Resistant Pest Management Newsletter

A Biannual Newsletter of the **Center for Integrated Plant Systems (CIPS)** in Cooperation with the **Insecticide Resistance Action Committee (IRAC)** and the **Western Regional Coordinating Committee (WRCC-60)**

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Letter from the Editors

We are pleased to present our tenth issue of the Nesletter. This issue is international in scope with a sweep of resistance related topics. Thanks to all the contributors. We remind the subscribers that all the news, reviews, abstracts, etc. are unreferred and should be recognized as such.

Newsletter news:

1. We are considering the possibility of converting this Newsletter into an E-mail bulletin board. This would result in significant savings, and easy access for anyone with the equipment to access Internet. But there are potential disadvatages as well. Some subscribers may not have the equipment to access the bulletin board. In addition, we are unsure how easily it can be incorporated into the bulletin board. At this point we are investigating the bulletin board as an alternative to the hard copy version. We would likely transition over time into the E-mail format while providing hard copy to those that request it. We would appreciate your opinion. Would going to an electronic bulletin board cause difficulties for you? Let us know what you think.

2. The staff of the Resistant Pest Management Newsletter has had considerable difficulty in mailing some Newsletters due to incomplete mailing addresses. We dutifully request that first time subscriber's application forms be filled out completely with telephone and fax numbers noted. The information must be completed in English, including the country name. If you have moved and would like to continue receiving this publication please let us know. This moment of your time will ensure your timely reception of the publication and we greatly appreciate your effort.

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Resistance Management Reviews

Methyl Bromide: A Fumigant With a Future?

All of the previous articles in this Newsletter have been devoted to problems associated with pests and diseases of growing crops. At present, world crop losses to pests are estimated to be about 35%, due to destruction by insects (12%), pathogens (12%), weeds (10%) and mammals and birds (1%). Post-harvest losses can be equally significant, with estimates ranging from 9% in USA to upwards of 20% in less economically advanced countries in the tropics (Gorham, 1991). Trade in stored grain and durable commodities has increased enormously in recent decades, in line with world population growth and forms a vital part of many countries' economies. Transfer of treated, insect-free commodities is a pre-requisite for commercial success. Shipments lost through insect contamination are expensive to replace and more importantly allow transfer of pests from one country to another. Rapid, simple methods of disinfestation are therefore required before food produce can be exported from a country of origin.

The treatment of stored grain and other durable commodities throughout the world continues to rely heavily on fumigation with methyl bromide or phosphine, the only fumigants now in regular use. Both compounds are highly toxic to man and strict conditions pertain to their use. Phosphine is usually preferred owing to its ready availability, ease of application and low cost. For fumigation to be effective, treatments should last a minimum of 7-14 days. Currently the main use of methyl bromide is for quarantine purposes and in countries where the temperature is too low for an acceptable fumigation period with phosphine. Fumigation with methyl bromide is technically more difficult but is achievable in 24 hours. The rapid action of this fumigant means that any produce found to be contaminated by insects, can be treated quickly, and shipped to its destination without undue loss of time.

A consequence of the Montreal Agreement has been to seek ways of reducing or banning known ozone depletors from commercial use. Methyl bromide, a readily identifiable ozone depletor has therefore come under increasing scrutiny and there are calls for its complete withdrawal. The point of this article is to emphasize the importance of methyl bromide as an effective, responsible way of disinfesting stored produce.

When the Insecticides Resistance Action Committee of GIFAP commissioned a world survey of insecticide resistance in 1986, the results on stored products pests revealed significant field resistance in a total of 16 arthropod species (Badmin 1991). No significant fumigant resistance was reported then, although low levels of phosphine resistance in the Flour beetle Tribolium confusum and Grain beetles Cryptolestes spp. were considered to be "a cause for future concern". In the intervening years the evidence suggests that some insects are acquiring an unacceptable degree of resistance to phosphine (Taylor, 1989). Thus there is a growing need to contain phosphine resistance where it occurs.

Store managers need to be able to integrate a resistance management strategy into their overall management plan, to know what options are available and to prioritize them according to local conditions. In the case of suspected phosphine resistance a manager may be able to treat his infested produce with an insecticide which will then require a period of time to achieve its full effect and for residues to decline to an acceptable level.

However he may need to treat more quickly and to use a fumigant. There are just two fumigants widely available for stored products use. The modes of action of methyl bromide and phosphine in insects are entirely different and so the former may be used to control pests showing resistance to phosphine (see Price, 1985 for a discussion of the mode of action of fumigants). The option of being able to substitute one fumigant for another with a different mode of action is crucial in delaying the selection of resistant strains. Thus it is vital that both fumigants remain available for disinfesting stored produce.

The amounts of methyl bromide used for disinfesting produce are relatively small by comparison with the amounts used for soil sterilization in certain parts of the world. An international committee, part of the United Nations Environmental Programme, has the responsibility of listing the various uses of methyl bromide and to obtain estimates of the quantities of material involved. This will include the practice of fumigating stored produce. Separate studies have indicated that more efficient fumigation procedures and the introduction of better designed fumigation chambers may reduce the quantities of methyl bromide and other fumigants used by a considerable margin. There are studies in progress looking at ways of recovering methyl bromide after fumigation. The net result of this will probably be to extend the period of fumigation since removal of very low concentrations of free gas or sorbed methyl bromide from treated produce may require lengthy extraction procedures.

At present there are no known fumigants which offer quite the same performance characteristics as methyl bromide, although a number of minor products has been used from time to time. Any other halide product, such as methyl chloroform or the old liquid fumigants are essentially covered by the Montreal Protocol and in addition have toxicology profiles which are far from ideal. Thus, there appears to be little chance of introducing alternatives in the near future, although people are re-examining the use of hydrogen cyanide. Removal of methyl bromide would have two immediate effects i) there would be an upsurge in the use of phosphine as the only commercially available fumigant, coupled with increasing pressure to use shorter exposure times leading inexorably to the selection of strains highly resistant to phosphine and ii) a search for novel fumigants or ways of treating stored produce. The effects of the first are difficult to assess, but it is likely that this would lead to a gradual breakdown in the trade of "pest-free" commodities around the world. The second effect is to be welcomed as it will focus our minds on finding new ways of protecting stored produce. Possible alternatives, currently under investigation, include irradiation and the use of "controlled atmospheres", but each of these has its limitations. For example, buildings which are designed for controlled atmosphere use offer scope for long term storage of produce as pest control is achieved over a period of months rather than days, but offer little hope for the vast bulk of produce which is transported daily around the world.

At the forthcoming 6th International Working Conference on Stored Products Protection to be held in Australia in April 1994, IRAC proposes to organize a Workshop aimed at discussing the major elements involved in storage design and management, as part of a co-ordinated strategy to delay the onset of resistance to stored products pesticides. Problems of insecticide resistance are increasing at a time when more restrictions are being placed on pesticide usage and registration costs are soaring. To improve the efficacy of pesticides (and that includes fumigants), there is a need to re-examine all aspects of the storage environment, and for all disciplines to be involved, store designers, construction engineers, managers, fumigation and pest control experts, and economists, to work together in a concerted effort to reduce the likelihood of infestation and to improve early detection of problems. Hopefully the Workshop will provide an opportunity for a useful dialogue between these groups.

