X:\ENGLISH\RECORDER\90\SEPT

*Where X = the drive letter of the CD-ROM

Introduction

The third issue of *The ICAC Recorder* in 1990 contains a status report on the battle against pyrethroid resistance in *Heliothis spp.* Over the past five years this problem has taken on international scope and significance. The pyrethroids, only little over ten years on the market now, are considered an effective and relative safe type of insecticide for use in cotton. Losing them for *Heliothis* control would undoubtedly lead to losses in yields and higher costs of production. Thus, delaying resistance development by more intelligent use of these compounds suggests a high pay-off for both producers and pyrethroid manufacturers. The article describes the basics of the resistance management programs, reports on experiences in implementing the programs and describes the international cooperative efforts on the way.

A second article draws the attention to a new concept in plant physiology: Thermo-Kinetic-Window. Although of still limited use, this concept has potential in breeding programs, in genetic engineering, and as a tool for production managers. Research carried out in Lubbock, Texas, has proven the validity of the concept, and significant articles have been published in scientific journals.

Recently, the Technical Information Section has contracted for a third article in our series of review articles on cotton production technology. Prepared by Dr. James McD. Stewart of the University of Arkansas, the article will describe the state of the art in genetic engineering and other biotechnology in cotton and will be due at the end of the year.

Also, two regional meetings have been tentatively planned for 1991. Officials in both Zimbabwe and Brazil have agreed to host meetings of African and Latin American cotton researchers respectively. Both meetings will focus on cotton research for improved cotton quality. An announcement about dates and sponsorship is awaited shortly.

A document on current cotton research projects is being prepared for the 49th Plenary Meeting to be held in Montpellier, France, at the end of September. The document will contain brief descriptions of ongoing research projects in cotton producing countries, as well as short descriptions of the structure of research. Also, there will be a list of names and addresses of

cotton research institutes and project leaders. We would like to thank all those who have responded to our requests for information concerning this topic.

Pyrethroid Resistance Management: Theory, Research and Practice

More than forty years ago a research program was initiated by Dr. Charles Potter at Rothamstad Experimental Station, U.K., to develop a new generation of insecticides for use in agriculture and public health. The challenge was to copy, in some way, the natural pyrethrins known for centuries for their toxicity towards insects and harmlessness to mammals. It took the energy, skills and determination of many chemists and entomologists ---- as well as many millions of dollars in research and development spending of both public and private sectors ---- to overcome the numerous obstacles in developing a product with commercial potential. The main problem encountered by the researchers involved was to increase the products' photostability while maintaining a very low toxicity towards mammals.

Only in 1975 did this elaborate effort result in the initial marketing of three new substances: permethrin, cypermethrin and fenvalerate. These products represented a significant step forward in agricultural pest control. Being highly effective against almost all major species of *Lepidopterae,* as a result of the inherent chemical structure and the very low effective application rates, they were, at the same time, relatively safe for the environment. Also, because of the low application rates, they were more cost-effective than comparable insecticides. The availability of the new pyrethroids came at an appropriate time, as previous generations of insecticides were rapidly losing their effectiveness due to increasing levels of resistance in insects and unacceptable environmental hazards associated with some substances.

Presently, almost 15 years after launching, pyrethroids account for 1.5 billion dollars in sales or 25 percent of the annual world insecticide sales. In cotton protection programs alone, the pyrethroids are estimated to account for close to 50 percent of total sales of insecticides. Research to develop new pyrethroids still continues and, as patents expire, variations of existing products keep coming to the market as well. One study indicates that replacement of pyrethroids in cotton pest control in Arkansas, USA, might cost farmers an additional $35 per acre or as much as 4.5 cents a pound!

However, as early as in the 1982/83 season, pyrethroid field failures associated with resistance of *Heliothis armigera* were first reported from

Queensland, Australia. Although it is now generally assumed that resistance against any major insecticide group will eventually develop after about ten years of use, these first reports still came as a surprise to many. This is not to say that nobody anticipated such events. As early as in 1979, eager to guard the effectiveness of pyrethroids against the highly damaging *Spodoptera littoralis,* the Egyptian Agricultural Administration issued a series of decrees meant to expose each year only one generation of this insect species to pyrethroids.

Also the chemical industry has always been painfully aware that field failures would occur eventually. In 1979 all major companies involved in manufacturing pyrethroids chose to associate themselves in the Pyrethroid Efficiency Group (PEG). The objectives of this group are to compile data on resistance development and to advise and assist countries in conceiving and implementing resistance management strategies.

Over the past few years new occurrences of pyrethroid field failures have emerged from various corners, especially from the cotton world. In 1984 serious problems were reported in Thailand; in 1985 scattered but alarming field failures occurred in the USA; and in 1987 both Colombia and India had to be added to the list. But, at the same time, important lessons have been learned, a vast amount of research is underway and resistance management is in the process of being recognized as a major issue in modern agriculture. This article is a report of a conference held in April 1990 in New Orleans, where leading entomologists of both private and public entities met to discuss the achievements of the past and to set out the lines for further research and action. The report initially discusses the institutional framework presently in place to coordinate and assist the public sector in managing resistance. Following are short sections about the experience with these programs and the supporting basic and applied research associated with them.

Institutions

As mentioned, representatives of the chemical industry, with their economic interest at stake, were the first to form an association (PEG) as a means of centralizing information and advising on possible counter measures. The group has been active in both Thailand and Colombia and is presently in discussion with all parties involved in India to take a more active role in designing and implementing a resistance management strategy. We will come back to the case of India later in this article.

In 1986 it was decided that, given the potential scope and consequences of the development of insect resistance against pyrethroids, a separate industry group would focus entirely on the USA. The group, PEG-USA, has been very active in developing in an short time an elaborate monitoring system based on the quick Adult Vial Test (AVT). The objectives of PEG-USA were summarized by its present chairman, Walt Mullins of Mobay Co., as follows: to determine current levels of pyrethroid tolerance; to develop comparative data relative to laboratory and field strains of resistant *H. virescens,* to relate tolerance levels to field failures; to gain a better understanding of resistance mechanisms; to estimate the effectiveness of management strategies; and, finally, to make data available to anyone concerned with pyrethroid resistance.

In addition to the two PEG groups (PEG International and PEG-USA), the chemical industry has another working group dealing with insect resistance in general, the Insect Resistance Action Committee (IRAC). This committee operates under the flag of GIFAP, the agrochemical industry international association. GIFAP has other such committees dealing with herbicide resistance and fungicide resistance, respectively.

The objectives of IRAC are to give expert advise to GIFAP, to handle public relations concerning insect resistance, to present the industries' view on this matter, to work on technical strategies to counter resistance, and to do applied research. IRAC also has a subgroup focussing exclusively on the situation in the USA (called IRAC-USA) and it has a subgroup on cotton insect pests. Apart from the *Heliothis virescens* issue, the group focuses on resistance problems in aphids, mites and whitefly. The group provides protocols for monitoring techniques, makes available resistant strains and collects and tabulates data from all sources. It cooperates closely with the PEG.

