CHEMICAL USE AND RESISTANCE - THE THREAT AND THE COSTS

N.W. Forrester

Senior Entomologist

NSW Department of Agriculture

Agricultural Research Station, Narrabri.

The threat of insecticide resistance is now widely recognised as being the single most serious problem for pest control throughout the world. Many organisms have developed resistance to pesticides, eg, bacteria, protozoa, nematodes, arthropods, fungi, rodents and weeds. However the arthropods (ie, the insects, ticks and mites) have by far been the most troublesome group. Since the first case of insecticide resistance early this century, there has been a dramatic increase in the number of arthropods resistant to insecticides so that there are now well over 500 cases. They have displayed a remarkable propensity to develop resistance to virtually all the insecticide groups developed by man including the organochlorines, organophosphates, carbamates, pyrethroids, formamidines (chlordimeform), insect growth regulators and even to biological insecticides such as *Bacillus thuringiensis*. It would seem that given the right conditions, that it is possible for arthropods to develop resistance to most toxic substances. We must learn to accept this fact and to adapt our thinking to either avoid resistance or to at least manage it.

Thus the threat of resistance has been realised, and no doubt will continue to be realised in the future. What then is the cost once resistance has developed? The answer to this question depends very much on the cropping system involved and on the availability of economic alternative insecticides. To illustrate this point I will consider the example of resistance in *Heliothis armigera* in Australia and Thailand. In the early 1970's *H. armigera* developed resistance to all the available chemical groups in the Ord valley of Western Australia. Profitability declined which eventually led to the abandonment of cotton growing in the area. However, resistance was not the sole cause for the decline of the industry in this area. It seldom is. Rather, the extra costs of production due to increased spraying of often higher rates or more expensive alternatives coupled with decreased control, result in decreasing gross margins which may already be under pressure from other economic factors. Thus resistance can often tip the balance from profitability to deficit and assumes greater importance when costs of production are high and/or cotton prices are low. The cotton industry in the Ord River was already under economic pressure from other sources and resistance was simply the nail in the coffin. Because of the high capital investment in their technologically advanced industry, cotton growers in the Ord could find no real economic alternatives. Consequently, the cotton industry was abandoned in this area and even today, agriculture in the Ord has not yet recovered.

This contrasts markedly with the situation in Thailand when *H. armigera* developed resistance to the pyrethroids. The peasant Thai cotton farmer has no real investments in his farm other than his own labour. The crop is raingrown, hand sown, hand weeded and hand picked. The only capital investment is a small mist blower. When resistance occurred control costs rose accordingly while production decreased leading to the all too familiar cost/price squeeze. In this case, low cotton prices proved to be the nail in the coffin and cotton production declined dramatically, particularly in those areas hit hardest by resistance. However, the economic consequences of this resistance were quite different. With no problems of high capital investment in irrigation lay outs or specialised machinery, Thai cotton farmers simply changed crops. Agricultural communities remained stable albeit reluctantly accepting the lower returns of alternative crops such as maize, soybeans and sesame. Thus the economic impact of resistance depends very much on the cropping system under threat. Systems which lack the flexibility to adapt to economic imbalances caused by resistance are at greatest risk to resistance. This inflexibility can be due to:

(1) High Capital Investment (which narrows the choice of crops grown to those capable of high returns).

(2) Highly Specialised Equipment (eg, cotton pickers and module makers).

(3) Necessity for a high value Cash Crop (eg, many developing countries particularly in Africa, Asia and Central and South America have become dependent on the production of cotton as a much needed source of foreign exchange).

Thus the economic impact of resistance will vary from country to country and there is little reason to believe that worldwide production of food and fibre is threatened in the foreseeable future by resistance, considering the widely varying geographical patterns of resistance development, pesticide useage and crop management practices. More likely, however, is a buildup of a resistance problem to the point at which national and regional production is threatened. Dr Gordon Conway of Imperial College in London has identified several regional food/crop systems at high risk:

- cabbage in South East Asia
- rice in South East Asia
- corn in USA
- sugar beets in UK
- potatoes in eastern USA, Europe
- cotton (in most parts of the world but with the most economic impact in the technologically advanced countries such as Australia and the United States and in the highly dependent cash crop economies of countries such as Egypt, Zimbabwe, Pakistan, Guatemala etc).

If resistance became uncontrollable in these or other important production systems, then this would cause extensive repercussions in the global food and fibre markets.