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Resistance Management from around the Globe

Diazinon Resistance Mechinisms in Western Flower Thrips

Western flower thrips (WFT), *Frankliniella occidentalis* (Pergande), are major pests of numerous crops, especially some ornamentals. In addition to feeding damage, WFT also transmit tomato spotted wiltk virus which has an extensive host range among ornamental and vegetable species. Field populations of WFT have developed resistance to numerous insecticides including some organophosphates, carbamates, and pyrethroids. The problem with WFT is so severe that certain varieties of ornamentals are no longer grown in some Missouri greenhouses. We examined the mechanisms of diazinon resistance using UMC and KCM WFT. These two strains of WFT differed in their susceptibility to diazinon by 14.3 times, with KCM thrips being more tolerant. Diazinon-14C penetration, metabolism, and excretion were faster in KCM than in UMC thrips. Metabolism of diazinon in both strains was mainly oxidative. No interstrain difference in glutathione-S-transferase activity was observed with 1chloro- 2, 4-dinitrobenzene as substrate. However, carboxylesterase activity, as assayed with -naphthyl acetate, was significantly lower in KCM than in UMC thrips and was 9.6 and 20.4 times /less sensitive to diazoxon and eserine, respectively. Acetylcholinesterase (AChE) activity in KCM and UMC thrips was similar but that in KCM thrips was 9.6 times less sensitive to diazoxon. Butyrylcholinesterase (BuChE) activity in the two strains was similar and was appreciably higher than AchE activity. BuChE activity in KCM thrips was 170 times less sensitive to diazoxon than that in UMC thrips. It was concluded that diazinon resistance in KCM WFT was due chiefly to rapid metabolism and insensitive AChE. The significance of the presence in WFT of high levels of BuChE activity and of its role, if any, in diazinon resistance is not presently known; however, by serving as an alternate phosphorylation site BuChE might be functioning as a scavenger enzyme.

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Preliminary Trials of Resistance Detection for the German Cockroach (Dictyoptera: Blattellidae) with Glue-toxin Traps

A method to detect insecticide resistance in German cockroaches which uses sticky traps with insecticide impregnated glue was developed (Moss et al. 1992). Field trials to assess whether trap survival can be used to predict the efficacy of standard insecticide treatments were conducted. The objective was to develop a practical pest management tool designed to estimate mortality rates from treatments as opposed to a way to detect the degree of resistance. In this approach, resistance is relatively unimportant if it is not high enough to cause survival of the insecticide treatment. Doses are formulated based on analysis of toxicity of insecticide impregnated glue to a susceptible laboratory strain. A resistance diagnostic dose of 10 times the LC50, as suggested by Rust & Reierson (1991) for a pest management threshold level, was used as a starting point.

In some cases, traps with diagnostic doses of pesticide were sent to cooperators to evaluate whether the traps would indicate that control failures were caused by insecticide resistance. In other cases, pre- and post-treatment trap counts were conducted to see if population reductions could be predicted with insecticide resistance diagnostic doses.

In the first tests, several apartments were surveyed with baited sticky traps one day before insecticide treatments and again two days after the treatments. The pre-treatment survey traps contained insecticide diagnostic doses. The chlorpyrifos treated trap mortality (Table 1) reflected the outcome of the Dursban treatments. The bendiocarb treated traps overestimated the kill by Ficam and the cypermethrin traps grossly underestimated the kill by Demon. During these tests, it became obvious that the LC50 x 10 diagnostic dose for cypermethrin resistance was too low so the trap dose was increased to 15 and 20 times the LC50. Even the LC50 x 20 diagnostic was too low because the treatments were killing all of the cockroaches while the traps indicated survival would occur.

Table 1. Trap (diagnostic-dose) and insecticide treatment (cleanout) mortality. Low income Apartments: Diagnostic doses = multiples of LC50 of the susceptible strain. Data are combined from several apartments.

Kill Rates									
	Time	Male		Female		Nymph		Combined	
Ficam	10.00	0.56	0.33	0.34	0.33	0.53	0.07	0.47	0.20
Dursban	10.00	0.42	0.51	0.15	0.30	0.60	0.46	0.48	0.47
Demon	10.00	0.30	1.00	0.08	0.97	0.32	0.93	0.30	0.97
Demon	15.00	0.69	1.00	0.05	1.00	0.68	1.00	0.58	1.00
Demon	20.00	0.77	1.00	0.22	1.00	0.74	1.00	0.63	1.00

An enclosed caged layer facility had a severe German cockroach infestation following the successful use of sanitation to control the flies, and insecticide treatments were reported to give poor control. We prepared sticky diagnostic dose (LC50 x 10) traps with malathion and permethrin. Baited jar traps were placed in two hen houses before and after spraying with either malathion or permethrin. The malathion treated trap mortality was 50% while the reduction in trap catches after the treatment was 42%. The permethrin treated trap mortality was 21% while the reduction in trap catches after the treatment was 72%.

After being aware an apparent Dursban control failure at an Army facility at Fort Cambell, KY we sent chlorpyrifos and propoxur traps which contained an LC50 x 10 diagnostic dose for each insecticide to the facility. We wanted to see if resistance to propoxur would be high in a population which had not been treated with the carbamate for more than a year. The suspected chlorpyrifos resistance was apparent (Table 2) and there was some apparent susceptibility to propoxur (about 60%). Treating a population which had 40% resistant individuals could be considered a questionable practice, however this would depend on the diagnostic dose chosen and the strength of the insecticide formulation chosen.

Table 2. Resistance diagnostic dose (LC50 x 10) mortality in Fort Cambell, KY, where there was control failure with chlorpyrifos and no recent propxur treatments.

	Adults			Nymphs		
	Alive	Dead	Kill Rate	Alive	Dead	Kill Rate
Dursban	14	0	0.000	22	2	0.083
Propoxur	5	8	0.615	3	6	0.667

Data: Brian Zeichner, U.S.A.E.H.A.

We surveyed a U.S. Navy ship which was to be treated for German cockroach infestations. Three insecticides were used in different parts of the ship and the areas were monitored (using the LC50 x 10 as diagnostic dose) for resistance to the insecticide which was to be used. The prediction for adult mortality (Table 3) from the chlorpyrifos treatment versus the actual kill is close enough for pest management decisions. The propoxur and d-phenothrin traps both overestimated the actual estimated reduction in adult cockroaches. Although there were differences in predicted and actual apparent mortality, both test traps indicated that there was an expected survival of at least 20% of the treated populations. The traps, even at this unrefined stage of development rightly indicated that these insecticides were not the optimal choice in this situation.

Table 3. Diagnostic dose testing (Trap) with the indicated insecticides on the U.S.S. America, Norfolk VA, and insecticide treatment mortality (Actual).

	Adult Mortality		
	Dursban	Baygon	d-phenothrin
	Aft Galley	CPO Mess	Breakout room
Trap	0.94	0.79	0.74
Actual	0.8	0.57	0.47

Data collected by Lt. Cdr. Barry Annis
Diagnostic dose = LC50 x 10

Until now, we have been using a somewhat arbitrary diagnostic dose chosen from several that have been suggested in the literature (Rust & Reierson 1991). As we saw above, this was inappropriate for predicting the results of cypermethrin (Demon) treatments. Our intention is to produce a monitoring system which will give an approximation insecticide treatment results. Information beyond this is of little use to pest control applicators and others who are attempting to control insects. In other words, there is little reason to alter a treatment decision because of ten fold resistance to an insecticide if the formulation is such that it kills insects which are as much as 100 fold resistant.

For these reasons, we are changing our approach to resistance diagnostic dose formulation. Treatment kills are a function of application methods, potency of the insecticide and the amount of insecticide applied (active ingredient concentration). A reliable diagnostic dose will therefore need to reflect the potency of the insecticide and the amount of active material. We do not know of a way to calculate a diagnostic dose for resistance to an insecticide treatment using information on potency, application rate and insecticide/glue mortality. We do, however, have reasonable mortality predictions from our chlorpyrifos diagnostic doses. Taking this as a starting point, we can work backwards from the chlorpyrifos diagnostic dose and use the potency and application treatment dose to arrive at a factor which is needed to arrive at this diagnostic dose. We plan to then use this factor to calculate the diagnostic dose for other insecticides to avoid the trial and error approach to diagnostic dose formulation. Field trials will then be carried to test this dose and adjustments will be made if needed. We have used diagnostic doses arrived at in this way to look for resistance in a German cockroach population which had a history of poor control by acephate and cypermethrin. The trap induced mortality (Table 4) indicated that we would not have expected much control in this situation.