A fairly recent development is the formation of the International Organization for Pest Resistance Management (IOPRM). This organization, still in the process. of establishment aims to bring together governments (research, extension and regulatory agencies), U.N. organizations (FAO, UNEP, WHO), universities and international agricultural research institutes, farmers' organizations, the food industry, the agrochemical industry, and consumers organizations. The objectives of this broad-based organization will be "to promote the concept of pest resistance management within the context of Integrated Pest Management (IPM) and to facilitate the implementation of programs in industrial and developing countries and in emerging democracies." As a first goal, IOPRM will organize the First International Pest Resistance Management Congress which will serve at the same time as the first General Assembly of the organization. At this occasion, planned for October 1991 in Washington DC, it is expected that a drafted congressional charter will be adopted and a budget and working program will be assigned. Expected budget requirements are $500,000. The pre-establishment activities are underway thanks to sponsorship from GIFAP and USAID.

Within IOPRM several working groups are operating, one of them on Insect Resistance Management. The chairpersons of this group are Dr. G. Jackson (IRAC/GIFAP) and Dr. R. Frisbie (Texas A&M University, USA). A cotton subgroup headed by Dr. Frisbie will present a status report at the congress on insect resistant management strategies implemented in various countries. This subgroup consists of specialists in the field of biology, entomology and social sciences. To prepare their status report, fact-finding missions will be conducted in Central America, Thailand and Francophone West Africa.

Mechanisms of Resistance

To ultimately develop compounds which would extend the economic life of existing pesticides or to introduce new products with a supposedly longer period of effectiveness, it is important to understand better why certain individuals develop tolerance to particular control agents.

In the case of *Heliothis,* this type of research is mainly conducted at the School of Animal and Microbial Sciences of the University of Reading in the UK. The program is directed by Dr. Allan McCaffery who was in New Orleans to report on the latest findings.

The objectives of the research program are to examine in detail the mechanisms of resistance of *Heliothis* against pyrethroids, to develop rapid diagnostic tests to determine which type of resistance is present, to conduct a breeding program to increase the availability of various types of strains for research, and to develop a model able to explain and predict the development of resistance.

Extensive research has revealed that in principle four mechanisms of resistance exist:

- Reduced cuticular penetration
- Increased rate of metabolism aided by enzymes of the mixed function oxygenase type
- Nerve insensitivity
- Alterations in behavior

Of these four types of resistance, research indicates that the increased metabolistic activity is of major importance in the onset of resistance. Resistant larvae excrete metabolized cypermethrin at a much faster rate compared to susceptibles. Also, by combining doses of cypermethrin and the monooxygenase inhibitor piperonyl butoxide (Pbo), a considerable reduction in the LD50 and LD90 were obtained. At a concentration of 1 percent

Pbo, the effective dose of cypermethrin required was only 10 percent of the dose without Pbo.

Regarding nerve insensitivity the experiments measured spontaneous multi-unit activity (sMUA) of the lateral nerves of the first instar larvae. For this purpose a dorsal incision is made in the body wall exposing the dorsal nerve. Activity of the nerve in contact with various doses of cypermethrin was measured with an electrode. It appeared that some tolerant individuals had the same nerve sensitivity as the susceptibles, whereas others showed more, and sometimes considerably more nerve insensitivity. The significance of these results is not yet clear but it appears that nerve sensitivity does play a role, which varies from strain to strain.

Delayed penetration has been proved as well but is considered of minor direct importance. However, it is hypothesized that it may well have an influence on other mechanisms of resistance. Relatively little research is done on behavioral alterations. At present this is considered to be of less importance.

The researchers indicate that the principles used to detect a metabolistic type of resistance (foliar residue test in combination with radioactive labeling of cypermethrin followed by a study of the body excretions, as well as those used to detect nerve insensitivity and delayed penetration) can be used to develop diagnostic kits to analyze the resistance mechanisms at work in field strains in different parts of the world.

In the USA research carried out by Dr. Bill Plapp at Texas A&M University indicates that in the tolerant strains, isolated in the USA, nerve insensitivity seems to be the dominant resistance mechanism. It is also strongly suggested that this trait is genetically determined by one single gene of the recessive type. This, of course, would have important implications for the rate of development of resistance and the associated resistance management programs.

Resistance Management with Imperfect Knowledge: Theoretical Considerations

In a presentation by Richard T. Roush of Cornell University, Ithaca, some light was shone on the theoretic principles behind the selection of an effective pesticide resistance management strategy. According to Dr. Roush, the selection of a proper strategy is presently done largely in the absence of extensive knowledge on resistance genetics and its mechanisms. Instead, the choice and development of a strategy has been guided by pragmatic arguments and a careful evaluation of the existing options. In his presentation Dr. Roush argues that this procedure works out satisfactorily, permitted that the reasoning takes account of some basic principles. Models were constructed to evaluate the effectiveness of some of the most debated strategies such as using mixtures, increasing doses, or the use of two or more pesticides in an alternated fashion. His measure of effectiveness is defined by the number of generations of a given pest population which can be economically controlled by a pesticide.

Pesticide resistance management strategies mostly aim at minimizing the relative fitness of resistant genotypes, either by allowing at least some susceptible homozygotes to survive or by killing resistant homozygotes as well as heterozygotes. Although there are various ways in which both objectives can be at least theoretically obtained, Dr. Roush argues that with the presently available technologies and current standards for crop protection only a limited number of strategies merit further consideration. Therefore, on practical grounds, the real options in pesticide resistance management are higher doses (killing the resistant genotypes) or lower pesticide doses (survival of more susceptibles), and the issue of either alternating two or more pesticides in time ("alternation strategy”) or alternating across space ("mosaic strategy”), or the use of mixtures.

Concerning the issue of higher versus lower doses of pesticides various arguments can be advanced. Two major problems are associated with the high, kill-all, dose. Firstly, it cannot be assumed that for practical and economic reasons, all resistant genotypes will be killed with a given pesticide. If, for example, only and exclusively some resistant homozygotes would survive, resistance would occur very quickly. Studies show that this strategy can only be successful if the resistant allele is very rare. On the other hand, it has been shown that it is extremely useful to set doses at such a level that at least a fraction of the susceptible homozygotes can survive or immigrate, to interbreed with the resistant genotypes. For the same reason it is recommended that pesticides have a short enough persistence to retain the fitness of the immigrating susceptibles.

