton crop sets as soon as possible, hopefully before the bollworm population gets too large.

This approach should give the grower a breathing space, and research workers time to find other ways of keeping bollworm populations down. Finding a cotton variety that matured earlier would obviously help.

Early in 1974, Mr Wilson joined other research workers at the CSIRO Cotton Research Unit at the New South Wales Agricultural Research Station near Narrabri. In cooperation with officers of the State Department of Agriculture, these



researchers are now trying to develop an effective system of integrated pest control for the crop.

One approach has been straight biological control with an American wasp called *Trichogramma*, which preys on all *Heliothis* species. The wasp hasn't been tried in the Namoi Valley, but releases on the Ord and at St. George in Queensland failed. The wasp could not keep bollworm and budworm numbers low enough —even two larvae per metre in a cotton row can cause serious economic damage.

Another idea was to bring in a commercial virus spray already available in America, but this proved to be too unstable and expensive—it had to be flown from the United States in dry ice. Nevertheless, Mr Bob Teakle of the Queensland Department of Primary Industries is looking at the use of local virus diseases.

Strangely enough the most hopeful agent has been around for some time. This is a bacterium—*Bacillus thuringiensis* —which by itself could not do the job. However, a research worker in America tried mixing it with the chemical chlorphenamidine and found that, astonishingly, the two had a synergistic effect that is, the two together proved much more effective than either separately. Effective control of *Heliothis* has been claimed following applications of the mixture at as low a rate as 280 grams per hectare. (Compare that with 125 kg of DDT on the Ord.)

When DDT resistance appear in <i>Heliothis</i>	red
Peru	1952
Louisiana, U.S.A.	1956
Arkansas, U.S.A.	1961
Lower Rio Grande, U.S.A.	1963
Mexico	early 1960s
Nicaragua	1965 –66
Ord River, Australia	1970–71
Namoi Valley, Australia	1972–73



The spraying's to stop boll damage like this.

Mr Wilson and his colleagues are following this up, since it should mean that control is possible using very little insecticide indeed, so resistance should take a very long time to appear.

Further north, especially on the Ord, prospects for bollworm and budworm control don't look so good. In a tropical climate the bollworms can breed all the year round, so they don't have a vulnerable phase in the ground. It may be possible to reduce the numbers of bollworms by introducing a crop-free period, and then cultivating in the crop residues and ruthlessly keeping down any weeds on which the cotton bollworm can feed. Growing sorghum and maize nearby would also have to be forbidden, since these act as reservoirs. Even so, the native budworm and the host of other potential pests that live naturally in the bush nearby would still be there.

More about the topic

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