Table 4. Cockroach mortality in insecticide diagnostic glue traps at U.S. Army food service installations in Lexington, KY. Treatment history: Acephate and Cypermethrin with failures after "cleanout" treatments.

Trap Contents	Trapped Nymphs	Nymph Mortality	Trapped Adults	Adult Mortality
Acephate	42	0.57	27	0.33
Cypermethrin	63	0.57	53	0.26
Control	34	0.12	16	0.06

Sticky traps contain these insecticide resistance diagnostic doses: Acephate: 27 x LC50 of susceptible male cockroaches Cypermethrin: 43 x LC50 of susceptible male cockroaches

Data: Brian Zeichner, U.S.A.E.H.A., Aberdeen MD
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Our plans are to continue field testing this method of insecticide diagnostic dose determination. Although the method lacks a satisfying theoretical basis, we feel that this approach or a similar one is the only way to predict treatment results or diagnose apparent resistance problems.

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A Reliable Insecticide Resistance Field Test Kit for Coffee Berry Borer *Hypothenemus hampel*

The coffee berry borer, *Hypothenemus hampei* (Ferrari), is a major pest of coffee in most parts of the world. Its range has been increasing in Central America since its introduction in 1971. It is now well established in Mexico, Guatemala, El Salvador, Honduras (Baker et al., 1989) and more recently was found in various regions of Colombia. Several attempts have been made in the past to control *H. hampei* in South America and the Far East by the use of wasps from Africa (Le Pelley, 1968; Waterhouse et al., 1989), but with little success. Insecticide applications remain the most effective method of control. Due to the strong vapor action against CBB inside coffee berries (Parkin et al., 1992), endosulfan is the most widely compound used worldwide.

In New Caledonia, CBB arrived in 1948 and plantations were regularly treated with lindane until 1975, when it was replaced by endosulfan. Following regular increases in coffee bean infestation levels, which diminish the value of the crop, endosulfan resistance was confirmed in the three major coffee production areas. Resistance levels, evaluated through Potter tower direct spray, were found to be as high as over 500-1000 fold (Brun et al., 1989 a).

A reliable field test was developed in 1988 for the use of field laboratories in developing countries (Brun et al., 1989 b). The test kit is basically a "sandwich" of 3 rectangular perspex plates (80 x 140 x 3 mm), the middle one with two rows of five holes (20 mm diameter) maintains insects above a previously treated filter paper with a discriminating concentration of 400 ppm, assessed at 6h. To prevent the borer from beetles eating the filter paper, a fine nylon gauze was placed between insects and impregnated paper. A large scale survey was conducted over >200 fields (Brun et al. 1990), using the two monitoring methods (Potter tower and field test kit), giving similar precision at estimating the frequency of resistant populations. In the five regions - located along the East Coast - where resistant populations were present, the three middle ones showed resistance levels from 63 to 100% and the two external ones less than 10%. The field test kit was also evaluated at five temperatures, from 22C to 34C, and showed consistent results (Brun et al. 1991). It is therefore sufficiently robust to be used under a range of conditions for early detection of endosulfan resistance in coffee berry borer. This test kit was used for resistance distribution studies within fields, showing high levels of resistance along roadside from where insecticide applications in New Caledonia are made. Increased resistance frequencies occurred when endosulfan was used, while the use of the organophosphate fenitrothion led to decreased endosulfan resistance levels, as did no treatment at all.

The field test kit has also been used for study of R and S phenotype dispersal rates, using the resistance as marker. We are now looking forward to possible genotype evaluation with this method and we hope, in the near future, to examine the precision of the bioassay technique to evaluate the resistance frequencies by comparing bioassay-based identification with a molecular diagnostic based upon PCR mediated amplification of specific alleles. (FfrenchConstant et al, submitted).

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Carboxylesterases of Susceptible and Resistant Brown Planthopper

More than 10 molecular forms of carboxylesterases were observed with -naphthyl acetate as substrate in brown planthopper (BPH), *Nilaparvata lugens* Stal, using isoelectric focusing. The three most active ones, E1, E2 and E3 (Fig. 1) were purified and characterized. They displayed more common features than distinct ones. With similar subunit molecular mass and pl, they were immunologically related. They served both as a catalytic protein for the hydrolysis of some insecticides, e.g., malathion and trans permethrin, and a binding protein for the oxons of several OPs, e.g., paraoxon, methyl paraoxon and malaoxon, and possibly some carbamates and pyrethroids. The increased carboxylesterase activity in resistant strains of BPH as compared with that in susceptible strains (Fig. 1), was due to an over-production of all isozymes (Chen and Sun 1994). It was proposed that the gene encoding E1, E2 and E3 (and possibly other less active isozymes) was expressed to a greater extent in resistant than in susceptible BPH; and the isozymes might represent the products of post-translational modifications of the nascent protein. Protein subunits immunologically related to E1 of BPH were detected in two other rice planthoppers, *Laodelphax striatellus* and *Sogatella furcifera*.

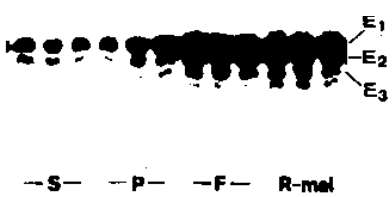

Figure 1. Isoelectric focusing analysis of carboxylesterases of susceptible (S and P) and resistant (F and R-mal) strains of the brown planthopper. The gell was stained for activity toward α-naphthyl acetate.

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Mechanism and Countermeasures of Daltamethrin Resistance in *Aphis gossypii* Glover

The Cotton aphid (*Aphis gossypii* Glover) is one of the most resistant agricultural pests to insecticides in China. It has been found to be resistant to more than 10 kinds of conventional insecticides belonging to 3 different types (organophosphates, carbamates and pyrethroids). Only few conventional insecticides are still effective for control of this cotton pest nowadays in North China.

Studies have been carried out with both laboratory selected resistant strain and field strain cotton aphids to search for the mechanism and countermeasures of deltamethrin resistance, the most serious pyrethroid resistance of cotton aphids. The results obtained are briefly summarized as follows:

1. The special features of deltamethrin resistance of cotton aphids:

   Cotton aphid populations are very easy to develop the capability to increase the tolerance to deltamethrin. Even after 3-4 successive sprays of deltamethrin, all sensitive strains enhance their resistant ability dramatically. The resistant level to deltamethrin was very high: the LD50 value for fundatrigenia of resistant strain was 12,000 times greater than that of sensitive strain; the LD5 value of the former was still about 40 times greater than the LD95 value of the latter.

The degree of deltamethrin tolerance of cotton aphids varied significantly in different seasons. Testing with different individuals of the same sensitive strain, the LD50 values increased about 10 times from spring fundatrigenia to summer alienicola. The summer alienicola of resistant strain became so tolerant that the LD50 value could not be evaluated because the top mortality was only about 30% with permissibly dilutable dosages.

2. Physiological and biochemical mechanisms:

Based on the results of various biochemical and physiological experiments, it was found that the knockdown resistance was the main mechanism for cotton aphid resistance to deltamethrin. Metabolicenzymes, esterases, and MFO took some part in detoxification processes of deltamethrin, but they exhibited similar and equivalent roles both in resistant and sensitive strains. The rate of penetration of pyrethroid also showed no significant difference. Therefore, thay are all complemental agents for this kind of resistance.

Deltamethrin- resistance in cotton aphids likely resulted from the modification of the target site only for pyrethroids.

3. Hereditary characters of deltamethrin-resistance in cotton aphids:

The deltamethrin-resistance of cotton aphids is regulated by a single recessive gene, which is a frequency mutant one. Inbreeding descendants of the sensitive strain or the resistant strain of cotton aphids almost possessed the same tolerant capability as their parents, respectively. Cross breeding of sensitive strain with resistant ones produced sensitive aphids only in the first filial generation (F1), and no difference was found between crosses of R x S and S x R. Besides, segregation occurred in the second filial generation with the ratio of 78.8 : 21.2 for the sensitive to the resistant offsprings, which was quite approaching the phenotype segregation ratio (75:25) o the single recessive gene. On the other hand, the results of successive selection experiments with deltamethrin revealed that there was about 10-4 of resistant cotton aphids in the natural sensitive population, and successive observations, generation by generation, of the resistant strain showed that reversal mutation frequency of the resistance gene was about 10-2. Based on calculation, the mutation frequency for the resistance gene was 10-4.