Other studies have shown that lowering the doses would not present many positive results either. In order to maintain a significant competitive susceptible population it was shown that applications had to be reduced to a 30 percent survival rate of susceptible homozygotes, a level unacceptable for proper crop protection. Also it is argued that, in the case of *Heliothis armigera,* changing the doses would simply put the survival stress on a different larvae age group and, therefore, only shift the "selection window" back and forth. Reviewing these arguments Roush comes to the conclusion that the high versus low dose is simply a "dead-end," not leading to any improvement in strategy.

The other issue, alternation versus mosaics versus mixtures, presumes that at least more than one effective pesticide is available. It is assumed that resistance genes against these pesticides are non-linked and are not located very closely on one chromosome. The principle behind both alternation and mosaics is that a fraction A of the susceptibles has a distinct advantage of fitness over the resistant genotypes if the period pesticide A is not applied, and another fraction B, when pesticide B is not applied.

To compare the effectiveness of the multi-pesticide strategies, Dr. Roush constructed a simulation model. The essential assumptions for this model are the existence of two non-linked resistances alleles against pesticides A and B respectively, a fraction of 10 percent always escapes treatment, the applied dose has no effect on resistant homozygotes, a varying fraction of the resistant heterozygotes survives, and susceptible homozygotes have varying fitness advantages.

When the strategies alternation and mosaics are compared, the model suggests that there is hardly any difference in the time after which resistance develops, provided that the susceptibles have zero fitness advantages. However, when these advantages do exist and resistance is more recessive, an alternation strategy clearly outperforms a mosaic strategy. It should be noted that the model assumes completely random mating.

The reason for this result is that in the case of alternation all of the surviving heterozygotes suffer reduced fitness at any time, whereas in mosaics, because of the random mating, some resistant heterozygotes are as fit as their competitors.

From this it also follows that any overlap in generations, while changing from one pesticide to the other, should be reduced as much as possible. Weekly alternations between pesticides are far less effective than alternations based on the life-cycle of the insects. It also follows that farmers' non-compliance to an alteration program reduces the program to a mosaic type of strategy and thereby reduces its efficiency significantly.

Comparing an alternation strategy with the use of mixtures, Roush quotes from a study by Mani which concluded that mixtures are always more effective than alternation as long as some fraction of the population escapes exposure. Roush's simulation study, however, points at two more critical assumptions regarding the dominance of mixtures: the pesticides in the mixture should have equal persistence, and each of the pesticides should be 100 percent effective against susceptibles. The model showed that even a 5 percent difference in persistence could change a mixture to a worse strategy. On top of these two prerequisites it should also be certain that at least a threshold fraction of the population escapes exposure or, alternatively, there is a threshold recruitment of susceptibles from untreated nearby populations.

As, in contrast to other biological parameters, both persistence and efficiency can be easily measured, it would be possible to establish *a priori* which type of strategy would have the highest probability of success. Although research on resistance mechanisms is highly valuable, the simulation models indicate that it is possible to select a management strategy without full knowledge of these parameters. In most practical cases it seems that alternation strategies outperform mosaics in delaying resistance. Limiting the choice to one between alternation and mixtures, the outcome seems to depend, then, on easy-to-measure parameters. Evidently, this does not mean that there are no uncertainties, but according to Roush these are the same uncertainties that appear in any integrated pest management program which, at least for the time being, are part of the occupational risk of the entomologist.

Monitoring the Evolution of Resistance in the USA

In the USA field failures of *Heliothis virescens* first occurred in 1985 in Texas. In 1987 the PEG-USA Pyrethrold Resistance Monitoring Program was initiated. In 1988 this program was expanded with increased cooperation from non-industry researchers. The main activity of the group has been the development of a massive monitoring system to evaluate changes of *Heliothis virescens* tolerance to pyrethroids.

For this purpose pheromone traps are placed at monitoring sites throughout the US cottonbelt. The trapped adult male moths are then subjected to a standard toxicity test. Since its start in 1987, the group has opted to use the Adult Vial Test developed by Dr. Bill Plapp. The glass vials are coated with increasing doses of cypermethrin (doses 1, 3, 10, 30 and 100, mg/vial). One moth per vial is used and 20 moths are tested for each rate. After 24 hours moths are counted as live, moribund or dead. From these results LC50/LC90 values are calculated. For comparison a pyrethroid susceptible strain (labeled BRC) was tested using the same method. The Adult Vial Test is mainly retained because of its convenience of use under field conditions. The 10 mg ai/vial dose has generally been agreed on as the discriminating dose for *H. virescens.* Adults surviving this dose are considered homozygous pyrethroid resistant. Surviving fractions of this dose are the key variables used in most analyses of the PEG-USA group. Other tests such as the foliar residue test and a topic test would discriminate better between susceptible and tolerant individuals, but they take more time and are more expensive.

In the 1987 season a total of 12,500 moths were tested. This number increased to 60,000 in 1988 and even more in 1989. The majority of efforts are concentrated in the Mississippi Delta and Texas.

The essence of this massive monitoring effort is to be able to detect changes in susceptibility of insect populations over time and space, and eventually measure the impact of resistance management programs. The data collected in 1987 serve as baseline data and later observations are evaluated in relation to these.

A problem with this monitoring program so far is that the obtained susceptibility data do not seem to correlate well with experienced field failures and, therefore, are not suited as predictors of such events. The reason for this is that an actual field failure depends on more factors than the level of tolerance alone. Most importantly, field failures are very much related to the general infestation level of the field and to the frequency of highly tolerant larvae in that particular field. Also, it should be kept in mind that the AVT measures susceptibility in adults which does not necessarily correlate fully with susceptibility of larvae.

After three years of monitoring the following main conclusions were drawn:

- Since 1987 resistance levels appear to have decreased in some areas (Texas), and increased in others (Mississippi, Louisiana). The resistance management programs in place in the mid-South states and Texas appear effective in delaying resistance development.
- A definite seasonal pattern in susceptibility levels could be determined. Levels peak in August and September with moderate decline in the fall.
- Resistance levels may vary considerably within a single county. Also levels may vary significantly on one location on successive days. These observations lead to reflections on sample size and migration activity.
- In many instances higher resistance levels were associated with higher population levels. In this respect, it is suggested to look into eventual measurement bias.

- Standard deviations for survival values from the AVT were frequently large.
- Pyrethroid tolerance extends to all pyrethroids.
- There is a general satisfaction with the AVT as the key monitoring devise despite some limitations.

In addition to these conclusions, an increasing tolerance in *Heliothis zea* was observed in the Southeast last year. This fact was viewed as very disturbing as *Heliothis zea* is generally more difficult to control and is a significant pest for a wide range of crops.

Finally, it has been found that first instar larvae of resistant parents can be controlled with normal doses provided that no egg hatch or larvae escapes.