What then is the best way to combat resistance? In the past, resistance has been considered a one-way street. The problem was circumvented by introducing new chemical groups with no resistance problems. This "strategy" was mostly successful except on those occasions mentioned already, where there were no real alternatives.

It was also underpinned by an unshakeable faith in an inexhaustible supply of these new chemical groups. This was probably well founded in the heady days of the first three decades of the insecticide era (1950's to 70's) but is far from the case today. The introduction of new chemical groups has slowed down dramaticaly as indicated by the ratio of compounds screened to those marketed. This has climbed steadily from 1,800:1 in 1956 to 12,000:1 in 1977 to aproximately 50,000:1 in 1984. This productivity decline stems in part from the need to meet higher health and safety standards than in the past but mainly it is a depletion phenomenon. Effective chemicals that are easy to synthesize have already been discovered. New chemicals meeting today's criteria for success are on the whole much more complex and difficult to synthesize. They are much more expensive with the estimated cost of developing a new chemical ranging from $US30-35 million. Thus the pace of discovery is slowing, the range of chemicals is narrowing and the cost of replacements accelerating, with the result that resistance poses a more serious challenge now than it did in the first 30 years of the modern insecticide era. It must be clearly understood that new chemical groups are not mined from a bottomless pit but that they are a limited resource, which must be managed the same as other farming resources such as soil and water.

In order to confront this problem, 2 types of resistance management strategies have been introduced:

(1) Proactive (or preventative) Strategy

(2) Reactive (or curative) Strategy

Proactive strategies have been introduced in Egypt for the preservation of pyrethroids against *Spodoptera littoralis* on cotton and in Zimbabwe for pyrethroids against *H. armigera* in cotton. In these strategies pyrethroid use has been restricted to varying degrees in the hope to delay or even prevent the onset of resistance. It is important to recognise that this type of approach will probably only be possible in centrally planned economies capable of imposing such restrictions. They will also be most likely to be adopted in those situations where cash crops critical to a country's economy are at high risk to resistance. Unfortunately, I cannot see the introduction of proactive resistance strategies in free market economies. Authorities in these countries will most likely have to wait until the unequivocal demonstration of control failure through resistance before introducing a curative strategy. This has been the situation in Australia and will most likely be the situation in the United States. However, curative strategies which have to deal with the widespread high frequency of resistance genes, by necessity have to be much more restrictive but even so, have far less chances of success than preventative strategies.

The Australia Insecticide Resistance Management Strategy is probably the first truly reactive strategy. It was designed specifically to manage resistance to the 2 most commonly used insecticides in cotton in Australia (endosulfan and the pyrethroids). These 2 chemicals alone account for about 80% of insecticide use against *Heliothis* in cotton. Resistance exists to both these chemicals and it requires a delicate juggling act to balance the use of one group to counter resistance to the other. The Australian Strategy attempts this by alternating insecticides on a per generation basis alongwith a strong reliance on the use of ovicide/larvicide mixtures. In fact the use of ovicides (in particular chlordimeform) to supplement the larvicides during periods of high pest pressure, is so critical to the ultimate success of the strategy, that it is not unreasonable to claim that the Australian cotton industry is dependent on virtually only 3 insecticides for its continued existence: endosulfan, pyrethroids and chlordimeform. The removal of any one of these 3 chemicals from the system for whatever reason (resistance or legislation) would place an intolerable burden on the others. Production costs would rise dramatically without any concomitant increase in yield. Profitability would decrease and the industry would enter a period of decline, accelerated by low cotton prices.

The outcome of the Australian stragegy has important ramifications for many cropping systems throughout the world. It is really the first curative resistance management strategy and its success is critical for those economies unable to introduce proactive resistance strategies and with no prospect for the introduction of new, effective and economic chemical groups.

I would predict that resistance will remain a continuing problem for Australian cotton growers and scientists. We have one particular species of *Heliothis* (*H. armigera*) which is restricted to the cultivated crops with very few native or naturalised weed hosts. With the constant problem of recurring droughts, *H. armigera* is often concentrated onto the heavily sprayed irrigated crops with little possibility for dilution of resistance. This oasis effect, coupled with an inability or perhaps even an unwillingness to manage the use of new chemical groups, will ensure that Australia will retain its position at the forefront of the resistance development race. This notoriety is probably quite undeserved as it reflects more on the pecularities of our climate and pest biology, than on indiscriminate insecticide use.