4. Mechanism of outbreak of deltamethrin-resistance in cotton aphids:

Insecticide-selection pressure was the main cause for the onset of deltamethrin resistance. When exposed to deltamethrin, resistant cotton aphids were found to survive at much greater rate than sensitive ones and the resistance selection followed a hyperbol correlation with the dosages used. On the other hand, the insecticide residue on the cotton plants also retarded the growth of the sensitive aphid population in the field within its effective period, but it had little effect on resistant aphids. The reasons for rapid development of deltamethrin resistance within the same growing season are summarized as follows:

1. Deltamethrin-resistance is a monogenic hereditary feature. Frequency of resistance gene is high in the natural population. Resistant aphids are easy to be selected by deltamethrin and then reproduced rapidly by parthenogenesis.

2. Deltamethrin can induce cotton aphids to increase their tolerance when used in low dosages. Thus, aphids survived sprays of deltamethrin can increase their tolerance dramatically.

3. Owing to seasonal variation both of cotton plants and aphids, the tolerance of cotton aphids to deltamethrin increases obviously with summer coming.

5. Mechanism for sensitivity recovering of resistant cotton aphids:

Sensitivity recovering of resistant cotton aphids mainly depends on the reversal mutation of the resistance gene. There is no obvious difference in fitness between resistant and sensitive cotton aphids. Resistance to deltamethrin can not be reduced by natural selection, but reversal mutation could decrease 50% of resistance gene frequency in 70 generations or about 3 years without spray of pyrethroids, and finally resistance genes fall to natural level gradually.

6. Cross-resistances between deltamethrin and other insecticides:

   Deltamethrin-resistant cotton aphids exhibited strong cross resistance to other pyrethroids, but little to organophosphates and carbamates. For identifying cross resistance from multiple resistance, a new method was established: First, selecting several (more than 4) different resistant strains (by means of body-color, isoenzymes of esterase, etc.) and sensitive strain of cotton aphids; secondly, testing resistant level of each strain with various insecticides to be tested; thirdly, calculating correlation coeffecient to determine whether there was cross resistance between the pair of insecticides or not; and then, evaluating the degree of "cross relationship" by comparison of resistances of the different pairs of insecticides.

7. Effect of insecticide mixtures on the development of resistance:

   Adequate mixtures of pyrethroid with organophosphate could control deltamethrin-resistant cotton aphids, but the control effect depended on the complementary organophosphate only. Mixtures could not delay the development of pyrethroid resistance except using the high dosages which ensure each component part can kill its own sensitive individuals.

8. Effect of rotational use of insecticides on resistance development:

   Rotational use of different insecticides in rational intervals is likely an effective method to restrict resistance development. But spraying with low dosages of different insecticides in turn has little effect. Finally, based on experimental results, 0.003g / aphid is proposed as discriminating dosage for monitoring frequency of resistant aphids in populations and the computer program is established for prediction of deltamethrin resistance in cotton aphids. Suggestions for cotton aphid resistance management are proposed as fellows: (1) Putting IPM into full use and reducing sprays of insecticides as far as possible; (2) Using different non-cross-resistance insecticides to control cotton aphids in seedling and following periods. Pyrethroids should only be used in cotton seedling stage and no more than two times for cotton aphid control; (3) Adequately applying with high dosages of insecticides and suitable spraying techniques so as to reduce cotton aphid survival rate as far as possible; (4) Monitoring pest resistances systemically and altering in use of insecticides in time; (5) Exploiting more types of insecticides suitable for resistance management.

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Resistance of Diamondback Moth to *Bacillus thuringiensis* in China

The diamondback moth (DBM), *Plutella xylostella* (L.), developed resistance to most pyrethroid and organophosphorus insecticides in 1980s in P.R. China (Zhu et al. 1991). As an alternate, the *Bacillus thuringiensis* (Bt) insecticides became more important to control DBM, especially in the south of China where pyrethroids resistance in DBM was more severe. The production and application of Bt developed quickly in late 1980s in China, with the Bt formulations less than 0.3 millions kg in 1985 increased to 1.5 millions kg in 1990. About 20% of Bt insecticides was used for the control of lepidopteran pests in crucifers.

The resistance of DBM to Bt has been reported in fields in the United States (Tabashnik et al. 1990, Shelton et al. 1993) and Malaysia (Syed 1992), and in greenhouse in Japan (Tanaka 1992). All of these cases were related with the extensive applications of Bt to control DBM. So we selected four areas in China for the detection of Bt resistance in DBM, i.e. Shenzhen (Bt used most extensively), Shanghai (extensively), Wuhan (less extensively) and Beijing (inextensively) (Zhao et al. 1993).

The DBM larvae and pupae were collected from Brassica fields in October and November 1992 in

Shenzhen, Shanghai and Wuhan, and in May 1993 in Beijing. A susceptible (S) DBM strain was provided by Prof. Y.Q. Sun. DBM larvae were reared on fresh cabbage leaves at 25+1C and photoperiod 14:10 (L:D). Third instar of F1 or F2 and leaf disk dip method similar to Tabashnik et al. (1990) were used for bioassays. Wettable powder (WP) formulation with the potency of 1,5000 IU/mg of the HD-1 strain of *B. thuringiensis* subsp. *kurstaki* from Hubei Academy of Agricultural Sciences was used for the study. DBM larvae were kept for 48 h at 25+1C before the mortality was determined. The discriminating concentration method for resistance monitoring was also used for comparison with concentration mortality tests.

Table 1 shows the resistance ratios (RRs) of DBM to Bt and their relationship with the % survival at a discriminating concentration. Compared with the LC50 of S strain, the RRs of DBM populations in Shenzhen and Shanghai were 41.4- and 6.1- folds, respectively, with Wuhan and Beijing populations not significantly different with S strain. These results were comparable to the fields Bt application history in each of the areas.

The survival rates at the discriminating concentration of 25 IU/l (equivalent to 50 mg [AI]/litre) led to similar conclusions with the concentration tests on the relative susceptibility of five DBM populations to Bt. The concentration-mortality tests did not show significant difference in resistance between Wuhan and Shanghai populations, but the discriminating method did (Table 1). From this result we could get a same conclusion as Tabashnik et al. (1993) (in which the concentration was about half of that we used), i.e. bioassays using short time intervals and a single concentration may greatly increase efficacy for routine evaluation of resistance. We thought 25 IUl was a suitable discriminating concentration for on-farm resistance monitoring to Bt in DBM in China.

Table 1. Susceptibility of diamondback moth populations in China to *Bacillus thuringiensis* formulation.

Population	Slope ± SE	LC50 (95%FL) IU/µl	RR	% Survival at 25I/µl
Susceptible	1.46 ± 0.20	0.50 (0.30 - 0.82)	1.0 c	0 c
Beijing	1.23 ± 0.21	0.54 (0.26 - 1.10)	1.1 c	0 c
Wuhan	1.39 ± 0.23	0.82 (0.41 - 1.66)	1.6 bc	0 c
Shanghai	1.92 ± 0.36	3.07 (1.62 - 5.83)	6.1 b	7.4 b
Shenzhen	1.86 ± 0.27	21.05 (12.68 - 34.95)	41.1 a	48.4 a

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Resistance of Cotton Insects to Insecticides in Nicaragua

Insecticides are the primary means used to control pest species of cotton in Nicaragua as well as all of the other cotton producing countries of Central America.