Pioneering a Resistance Management Program: the Australian Experience

The past growing season has been the seventh season in which the Field Crop Insecticide Resistance Management Strategy has been in place. The case of Australia could be considered as a test case for the elaboration and implementation of resistance management programs based on chemical alteration. Although such programs had been previously put into practice in Egypt and Zimbabwe, the principles had never been tested in a situation where resistance was already in an advanced stage.

The Australian cotton industry has been very quick to respond to the first field failures of *Heliothis armigera* control with pyrethroids. Within six months a control strategy was conceived which could be implemented the cropping year succeeding the first field failure. Certain factors have been particularly beneficial to this quick response: the presence of a relatively small number of large farms, the high level of expertise available in the Australian agricultural community, a strong sense of common interests among farmers, full cooperation from the agrochemical industry and the efforts of a number of committed and highly energetic individuals.

It is important to realize that the Australian pest resistance management program does not limit itself to cotton and that it targets more insects than *Heliothis armigera* alone. In fact, the program covers all summer crops (cotton, sorghum, maize, wheat, soybeans, sunflower etc.) and intends to slow down resistance against both pyrethroids and endosulfan in, among others, *Heliothis,* the sorghum midge and armyworm. The strategy divides the season in three stages: the first from early September to January 10, in which no pyrethroids are applied; the second from January 10 to February 20, in which pyrethroids are used in case economic thresholds are reached; and the third after February 20, when the pyrethroids are not to be used anymore. In addition to this calendar, the program demands the discontinuation of the use of endosulfan, except for cotton, after February 20.

To monitor the development of resistance and the effectiveness of the program, Australian researchers have opted to subject the larvae hatched from field collected eggs to discriminating doses of fenvalerate. Susceptible strains collected in the field serve as the standard against which resistance is measured.

The results show an escalating effect, with resistance at a low at the start of the season, rapid increases during stage two, and decreasing resistance in stage three to levels just above those prevalent at the start of the season. The high of the peaks in stage two and the degree of decrease in stage three seem to depend on the population pressure and the associated spraying frequencies. In 1987/88, a season with only moderate *Heliothis* pressure, the peak in stage two was lower than in the two previous seasons and the decrease in stage three brought resistance back close to the level prevailing in 1984/1985. However, with severe selection pressure in 1988/89 resistance reached unprecedented levels (close to 80% survival of the discriminating dose!) An important factor is thought to be the increase in resistance in locations outside the program area, which previously provided for a pool of susceptibles frequently immigrating into the program area.

For the 1989/90 season, the stage two period in the strategy has been contracted to only five weeks, ending February 13. The argument forwarded is that it brings the "pyethrold window" back to 35 days which does correspond better with the generation time of the developing larvae. In other words, a 6 week "window"implies applications on both third instar larvae and adults during the sixth week, which results in a surge in resistance in the week after the "window” closes. For the growers this will mean an increase in crop protection costs, as the chemicals used in stage three (mostly endosulfan) are more expensive than the pyrethroids. Preliminary data from the 1989/90 season show that this modification has at least stopped further deterioration of the situation regarding pyrethroids. Unfortunately, however, the season did produce the first endosulfan field failure.

The Australian experience shows that it is possible to implement and execute a full scale resistance management program based on alteration of chemicals. It shows as well that it is not possible to eliminate resistance or even to exclude further deterioration. Perhaps, the most realistic expectation should be that the economic life of the chemical compounds subject to resistance development can be extended by about five to ten years.

The complement of the chemical alteration program in this respect is research to develop synergists or newly structured pyrethroids. In the field of synergists Neil Forrester reported that, so far, experiences with piperonyl butoxide (Pbo) are not favorable due to poor light stability (effective residual life of less than one day), and limited supplies (Pbo is an abstract from the bark of a tree originating in the Amazon regions of Brazil, therefore, difficult and expensive to produce). Also, there are some concerns that resistance to the mixture might develop quickly if it is used commercially without any limitations or guidelines. Other fully effective synergists under study are Sesamex, synthetic analogues from Endura Spa and Sumitomo, and the two propenyl ethers/esters: TCPB (from T. Brown at Clemson) and CGA 84708 (Ciba Geigy). All experiments done with oil solvents and formamidines (e.g. chlordimeform) did not lead to useful results. Other promising research aims to make some adjustments in the chemical structure of the pyrethroids in a way which would make them less exposed to multi-function oxidase enzymes. For this purpose specific "vulnerable" sites in the molecule will be replaced by stable halogens. Dr. Forrester expressed confidence that such compounds could be available shortly.

The Art of Implementing a Resistance Management Program: India

The concept of reducing the speed of resistance development with a resistance management program based on within-season chemical alternation is well accepted. Apart from Australia, such programs are put in place in parts of the USA, Zimbabwe, Egypt (preventive) and Colombia. However, the implementation of such a program is by no means an easy affair. The process from actual conception to execution and control demands an industry-wide commitment from farmers, the chemical industry, regulators and scientists. It should not be regarded as a surprise when such an effort creates friction, conflict, delay or even failure. It has been reported that in Turkey, after the first field failures occurred, authorities opted rather to prohibit the use of pyrethroids altogether in light of the anticipated difficulties related to implementing a resistance management program.

It needs little insight to see that some characteristics of a cotton industry should be viewed as unfavorable toward an effective execution of an RMP, while for others the reverse would apply. One factor is related to the sheer numbers of players in the field, e.g., number of farmers, number of chemical companies, number of formulators, and number of states involved (or regulators). The more substantial these are, the more complicated the whole process will be. Other factors are related to the lines of communication between all industry segments involved.

Dr. Walter Reed, chairman of PEG International, reviewed some of these factors, as perceived by the Group, in the case of India. As mentioned, field failures of *Heliothis armigera* control were reported in the state of Andra Pradesh in 1987, following the immigration of substantial numbers of tolerant individuals into the research sites of ICRISAT in Patancheru, A.P. Also severe outbreaks of *Bemisia tabaci* in 1985 and 1986 in the same state have been associated with the ineffectiveness of the synthetic pyrethroids against this species. Some sources report that the average number of sprays in the state of A.P. is between 15 and 20 instead of the recommended 8 to 10. Partly as a result, cotton yields have been reduced substantially from a level of 608 kg/ha seedcotton in 1983/84 to only 263 kg/ha in 1987/88.

The situation has led to great concern in all segments of the industry. First and foremost, farmers have seen their revenues severely reduced and are facing replacement of pyrethroids by much more expensive products. Also the chemical industry is alarmed by a potential loss of a $77 million pyrethrold market. An industry association was formed along the model of PEG. Scientists have called meetings and workshops and requested the assistance of international experts. A "window"strategy was conceived, announced and partially implemented. However, despite all of these efforts there remain large obstacles before an effective (large scale) RMP is set in place. Fortunately, there are large populations of susceptibles left in the region which following migration will dilute tolerance as apparently happened in 1988, when virtually no tolerance could be detected.