A wide range of pest species including the Hemipteran, *Crientides* sp.; boll weevil, *Anthonomus grandis* Bohman; sweetpotato whitefly, *Bemisia tabaci* (Gennadius); Bollworm, *Helicoverpa zea* (Boddie); *Spodoptera* spp., including the beet armyworm, *S. exigua* (Hubner), fall armyworm, *S. fugiperda* (J. E. Smith) and *S. sunia* (Hubner) and the cotton leafworm, *Alabama argillaceae* (Hubner) attack cotton in Nicaragua.

I suggest that the most important pest of cotton is the boll weevil and methyl parathion is the most widely used insecticide for its control in Nicaragua and the other Central American countries. The boll weevil is present all season long. The bollworm and *Spodoptera* spp. are also important pests of cotton in these same countries. Insecticides are required for control of these Lepidopteran insects. However, larvae of these species are not present all season so the number of applications of insecticides required for their control is not as great as that required for the boll weevil. Because of numerous applications of a single compound, i.e. methyl parathion, resistance potential is established.

Here resistance is defined as the failure of an insecticide to "control" populations of an insect species after it previously provided "control". This means that "control" is not obtained in a "field", "area" or "political boundary" where it was determined previously. Thus, resistance is both a time and space phenomenon. Methods to determine resistance levels are variable but the declaration of resistance must include information on failure to "control" the insect in the "field", "area" or "political boundary". Laboratory experiments must be conducted each season, on populations collected over the cotton producing areas, to determine if the pest is resistant. Resistance must then be confirmed in replicated field plots. To date, field control experiments against the boll weevil, bollworm and *Spodoptera* spp. in Nicaragua have not been conducted to accept or reject "resistance" in the field populations.

Response of boll weevil to methyl parathion across Nicaragua was well documented from 1983 to 1984 (Table 1) with LD50's from 0.09 to 1.73. The greatest LD50's were observed in August at the beginning of the season and the lowest were observed in December. This indicates that weevils are more susceptible at the end of the cotton growing season than at the beginning of the season. Prior to these results, Herdocia (1980) showed LD50's for methyl parathion of 0.063 to 0.093 g/weevil in Nicaragua and these values are typical of those determined for weevils in South Texas, (Wolfenbarger et al. 1986). No LD50's have been determined in the 1990's in Nicaragua or any other Central American country. Except for the LD50 values of 0.063 and 0.093 g methyl parathion/weevil all LD50's reported from Nicaragua are greater than any LD50 determined for boll weevil in the United States (Wolfenbarger et al. 1986).

Table 1. Toxicity of Methyl Parathion by Topical Application (µl/weevil after 48h) to Boll Weevil in Nicaragua.

Greatest LD50 (95% Confidence Interval)					
Location	Year	August	September	October	December
Malpaisillo[1]	1983	1.73	1.02		0.18
Chiquimulapa[1]	1983	0.97	0.73	0.69	0.70
Soledad[1]	1983	0.87	1.16		0.31
Malpaisillo[1]	1984	0.40			0.51
Chiquimulapa[1]	1984	1.43			0.37
Chiquimulapa[2]	1984	0.68		0.26	0.09
Soledad[1]	1984	0.68			0.37
San Jose De Telica[2]	1984	1.52		0.25	0.14

1 Taken from Laboucheix and Gonzalez (1987) and Gonzalez and Laboucheix (1987)
2 Taken from Swezey and Salamanca (1987)

Cypermethrin, *Lambda* cyhalothrin and fenvalerate are more toxic to field collected boll weevils in Nicaragua, Casadei de Batista (1990) than in Louisiana (Leonard et al. 1991) and South Texas, Harding et al. 1977; and Davis et al. 1977; Wolfenbarger et al. 1986). Perhaps these pyrethroid insecticides could b used as replacement insecticides against this insect in Nicaragua should LD50 values of > 1.5 g methyl parathion/weevil (Table 1) prevail in the cotton producing area of northern Nicaragua. These values were the greatest determined for methyl parathion in Nicaragua. I suggest that field boll weevil control failures could occur to methyl parathion in cotton where the LD50 values exceeding 1.5 were found. however, there is no field control failure data available to support these results.

LD50's for bollworm to methyl parathion are greater in Nicaragua than reported in the United States (Wolfenbarger et al. (1981). In 1970, we determined an LD50 of 5 g methyl parathion/larva in Nicaragua (Wolfenbarger et al. 1971) while the greatest value we determined in 1971-72 was 54 g/larva (Wolfenbarger et al. 1981) for 20 mg larvae. In 1980 a field collected strain of bollworm from El Salvador showed an LD50 of 605.5 g methyl parathion/larva for 20 mg larvae. This is the greatest LD50 shown for bollworm in the Americas. Susceptible strains have LD50's for methyl parathion of ca. 0.5 g/larva. Thus we see some large differences in LD50 values. Pyrethroid insecticides have been widely used since 1975 in Nicaragua. An LD50 of 0.0059 g permethrin/20 mg larvae was shown

(Wolfenbarger et al 1981) in El Salvador in a field collected strain in 1980, which indicates susceptibility. For fenvalerate, an LD50 of 0.2 g/larva for this same strain also indicates susceptibility.

Dosages of methyl parathion required to kill the boll weevil are greater in Nicaragua than any location where this pest is found in North, Central and South America. Pyrethroid insecticides were shown to be toxic to this insect in Nicaragua and could be used as replacements for widespread use of methyl parathion. Perhaps methyl parathion should not be tank mixed with other insecticides which is frequently done in Nicaragua. If this were practiced then the amount of methyl parathion used in cotton in Nicaragua would be decreased. Perhaps the LD50 doses would decrease and control would be enhanced. Field control experiments should be initiated to determine if this could be proved. No LD50 values for methyl parathion or any other insecticide are shown for field collected strains of *Crientides* sp., the sweet potato whitefly, beet armyworm, fall armyworm, *S. sunia*, and the cotton leafworm in Nicaragua or other Central American country.

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Serious Explosions of the First and Second Generations of Cotton Bollworm in Hebei Province, China in 1992 and the Observation of its Resistant Level

Serious explosion of cotton bollworm in Hebei Province in 1992

The serious explosion of cotton bollworm in Hebei Province in 1992 seriously occurred not only in 800,000 hectares of cotton fields but generally in all the green leaf plants. It was rarely found out in the history about its early occurrence, great quantity of its moth and egg amount, tremendous force, wide acreage and more plants.

The first generation of bollworm attacked seriously to the wheat field. According to the report of 'Hebei Information of the Plant Protection' on 27th May, the cotton bollworm occurred in 570,000 hectares of wheat fields only from the statistics of six Prefectures of Handan, Xingtai, Shijiazhuang, Cangzhou and Hengshui. The density of larva generally reached 2-5 larva/m2, the heavy density 15-20 larvae/m2 and the highest density 195 larvae/m2. It was tenfold and even tens of times than the average year (in average year it was only under 1 larva/m2). According to the investigation of Guantao County, this year the percentage of injured wheat ear was 3%, the percentage of injured wheat seed was 5% and its loss reached about 10%.

The second generation of cotton bollworm occurred generally serious in the cotton district in Hebei Province, especially in the cotton district middle southern part of Hebei Province, it belonged to the specially great explosive year. Its characteristics were as follows: (1) The egg appearance dates were on 8-9th June, 10 days earlier than the average year, for example, the egg appeared on 9th June, 1992 but on 19th June, 1991 in Xingtai City. (2) The quantity of its moth and egg was especially great. The moth was seen on 8th June in Xingtai City but there were 960 accumulated eggs of one hundred plants on 12th June in Xingtai City, 1,450 accumulated eggs in Chengan County, 2,100 accumulated eggs in Handan on June with 100% of the egg plants; The average one hundred plants reached 16,422 eggs and the highest 26,548 eggs on 26-28th June in Gaoyi, Gaocheng and Lingshou counties. It was 4.4-fold of the total egg amount of previous 19 years. The moth peak appearance date was on 18 20th June. According to the statistics of Chengan, Gucheng, Qinghe, Hengshui Counties and City, in average the moth trap amount of one black light lamp reached 50,765 heads per day, the highest 77,692 heads and it was 37-fold than in 1982 when the cotton bollworm also appeared seriously. (3) The oncoming force was tremendous. The moth and egg daily increase amount was great. Each daily lamp trapped 597 moths on 12th June in Gucheng County but it reached 22,100 moths on 18-20th June. The eggs of one hundred plants reached 550 eggs per day on 11-12th June in Xingtai City and over 500 eggs in general 1,500 eggs the highest on 23th June in Weixian, Feixiang and Chengan Counties. The daily egg increase per hundred plants came down on 27th June but still was 100-200 eggs. (4) The larval number was great. The larvae per plants reached 10-30 heads in general on 23rd June in Handan, Henshui, Xingtai, Shijiazhuang and Baoding, etc. The Nangong Plant Protection Station investigated the accumulated larvae about 1,680 heads one hundred plants on 30th June. Up to the end of June, in general it was treated for 3 times and partly 5 times in the middle and southern cotton district in Hebei Province but according to the investigations in Handan, Xingtai and Shijiazhuang, etc. the survival larvae per hundred plants still reached 20-40 heads, the highest over 100 heads. Until 6th July in general, it was treated for 4 times, the greatest over 8 times in the cotton fields of the whole Hebei Province but the survival larvae still kept 10 heads one hundred plants and the highest 20-30 heads. (5) It occurred widely and attacked various crops. This year great number of cotton bollworm larvae could be seen in all the field green plants. According to the investigation on 20th June, the larvae of one hundred summer corn plants reached 900 heads in Weixian County and its wormy percentage was 96%. Until the end of June the common number of larvae reached 20-100 heads one hundred plants, the highest of that reached over 500 heads on soybean, peanut and vegetable crops and weeds.

The serious occurrence of cotton bollworm had the relation with the rapid development of its insecticidal resistance in recent years. All the plant protection system of county and city reflected that the pyrethrin pesticides, such as fenvalerate and Decis could be diluted for 10,000-fold and their control effect to cotton bollworm might reach over 90%, but dropped year by year after 1985. Until 1990-1991, their control effect with 500-1,000-fold only reached 70% and almost without effect in high resistant area.

The authors analyzed that the serious explosion of cotton bollworm had close relation with the following factors: (1) Enough base of cotton bollworm resource. Due to the rapid development of the resistance to cotton bollworm in recent years, its control effect dropped so that the survival bollworms were more than before after treatment, (2) It was warmer in the winter of 1991 and the cotton stalks were not pulled out in winter in recent years, so it created good condition for overwintering cotton bollworm, according to the investigation, the winter pupal survival was almost 100% was so its over wintered base was great; (3) Enough food. The first generation of cotton bollworm appeared in the wheat field with the wheat grain as their food so the larvae and moth body were larger than that of previous years to have a great quantity of egg laying, long laying season and great reproductive number; (4) The weather in the spring and early summer of 1992 was suitable for the growth of cotton bollworm for this period mainly was the sunny days and light rain at an interval of some time. (5) The acreage of the summer seeding cotton increased in Hebei Province, about 230,000 hectares. The summer seeding cotton was sown immediately after harvesting the wheat so the first generation of cotton bollworm damaged in the wheat field might enter into the cotton field directly and it was advantageous for their survival and damage, all these integrated functions led to the particularly serious explosion of cotton bollworm in 1992 in Hebei Province.

The observation of the cotton bollworm resistant level in Hebei Province in 1992.

Its result was published in Resistant Pest Management Newsletter, Volume 4, No. 1 (1992). In 1992 we also observed the resistant level of cotton bollworm to 4 pyrethroids continually with the same method in 3 representative cotton cultivated areas. The results were as follows:

1. The resistant level of cotton bollworm to fenvalerate in different areas in 1991-1992.

   To select Guan County in the northern part of Hebei Province, Dingzhou City in the middle part of Hebei Province, and Handan City, to collect the second generation of cotton bollworm, their observation was carried out with the 3rd instar by the topical application. Its result was shown in Table 1.

Table 1. The determination of the cotton bollworm resistance to fenvalerate in different areas in 1991 and 1992.

Location	Year	LD50 (ul/g)	95% confidence limits	LD99 (ul/g)	Resistant comparison
'S' strain		0.3154	0.2742-0.3628	4.5871	1
Guam County	1991	3.1035	2.5797-3.7336	84.5825	9.8
	1992	4.5219	3.4367-5.9498	75.3409	14.3
Ding zhou City	1991	7.2789	4.7282-11.2056	624.596	23.1
	1992	7.4487	5.8542-9.4775	241.3627	23.6
Gu cheng County	1991	15.3189	10.3771-22.6134	2417.29	48.6
	1992	13.7099	8.5145-22.0851	83.824	43.5
Handan City	1992	14.0341	11.8724-16.6541	85.824	44.5

2. The resistant level of cotton bollworm to decamethrin in different areas in 1991 and 1992.

   The LD50 of sensitive strain to decamethrin was 0.0196 g/g and its observation result was listed in Table 2, 3.

Table 2. The resistant level of cotton bollworm to decamethrin in 1991 and 1992.

Location	Year	LD50 (ul/g)	95% confidence limits	LD99 (ul/g)	Resistant comparison
'S' strain		0.0196	0.0165-0.0233	0.1833	1
Guam County	1991	0.3038	0.1981-0.4660	14.0126	15.5
	1992	0.3582	0.3005-0.4270	4.1184	18.3
Ding zhou City	1991	0.3938	0.3049-0.5086	8.034	20.1
	1992	0.4169	0.2882-0.5515	40.3615	21.3
Gu cheng County	1991	1.1308	0.8394-2.5063	25.5196	57.7
	1992	1.2376	0.8999-1.7019	37.7226	63.1
Handan City	1992	0.6542	0.4623-0.9260	15.2793	33.4

Table 3. The resistant level of cotton bollworm to cypermethrin in different areas in 1991 and 1992.

Location	Year	LD50 (ul/g)	95% confidence limits	LD99 (ul/g)	Resistant comparison
'S' strain		0.2082	0.1776-0.2440	1.8144	1
Guam County	1991	2.8524	2.1416-3.0607	93.2946	13.7
	1992	3.7364	2.8433-4.9010	62.8192	17.9
Ding zhou City	1991	5.7368	4.3258-7.6085	70.3719	27.6
	1992	6.2606	4.8105-10.3880	410.5765	30.1
Gu cheng County	1991	6.5153	5.0844-8.3525	76.9653	31.3
	1992	7.2344	5.9004-8.8674	48.5498	34.7
Handan City	1992	5.678	4.1422-7.7830	758.3929	27.3

3. The resistant level of cotton bollworm to cypermethrin in different areas in 1991 and 1992.

   The LD50 of sensitive strain to cypermethrin was 0.2082 g/g and its observation result was listed in Table 3.

4. The resistant level of cotton bollworm to cyhalothrin in different areas in 1991 and 1992.

   The LD50 of sensitive strain to cyhalothrin was 0.0218 g/g and its observation result was listed in Table 4.

Table 4. The resistance level of cotton bollworm to cyhalothrin in different areas in 1991 and 1992.

Location	Year	LD50 (ul/g)	95% confidence limits	LD99 (ul/g)	Resistant comparison
'S' strain		0.0218	0.0192-0.0248	0.1572	1
Guam County	1991	0.2124	0.1630-0.2775	3.0715	9.7
	1992	0.2387	0.1843-0.3092	3.2419	10.9
Ding zhou City	1991	0.4025	0.2703-0.5993	31.9162	18.5
	1992	0.3895	0.2751-0.5515	16.5393	17.9
Gu cheng County	1991	0.7244	0.4581-1.1655	69.4616	33.2
	1992	0.76	0.5903-0.9787	11.4339	34.9
Handan City	1992	0.6638	0.5280-0.8346	4.2723	30.4

5. Comparison among the resistant levels of the cotton bollworm to the different pyrethroids in different areas in 1991 and 1992.