According to Dr. Reed the complicating factors are numerous. A varying planting date makes the definition of an acceptable window in calendar terms almost impossible; most cotton varieties are late in maturing as they fit better into their cropping system or, in case of the extralong staples, fetch better prices; the number of pyrethroid manufacturers, as well as the number of formulators, is rather substantial (about 800, of whom more than 600 are independent, often operating very small units without much quality control); the cheapness of the pyrethroids compared to the other chemical components which has led farmers to overuse them; the widespread use of mixtures; the pursuit of political goals in some regulations in conflict with easy management of an RMP; high illiteracy levels among farmers making any written, quasi-scientific communication less effective; the widespread perception among farmers that rainfall is the dominating yield-determining factor, obscuring yield decreases associated with insect damage; and the prevalence of insect-use recommendations not based on the advise of entomologists.

The accumulation of these facts and perceptions would tend to let one think that the execution of an effective RMP under these circumstances represents a challenge in the cotton world more than anywhere. According to Dr. Reed this is the very reason why PEG International is eager to assist the local authorities and scientific community in overcoming some of the anticipated problems. The Group feels it can assist in developing an indispensable monitoring program, in suggesting guidelines for the agrochemical industry in relation to resistance management, in participating in educating farmers and retailers about the necessity of a sound spraying program, and in stimulating better interaction among industry, government and university agents.

Concluding Comments

Various speakers at the seminar emphasized that any RMP should be conceived in the wider context of an integrated pest management (IPM) program. Any insect management program should start out by selecting an appropriate variety (early season, pest tolerant), optimal and uniform planting dates, followed by an eventual early season in-furrow systemic insecticide application. Working from that basis the insect management program itself should benefit from regular scouting, sound sampling procedures and well-conceived economic thresholds. Especially in the case of the boll weevil, any program should have a regional scope rather than a farm by farm approach. Later in the season a correct date of crop termination is of vital importance for insect management.

Several speakers pointed to the importance of good timing for pyrethroid applications for *Heliothis* control. Research indicates that even tolerant individuals are still susceptible to normal doses of pyrethroids at the first instar larvae stage. This means that spraying should ideally coincide with the "brown egg" stage, and consequently be based on scouting of eggs.

Finally, an optimistic note came from Marc Whalon, chairman of the University Association WRCC 60 and editor of the *Pest Resistance Management Newsletter.* In his analysis, the recent and anticipated advances in molecular biology should provide the agricultural sector with new sophisticated arms to be employed in crop protection. Careful study of the plant-insect interactions will provide new fronts of attack, while the laborious screening of genes from plant and insect species will no doubt result in useful control strategies. Presently there are new tools being developed which would greatly facilitate both these study areas. Diagnostic tests based on DNA labeling, immunological studies focussing on correct identification of antibodies, and the introduction of particle acceleration guns to achieve gene insertion are only a few examples.

The development and application of new technologies in crop protection is, according to Whalon, governed by the genetic pool available to work with, the cost to produce genetically altered plants and insects, the ecological acceptability of these technologies, and socioeconomic factors. Within these limits, creativity, hard work, and sufficient support should secure the edge for the agricultural producer in his efforts to protect his crop.

Sources:

Various presentations at the seminar on Pyrethroid Resistance Management, organized jointly by PEG and IRAC, New Orleans, April 26, 1990.

Thermal Kinetic Window, Concept and Relevance in Cotton Production

One of the most stimulating disciplines today in cotton research is plant physiology. It has especially benefitted from new instruments and test protocols developed for the study of human and animal physiology. Most of this is basic research and generally hidden from the public eye, until new products or new technologies emerge from it.

Over the past two years a number of publications in the field of plant physiology, have dealt with a new concept in cotton research: the Thermal Kinetic Window. Most authors (see sources) are associated to the Plant Stress and Water Conservation Research Unit of the Cropping Systems Research Laboratory in Lubbock, Texas, USA.

In general terms the concept of Thermal Kinetic Window (TKW) has evolved from research into causes of plant stress. Plant stress is a term used by physiologists to indicate suboptimal conditions for growth, either due to physical conditions (climate) or biological conditions (pests). It has been found that because of stress of either nature, cotton yields only 20 percent of its potential. Although it would be economically impossible to grow a cotton crop under stress-free conditions, it might be possible to develop varieties, which would perform much better under specific types of stress.

Part of the applied physiological literature has focused on developing indicators of stress valuable in plant management. One of the most widely used indicators is the accumulated heat-unit or day-degree model, used to predict the development of a crop. In practice heat-unit models are especially valuable in selecting the optimal sowing date on the basis of a minimum of expected heat units in the weather forecast to have the seeds germinate correctly.

Other plant stress indicators have been calculated from the difference between air temperature and foliage temperature, corrected for vapor pressure deficit. In some instances these indicators have been used in determining the need for irrigation.

Most of these models however are largely empirical. In other words, there is hardly any link with the biochemical reactions provoked by the stress factors which result in reduced production. The TKW-concept tries to fill this void by providing an indicator based on temperature which is directly derived from the level of activity of plant enzymes. The model is also unique in other ways, as it challenges assumptions related to the way plants respond to temperature in general and the way leaf stomata function in particular. What follows is a brief summary of the concept definition and the experiments done so far to validate the basic TKW hypothesis as well as the results of some applied research.

The TKW-concept is based on the fact that many enzymes function in a temperature dependent fashion. The activity of an enzyme can be measured by the so-called apparent Michaelis constant or Km. Basically Km refers to the concentration of a chemical substrate required to reach precisely 50 percent of the initial maximum chemical reaction velocity. The lower Km is, the more active an enzyme is. Previous research with various plant and animal species has indicated that the Km values are highly temperature dependent.

Researchers in Lubbock have isolated two particular plant enzymes, glyoxylate reductase and glutathione reductase, from the leaves of both cotton (in this case Paymaster 145) and wheat. The enzymes were subjected to precise measurement on their level of activity when mixed with known concentrations of another substance, the NADPH. The results of these experiments showed that the apparent Km of the two enzymes extracted from both cotton and wheat are highly temperature dependent. The enzymes of wheat functioned optimally between 17.5°C and 23°C, whereas for cotton temperatures between 23.5°C and 32°C were ideal. Studies with other enzymes have confirmed this basic relationship and a TKW for cotton was consequently defined as 23.5°C and 32°C. The latter is the temperature at which the Km level had increased to twice its minimum value, a level at which, as others studies have reported, enzymes function optimally at values within 200 percent of the minimum Km.