   Now the whole observation results in two years were listed in Table 5.

Table 5. Comparison among the resistant levels of the cotton bollworm to the different pyrethroids in different areas in 1991 and 1992.

Pesticide		Fenvalerate		Cypermethrin		Decamethrin		Cyhalothrin	
Population	Year	LD50 (ul/g)	R.	LD50 (ul/g)	R.	LD50 (ul/g)	R.	LD50 (ul/g)	R.
'S' strain		0.3154	1.0	0.2082	1.0	0.0196	1.0	0.0218	1.0
Guam County	1991	3.1035	9.8	2.8524	13.7	0.3038	15.5	0.2124	9.7
	1992	4.5219	14.3	3.7364	17.9	0.3582	18.3	0.2387	10.9
Ding zhou City	1991	7.2789	23.1	5.7368	27.6	0.3938	20.1	0.4025	18.5
	1992	7.4487	23.6	6.2606	30.1	0.4169	21.3	0.3895	17.9
Gu cheng County	1991	15.3189	48.6	6.5153	31.3	1.1307	57.7	0.7244	33.2
	1992	13.7099	43.5	7.2344	34.7	1.2376	63.1	0.7600	34.9
Handan City	1992	14.0342	44.5	5.6780	27.3	0.6542	33.4	0.6638	30.4

The observation results of the resistant level to cotton bollworm for years in Hebei Province was shown that the resistance of cotton bollworm in the northern, middle and southern parts of cotton cultivated areas in Hebei Province has raised regularly, but there existed certain difference in different areas and among different varieties of pesticides. To sum up, the resistance of cotton bollworm in the southern part of Hebei Province still was at the high level, its resistance was all above 20-fold and the highest 63. 6-fold, although the resistance of cotton bollworm in the northern part of Hebei Province developed but still under 20-fold. However, the results showed that the resistance of cotton bollworm has been developing, which indicated that it is extremely anxious to carry out the integrated resistant management of cotton bollworm.

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Institute of Plant Protection
CAAS
P.R. China

Wei Yizhang, Wang Hejin, & Zhang Guobao
Agriculture Department of Hebei Province
P.R. China

Characterization of Resistance to Atrazine in a Velvetleaf (*Abutilon throphrasti* Medik.) Biotype from Wisconsin

Three atrazine-resistant velvetleaf biotypes from Wisconsin (WRB1, WRR1, and WRL1) have been confirmed since 1990. Previously, an atrazine-resistant velvetleaf biotype (MRB) was reported in Maryland. We have conducted research to 1) quantify the level of atrazine resistance in the WRB1 and MRB biotypes, 2) determine whether these biotypes are cross resistant to other selected herbicides, and 3) determine the competitive ability and productivity of the WRB1 biotype and a Wisconsin atrazine-susceptible (WSA1) biotype.

In greenhouse studies, postemergence atrazine GR50 values for WSA1 and WRB1 biotypes were 0.11 and 11.6 kg ai ha-1, respectively, indicating a 106-fold level of resistance; the MRB biotype demonstrated a 116-fold level of resistance. Following postemergence field applications of atrazine at 1.1, 2.2, and 4.5 kg ai ha-1, mortality of WSA1 plants was 56, 96, and 99%, respectively. Mortality of WRB1 and MRB biotypes was not affected by atrazine rates as high as 4.5 kg ai ha-1. WRB1 and MRB biotypes were not cross-resistant to cyanazine, metribuzin, ametryn, bentazon, bromoxynil, linuron, dicamba, thifensulfuron, or imazethapyr.

An addition series experiment was conducted in the field during 1992 to determine the relative competitive ability of the WSA1 and WRB1 biotypes. Seed production was similar between the two biotypes at densities of 36, 64, and 100 plants m-2. Above-ground plant dry biomass of WSA1 and WRB1 biotypes was similar at densities of 64 and 100 plants m-2; the WRB1 biotype had greater above-ground plant dry biomass at a density of 36 plants m-2. Productivity studies determined that leaf area, height, and above-ground plant dry biomass did not differ over time between WRB1 and WSA1 biotypes.

These results suggest that the WRB1 and MRB biotypes have similar whole-plant responses to selected herbicides and that resistance to atrazine does not reduce the intraspecific competitive ability of the WRB1 biotype. Current research is determining the mechanism of atrazine resistance in the WRB1 biotype.

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Resistance of Giant Foxtail (*Setaria faberi* Herrm.) and Large Crabgrass (*Digitaria sanguinalis* [L.] Scop.) Biotypes to Acetyl-Coenzyme A Carboxylase Inhibitors

Herbicides that inhibit acetyl-coenzyme A carboxylase (ACCase) are commonly used for management of monocot weed species in vegetable cropping systems. One biotype of giant foxtail (RW1-5) and three biotypes of large crabgrass (RW2, RL7, and RL5) that demonstrate resistance to ACCaseinhibitor herbicides have been identified in a carrot (*Daucus carota*), onion (*Allium cepa*) and corn (*Zea mays*) cropping system in Wisconsin. The number and frequency of fluazifop applications in this cropping system suggest that fluazifop provided the greatest herbicide selection pressure on monocot weeds.

In greenhouse studies, the ratio of herbicide GR50 values for resistant and susceptible biotypes of giant foxtail was 110, 20, 14, 4, and 4 for sethoxydim, fluazifop, diclofop, quizalofop and fenoxaprop, respectively. The selected giant foxtail biotype was not resistant to clethodim, alachlor, imazethapyr, or nicosulfuron. Similar studies of large crabgrass biotypes found that the ratio of herbicide GR50 values for resistant (RW2) and susceptible biotypes was 384, 70, 50, 23, 20, and 5 for sethoxydim, fluazifop, fenoxaprop, quizalofop, diclofop, and clethodim, respectively. The selected large crabgrass biotype was not resistant to imazethapyr.

Dose-response studies of in situ populations where herbicide resistant giant foxtail (RW1-5) and large crabgrass (RL7) biotypes were identified were conducted during 1992 and 1993, respectively. Herbicides were applied at rates less than, equal to, and greater than the recommended labelled rates. Mortality of giant foxtail plants 71 days after treatment (DAT) averaged over application rates for sethoxydim, fluazifop, quizalofop, clethodim, imazethapyr, and nicosulfuron was 33, 27, 59, 100, 93, and 100%, respectively. Mortality of large crabgrass plants 42 DAT averaged over application rates for sethoxydim, fluazifop, quizalofop, clethodim, and imazethapyr was 34, 2, 23, 76, and 92%, respectively. Current research is determining the intraspecific competitive ability and productivity of herbicide-resistant giant foxtail and large crabgrass biotypes.

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Resistance Management News

NSW Agriculture Video
The NSW Agriculture has just produced a video on the resistance management programme based at the Narrabri Agricultural Research Station. The video deals with the practical aspects of running a Heliothis armigera resistance monitoring programme and was made as an aid to familiarize visitors with the Research Station's activities.

For more information please contact: Neil Forrester Senior Research Scientist NSW Agriculture Myall Vale Mail Run Narrabri, NSW 2390 AUSTRALIA Telephone (067)99-1500 FAX (067)93-1186

Insecticide Resistance Action Committee (IRAC)
IRAC has met twice (Brighton, November 1992; Bruxelles, April 1993) under its new chairman, Jean Jacques Herve. Work continues to be concentrated upon monitoring, using reliable IRAC approved methods, and on devising and implimentating industry-wide use management strategies. The inclusion of resistance issues in EEC registration submissions also brings new implications to IRAC studies on resistance.

Pyrethroid Efficacy Group (PEG)
The group has published a set of resistance management principles in the US. These principles were presented at the Beltwide Cotton Conference in January 1993 and will be published in the "Cotton Grower Magazine". These principles are enshrined in the following:

- Always include any efficient cultural/biological control practices in your pest control program.
- Time the application of insecticides against the most susceptible life stages based on local pest thresholds.
- Do not rely on a single insecticide class.