From this still rather abstract notion at the enzyme level, researchers directly switched to the plant level to see if the TKW could have any practical value. To this effect individual plants were grown in a greenhouse under controlled conditions. Since the enzymes under study function in the leaves of the plant, the interest of the researchers was to measure foliage temperature and to relate this to other indicators such as air temperature, radiation, transpiration and relative humidity. To measure canopy temperature in these precise experiments, small thermocouples were placed in contact with leaves on four places on the plants.

The results of this study, published in 1988, showed that the leaf temperature with the highest frequency of occurrence (expressed in time-units) was 27°C, whereas the air temperature peaked at 30°C. The highest deviation between the frequency of leaf temperature and air temperature occurred at 27°C. This fact lead the researchers, Upchurch and Mahan, to conclude that apparently 27°C + /- 2°C is the preferentially maintained temperature. Further it was found that at temperatures below 27°C there was a strong linear relation between leaf and air temperature. The difference between the two was approximately constant at 1°C. It is believed that this difference should be attributed to a temperature gradient between open air temperature and the air temperatures in the canopy, and consequently any difference between air and leaf temperatures is not necessarily indicated.

At air temperatures above 27°C the leaf temperature was consistently cooler. For every 3°C increase of air temperature, the leaf temperature increased only 1°C. Researchers believe that this difference might even be higher if more precise measurements had been used. It is suspected that, with the measurements used in this experiment, the leaf sensors would in fact measure a mixture of leaf and air temperature and thereby smooth the effects. The persistent differences between air and leaf temperatures above 27°C occurred both during day and night. Detailed studies of the temperature sequences and other parameters over 24 hour periods indicate that the control of leaf temperature close to 27°C both during day and night is achieved by water transpiration. A persistent positive vapor pressure deficit between the air and leaf surfaces during the experiment is of course conditional to this process of leaf cooling.

This experiment in fact provided the researchers sufficient evidence to postulate the hypothesis that plants in relation to the temperature of their environment should be characterized as "limited homeotherms" rather than poikilotherms (species that "passively" take on the temperature of the environment). The term "limited homeotherm" then refers to the situation at which the lower limit of the temperature would in effect be controlled by the environment, and the upper limit would be, under a wide variety of circumstances, controlled and maintained by the plant at a normative value. However, this control mechanism is supposedly conditional on three factors: sufficient water supply for transpiration, sufficient energy influx to raise temperatures to the normative values, and enough air humidity to allow for cooling when necessary.

Obviously, this theory would imply also a change in thinking about the way leaf stomata function. So far, it is generally believed that the stomata open and close in response to water stress ("water use efficiency optimalization theory"). The posing of a thermal-kinetic-window and associated "limited homeothermy" theory would imply that stomata are responsive to temperature. These two hypotheses would be in conflict at high temperatures where the optimalization theory would indicate closing the stomata to retain water, while the TKW-theory would point at opening of the stomata to enhance transpiration resulting in cooling.

The evidence collected to support either one of the two theories indicate that both theories might be valid. However, not a the same time. In a survey of the research done in this respect, Radin, postulates that the optimalization process is an acclimation to water stress, and that the TKW-process determines the basic behavior of the stomata. In other words, cooling of leaves to the normative value occurs constantly, as long as there is no or little water stress.

The question now is how to relate the TKW-concept in a useful way to plant production. For this purpose Burke, Mahan, and Hatfield, conducted an experiment to investigate the relation between TKW and biomass production in both wheat and cotton. For cotton, a 100 by 40 meter plot was planted with the Paymaster 145 variety. In the plot a micrometeorological station was positioned to measure wet and dry bulb temperatures, wind speed, net radiation, soil heat flux, and foliage temperature. The latter was measured with an infrared thermometer placed at 1.5m above the crop canopy, monitoring a surface of 0.75 m^2. In addition, also a smaller-field-of-view infrared thermometer was used to make comparisons. Biomass development was calculated throughout the season by uprooting individual plants and determining dry weight.

This experiment showed that cotton foliage temperatures were only 25 percent of the time within the TKW (wheat: 30 percent). Also a strong linear relation appeared between the cumulative time the foliage temperature was within the TKW, and the accumulation of biomass. As biomass accumulation usually correlates well with economic production, this last result underscores the validity of the TKW concept as a stress indicator in cotton, and as a possible tool in applied research on production improvement.

So far, this applied research has taken two directions. The first is related to improvement of genetic material, the second to crop management practices. In other words, the first line of research tries to come up with varieties with a modified thermal-kinetic-window, while the second aims to better control the environment within the window.

As to conventional breeding concerns, the TKW concept would point in the direction of selection on leaf temperatures. In cool environments, selection should focus on warm leaves. In this situation, the TKW theory assumes that plants are selected with a TKW situated in a lower range of temperatures, with stomata being closed longer. In hot climates, cooler leaves should be the object of selection. Even if at these hotter temperatures the stomata were fully opened already (i.e. show maximum conductance), this selection criterion could still be useful and result in plants with a more appropriate configuration (angle of leaf display).

Also biotechnologists have been attracted to the TKW-concept. If it would be possible to identify the different enzymes responsible for temperature adjustment of plants, and, more importantly, identify the genes involved in building these enzymes, it might become feasible to genetically alter the TKW of a specific variety. If, in the most simple case, one single gene could be identified underlying many of the mechanisms involved in the biochemistry of the TKW, then it would be relatively easy to isolate this gene, i.e. in wheat, and incorporate it into cotton. This would obviously have a great potential for cotton production in especially cooler environments. Presently, Dr. Norma Trolinder of USDA-ARS is working on this aspect. The study of management practices using the TKW-concept has been confined so far to water management. The idea is to regulate water supply in such a way that the leaf temperature can be maintained as much as possible within the TKW and thereby reduce thermal plant stress. In other words use the canopy temperature as a criterion for irrigation.

A first experiment conducted in Lubbock in 1987 by Wanjura et al., indicated the validity of this concept by showing that applying irrigation whenever canopy temperatures exceeded 29°C, resulted in yields equal to those with an irrigation schedule based on weekly replacements of rootzone soil moisture.

Encouraged by these results, a second experiment was set up in 1988 at the same location. This time six irrigation treatments were compared. Three treatments were based on the TKW-concept with irrigations scheduled when canopy temperatures exceeded 28°C, 30°C, and 32°C. The other three treatments consisted of a non irrigated plot, a weekly rootzone soil moisture replacement treatment, and a treatment designed to replenish rootzone moisture every two weeks, after the first irrigation at first square stage.

To assess the canopy temperature, 4 degree field-of-view infrared thermometers were placed on each side of a row to monitor the upper one third of the canopy. Irrigation in the temperature dependent treatments was fully automatically applied with a drip irrigation system. Whenever the 15 minute average of the two infrared thermometers was above the threshold value and the wet bulb temperature (a measure of humidity, or, more precisely, the temperature attained when the air in a boundary layer of a surface is brought to adiabatically saturation by evaporation of water) was at least 20°C below the same threshold value, irrigation water was directed to the plot for a 15 minute period.

The two root zone replenishment treatments were based on simple water balance models, fed by data provided by neutron probe measurements at two soil depths (max. 2.1 m). Measurements were made twice a week.

The Paymaster 404 variety used benefitted from two preplant irrigations to assure sufficient soil moisture for germination. Fertilization consisted of one overall preplant application of 92 kg/ha of N, and 47 kg/ha of P. Additional fertilization was provided with the irrigation water at a rate of 2.2 Km N/ha/cm. Adjusted for a difference in total irrigation quantities, this method resulted in nitrogen application of 153, 100, 80 kg/ha for the three TKW-related treatments (28°C, 30°C and 32°C respectively), and 305 and 166 kg/ha for the weekly and bi-weekly compensation schedules.

The growing season was dryer than average with a total rainfall of 18.4 cm. Most rainfall occurred between 60 DAP and 90 DAP. There were 174 days between planting and first frost. In the first seven weeks after planting, canopy temperature measurements were necessarily a composite between leaf and soil temperature, as canopy density was too low to allow for separate measurements by the infrared thermometers.

Total irrigation quantities over the season were highest (138 cm) in the weekly compensation method. The three TKW-based treatments received irrigation water amounting to 70 cm, 46 cm and 28 cm, for the threshold levels of 28°C, 30°C and 32°C respectively. The biweekly compensation treatment received 75 cm. The TKW based treatments received much of their additional water within the first 60 days after planting, in contrast to the biweekly compensation method where most irrigation occurred in the second part of the vegetative cycle. Total water use, calculated from a simple water balance model, based on the neutron probe measurements, indicated a similar pattern. However, this model did not take into account; drainage beyond 2.1 m, and researchers indicate that .there might have been some drainage in the 28°C threshold treatment. The fact that irrigations early in the season were based on a mixture of soil and canopy temperature, might have led to water application in excess of the water holding capacity of the soil.

To monitor biomass development, 15 plant harvests were made during the growing season. Plant height of all treatments increased until DAP 75. After this day only the weekly compensation method showed continued vigorous growth. Correspondingly, the number of bolls in the latter treatment reached a peak 20 days after this event occurred in the other treatments. The rate of boll maturity, expressed in percentage of total boll load, was inversely related to total water use: the dryland plants always carried a higher percentage of mature bolls compared to the other treatments, and the weekly compensation treatment reached only 50 percent mature bolls at termination.

Lint yield was determined by stripper harvesting of single rows, followed by mechanical ginning. Lint yield was highest in the bi-weekly compensation method and the TKW-28°C threshold method, reaching 1430 kg/ha in both cases. Next in line were the weekly compensation method and the 30°C and 32°C threshold methods with yields of 1147 kg/ha, 1073 kg/ha, and 902 kg/ha respectively. The dryland treatment resulted in the lowest yield: 353 kg/ha. The water use efficiencies, expressed in lint production per cm water use were about equal in the three TKW-based treatments and the bi-weekly compensation treatment, all situated between 18 and 20 kg/ha lint per cm water. The dryland treatment had a production of 12.1 kg/ha/cm water and the weekly compensation method 8.6 kg/ha/cm.

Based on these results, the researchers concluded that irrigation scheduling based on TKW-related canopy temperatures is as valid as the use of other irrigation criteria. The method can be fully automated and is relatively easy and transparent to the growers. The choice of the right threshold value is important, as the experiment has shown a great sensitivity to yield.

In summary, the TKW is a good example of a useful concept generated from recent advances in the field of plant physiology. In effect, it links new insights in the way specific enzymes function to economic production and water efficiency. The TKW-concept will have to be further validated under various conditions, but it clearly has the potential to become a part of the vocabulary of plant breeders and irrigation engineers.

Sources:

Hatfield, J.L., Burke J.J., Mahan, J.R., Wanjura, D.F., “Foliage Temperature Measurements: A Link Between the Biological and Physical Environment." *Proceedings of International Conference on Soil and Plant Water Status Measurements*, Utah State Univ, Vol.2, July 1987.

Burke, J.J., Mahan, J.R., Hatfield, J.L., “Crop-Specific Thermal Kinetic Windows in Relation to Wheat and Cotton Biomass Production. ” *Agronomic Journal*, Vol. 80, No. 4, 1988.

Mahan, J. R., Upchurch, D.R., "Maintenance of Constant Leaf Temperature by Plants - I. Hypothesis - Limited Homeothermy." *Environmental and Experimental Botany*, Vol. 28, No. 4, 1988.

Upchurch, D. R., Mahan, J. R., “Maintenance of Constant Leaf Temperature by Plants - II. Experimental Observations in Cotton." *Environmental and Experimental Botany*, Vol. 28, No. 4, 1988.

Burke, J.J., Upchurch, D.R., “Leaf Temperature and Transpirational Control in Cotton." *Experimental and Environmental Botany, forthcoming*.

Burke, J.J., Hatfield, J.L., Mahan, J.R., “Quantifying Thermal Stress in Cotton through Thermal Kinetic Window.” *Proc. Beltwide Cotton Prod. Research Conf. 1989*.

Radin, J.W., "When Is Stomatal Control of Water Loss Consistent with the Thermal Kinetic Window Concept?” *Proc. Beltwide Cotton Prod. Research Conf. 1989.*

Wanjura, D.F., Upchurch, D.R., Mahan, J.R., “Application of TKW Principles to Cotton Production Management." *Proc. Beltwide Cotton Prod. Research Conf. 1989*.

Short Notes

- The use of flexible polyethylene irrigation tubing is gaining ground in the US. The plastic tube, made out of seamless, two-ply polyethylene, is 12 to 15 inches in diameter. It is used to feed in-row furrows. The tube can be rolled-out with a tractor, preferably in a very shallow feeder-furrow to avoid displacement. One side of the tube is attached to the water source and holes are punched in the plastic to feed the in-row furrows. The system saves in labor costs and is flexible. At present there is one drawback, it requires o disposal after use and polyethylene is hard to degrade or recycle. The manufacturer, Automated Agricultural Systems Inc., is developing better degradable plastic tubes. (Source: *Cotton Grower,* June 1990)

- In recent years the issue of carbon dioxide fertilization of cotton has resulted in various interesting experiments. After initial work to investigate the effects of CO_2 rich air on cotton yields, some of the attention has now shifted to the root-zone. The question is, do yields increase when irrigation water is carbonated? An industrial supplier Of CO_2, Airco Carbon Dioxide, has sponsored three years of field experimentation using CO_2 saturated irrigation water in an underground drip system. Dr. Jack Mauney, a plant physiologist residing in Phoenix, Arizona, comments that results of the experiments confirm earlier work done in this field ---- plants grew faster, especially in the early season, and flowering was initiated sooner. Surprisingly, radioactive tracing of the CO_2 molecules led to the conclusion that none of the CO_2 was actually absorbed by the plants. Mauney assumes that the growth and yield effects stem from a better functioning of the root system. The CO_2-fertilized plants showed better uptake of potassium and zinc. No effects were obtained using surface drip systems. Although the experiments showed positive financial gains, it is obvious that this technology in its present form will have a limited customer base. However, according to Mauney, it does point once again to the importance of the root-system and the physiology of nutrient uptake. (Source: *Cotton Grower,* June 1990)

- The USDA Office of International Cooperation and Development is considering initiating two international cooperation programs in the field of biotechnology. A notice of intent, issued by the Office, indicates joint research programs between Cornell University and the University of

Bologna, Italy, on the development of DNA-probes for identifying *Pseudomonas* syringe pathover glycine, and between the University of Florida and the National University of Singapore on the evaluation of *Brassicas* as a clone source for resistance genes against *Xanthomonas.* Other noteworthy research grants have been awarded to researchers from USDA, Clemson University and the ARO Volcani Center in Israel for the study on control of aphid transmitted viruses. These grants are part of the Binational Agricultural Research Fund. (Source: *AgBiotechnology News,* March/April 1990)

- In various African cotton producing countries, the issue of threshold spraying versus routine or calendar spraying is a hotly debated issue. Traditionally, most extension services have opted to recommend a calendar spraying program, easier to operate and less demanding on the skills of farmers or scouts. However, with increasing pesticide costs and pressing environmental concerns, cotton executives are looking for alternatives. In a previous issue of *The ICAC Recorder* we have carried an article on the proposals made by Dr. Cauquil of IRCT in this respect. He supports, in fact, a more flexible calendar spraying program with elements of threshold spraying. In Tanzania, the recommended six-biweekly spray program against *Heliothis armigera* has also become a subject of study. One indicator that it does not work is that farmers neglect it. According to Brigitte Nyambo, of the Agricultural Research Institute in Ukiriguru, only about one fifth of the farmers in Tanzania's western cotton growing area spray at all and of those who do spray, half apply about three sprayings only. In a pluriannual experiment researchers at Ukiriguru tested several spraying regimes based on damaged squares, egg-thresholds, and larvae thresholds. Thresholds were in the range of 0.5 damaged squares per plant per count, 0.3 eggs per plant per count, and 0.10-0.15 larvae per plant per count. These threshold programs were compared with a routine six-biweekly spray program and an unsprayed treatment. Results were very mixed between sites and years but, overall, the routine program resulted in the highest yields. Threshold spraying did not lead to consistently fewer sprayings and should not be considered a way to save costs. However, threshold spraying may lead to better timing and higher efficiency for sprayings. The researchers state that spraying on damaged square thresholds might be the most appropriate way to proceed in Tanzania, as it requires fewer skills from farmers and delays sprayings somewhat so that biological control gets a better chance. To control better the relatively low but persistent infestations (below the threshold), the use of flexible thresholds is recommended based on individual counts and averages of several counts. (Source: *Crop Protection,* Vol. 8, 1989)

- In a reaction to a *Short Note* on advances in hybrid research in India, which appeared in the March 1990 issue of *The ICAC Recorder,* Dr. B. G. Bathal, Director of Research at the Punjabrao Krishi Vidyapeeth University in Maharashtra, India, notifies us that the University has already introduced cytoplasmic male sterility in hybrid parents and also has developed a matching restorer for hybrid seed production. He further notes that this technology has had commercial success as well and is now employed on a large scale in Maharashtra.

- In Cameroon research continues to introduce more efficient spraying methods. Since 1974, the use of handheld ULV-sprayers is the common practice. Insecticides are formulated in concentrated oil-based formulations and sprayed at rates of 1 liter/ha. In 1988 a test-program was run on about 500 ha. to validate the use of a Very Low Volume (VLV) technology. VLV-spraying involves the use of water-diluted concentrated emulsions with the same ULV-sprayers but equipped with additional 5 liter (or 18 liter), feeder-reservoirs. The recommended dose for this technology is 10 liter/ha. The advantages sought by using this technology are better coverage and lower insecticide costs.

The test-program, conducted under the responsibility of SODECOTON, the cotton development corporation in Cameroon, was rated a success by both farmers and technicians. The logistics of bringing in water (from distances up to 2 km!) and preparing the mixtures did not lead to problems, nor sanitary hazards. Qualitative observations by both farmers and technicians indicated an overall better protection by VLV-technology as compared to ULV technology. It took anywhere from 1 hour and 40 minutes to 30 minutes to spray one hectare, depending on the number of sprayers used. It was recommended to conduct spraying with a team, each person taking three rows. Farmers made an average of 5.2 sprayings per hectare against a recommended number of 6 to 7. Battery consumption was 2.62 batteries (1.5 V) per hectare. This was more than in the ULV-technology and was rated a disadvantage by farmers. Although there were added risks of contamination and pollution during the preparation stage, the risks of pollution during spraying were rated lower because of much lower concentrations and less but more visible drift. (Source: *Coton et Fibres Tropicales,* Vol. 44, no.4)

- The available tillage equipment for cotton has been expanded by a new machine developed in Israel: the uprooter/shredder/mulcher (USM). This machine, introduced in Israel in 1982 and used to uproot cotton stalks, chops the stalks in small pieces, buries the chopped material and reshapes the seedbed. All these operations are done in one single passage. As such, the USM accomplished what otherwise would be done in five to seven passages and, therefore, leads to economies in soil preparation costs. Its inventor, Mr. Yarron Ben-Dor, indicates that this system could save between $30 and $50 per acre. The machine is flexible and has the options of spreading the chopped stalks and roots on the ground surface; burying the chopped material in the ground; idem but in conjunction with ripping and seed bed reshaping; or having the chopped stalks blown into a trailer for ultimate removal. The machine can work about 30 acres per day in two shifts and can be put in operation directly after harvesting. A study by the University of Arizona did indicate energy savings of about 40 percent, and cost savings of 32 percent compared to conventional systems. Also, substantial savings in time were recorded.

The machine, presently used in Israel, Australia and the US (mainly Arizona and California), sells in the US for about $41,000. (Source: *Cotton Gin and Oil Mill Press,* May 19,1990)

- A new book on whiteflies has been published by Intercept Ltd. in the United Kingdom. The book, titled *Whiteflies: Their Bionomics, Pest Status and Management,* is compiled and edited by Dan Gerling, Department of Zoology, Faculty of Life Sciences, Tel Aviv University. The articles in the book are derived from a symposium on the topic held in Hamburg, FRG, in 1984. The articles deal with a wide range of subjects, from morphology to methods of control. (ISBN 0-946707-16-2)