- Use insecticides at recommended rates and spray intervals.
- When there is more than one generation of insects, use different classes of insecticides in alternation.
- In the event of a control failure due to resistance do not respray with an insecticide of the same class.
- Ensure mixture components of different classes of insecticides are used at effective equivalent control rates.

The group continues to monitor resistance in *Heliothis virescens* and *Heliothis zea* in the US. This will be the seventh consecutive year of this monitoring using the adult vial test. This work is complimented by an IRAC sponsored study on resistance mechanisms (J. Ottea, Louisiana State University).

Last season monitoring revealed low levels of resistance pre season which increased under insecticidal pressure and continued moderate increases in late season.

Following on from a conference on resistance in Beijing (March 1993) a PEG China group was formed to coordinate industry actions towards the management of *Heliothis armigera* and *Aphis gossypii* on cotton.

Cotton Working Group

IRAC method number 7 (leaf eating larvae of Lepidoptera and Coleoptera on cotton, vegetables and field crops) has been approved following testing and with some modifications was used extensively in Pakistan during the 1992 season. A recent meeting in Seville, Spain, resulted in a useful discussion of resistance issues in Spain although it was not appropriate to inaugurate an IRAC Spain group.

Data on insecticide resistance in cotton from 25 countries is now available.

The USA group is sponsoring a study of methods and strategies to combat resistance in whitefly, as well as work on Heliothis virescens at LSU and USDA. The IRAC Cotton Mexico group has conducted a survey of *Heliothis* resistance and found largely susceptible populations. The data generated by IRAC Cotton Pakistan in 1992 is currently being analyzed. There are indications of moderately multiresistant populations in some areas.

Fruit Crops Working Group

The Spider Mite Resistance Management Strategy developed by the group (P. Leonard in "Resistance 1991, achievements and developments in combatting pest resistance"; see also G. Sterk and P. Highwood, Brighton Crop Protection Conference, Pests and Diseases, 1992, 517-526) is being publicized in order to maximize its impact on growers. Resistance management guidelines for *Myzus persicae* are being developed. In order to evaluate the risk of cross resistance and develop use management strategies prior to introduction, a research project using 4 novel acaricides in various stages of development is being planned.

Field Crops Working Group

Sponsored research by Edward Cheng in Taiwan validated the use of IRAC Method No 7 for Plutella and found no apparent cross resistance between acyl urea IGRs and other chemical groups. The group is currently gathering information on the resistance status of Colorado Potato Beetle in E. Europe and plans to collaborate with the Fruit Crops group on *Myzus persicae*.

***Bacillus thutingiensis* (Bt) Working Group**

This international group of 13 companies has funded a large number of projects addressing the questions of the potential for resistance development and use of management strategies. This approach is in order to have a strategy prior to the reports of resistance, as it should be noted that outside of the laboratory, only one isolated case of Bt resistance exists, in a situation of extreme pressure. Priority is being given to finding reliable monitoring methods.

Public Health Working Group

A joint meeting with WHO was held (Geneva July 1992) to discuss resistance strategies in *Anopheles* control and plan future work.

At a WHO ministerial conference on Malaria (October 1992) a statement was made that any increase in the spread of malaria was not due to any technical problems associated with anolpheline control but resulted from management constraints and limited resources. Industry looked forward to working with international agencies and governments in new initiatives to control malaria.

Stored Products Working Group

Continuing concern over the misuse of fumigants and specifically phosphine have led to the planning of a workshop session at the forthcoming 6th International Conference on Stored Product Protection (Canberra Australia). Methods for resistance monitoring of stored product pests are being examined.

EEC Registration

Following the inclusion of resistance risk assessment and management strategies in the draft harmonized

EEC regulations for registration of technical material and formulated product, IRAC together with HRAC and FRAC have issued a response to ECPA on the proposed regulations, which has been submitted to the EEC commission. This combined "RAC" view was based on the principles of resistance management and risk evaluation. At the time of writing, the combined "RAC" response has not produced any change in the proposed EEC regulations.

If you would like further information on any of the IRAC Groups or activities, please contact the author:

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Bt Management Group Focuses on Resistance

DAVIS, Calif. (May 7, 1993) -- The biorational industry is working to prevent insecticides based on *Bacillus thuringiensis* (Bt) from falling victim to the very condition that has made them a popular alternative to chemical pesticides: insect resistance.

Industry representatives are funding educational programs and field research on how resistance can be avoided by using Bt products as part of an integrated pest management (IPM) strategy, says Susan MacIntosh, chairperson of the Bt Management Working Group (BtMWG), an international group of scientists from 13 private companies. Over the past four years the group has provided $250,000 in funding, for Bt research projects.

"When Bt products are used wisely in IPM programs, and combined with a range of pest control measures, the risk of resistance is minimal," says MacIntosh. "Reports to the contrary are incorrect."

IPM strategies uses chemical, biological, cultural practices or other methods to insure that no one product or method is used so frequently as to promote insect resistance.

Insect resistance in biological insecticides has not been identified by the scientific community as a widespread or inevitable situation, adds MacIntosh, a scientist at Entotech, Inc. in Davis.

"But due to the diversity of Bt products, we anticipate wider use of biological pest-control tactics. It is time to take a proactive approach to minimizing the threat of insect resistance to these products," she adds.

"It is critical that Bt remains a viable option for agriculture," says MacIntosh. "After 30 years of successful use, Bt is considered one of the safest pesticides available. It is biodegradable and has no adverse effects on beneficial insects, other wildlife or farm workers. That's why we are encouraging the use of Bt within an IPM strategy."

The only documented cases of Bt resistance under field conditions have occurred in isolated incidents for a single species -- the diamondback moth, says MacIntosh.

The diamondback moth has relatively low mobility and a high reproductive capacity, up to 25 generations per year in tropical climates. Since these moths have developed resistance to all other insecticides, Bt was sprayed intensively with no additional pest control measures, a situation conducive to rapid resistance development, MacIntosh adds.

"There is no evidence, published or otherwise, that points to resistance development in gypsy moths," says Norm Dubois of the United States Department of Agriculture Forest Service in Hamden, CT.

Resistance, to certain Bt insecticidal proteins, has been induced in several other insect species in artificial selection experiments, but resistance appears to develop quite differently in the field as compared to the laboratory, says Dubois.

Bt is a bacterium which, under natural conditions, produces insecticidal proteins that controls a variety of insect pests. Bt use has increased at a rapid pace but remains only a small part of total insecticide sales.

For more information, please contact:

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Monoclonal Antibody Sales Forecast to Increase Dramatically

Reprinted from:
National Biological Impact Assessment Program
NBIAP News Report
November 1993

The concept and techniques associated with monoclonal antibody production were introduced about 20 years ago, and now seem like old technology to many. Monoclonals are, however, of continued importance in many aspects of diagnosis, treatment, and research. There have been tremendous improvements in the methods for generating and maintaining hybridomas and producing antibodies. Anti idiotypic monoclonal antibodies (designed to minic antigens against which other monoclonals have been made) have also been produced by many investigators, and may allow immunization against antigens which are in short supply. In the face of broadened usage and improved technology, interest in the area has continued to rise, suggesting a bright future for the technology. A recent article in Genetic Engineering News {13(14):3, 1993} predicted a 5-fold increase in sales during the next 5 years (to $3.8 billion). Other predictors of market fiutures suggest that much of this increase will come from expanded usage in domestic animal production and disease diagnosis and therapy

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Symposia

IRAC US Cotton Meeting Minutes

The third meeting of 93 was held on the 14th of September in Monroe, LA.

1. Resistance Management Statements for Insecticide Labels:

   The Miles statement and the Curacron Statement which had been previously distributed were reviewed. J. Long also provided a copy of the Kelthane statement which was very product specific. There was general consensus that the statements did not have to be generic and could be product specific and that all companies would include these on future label updates. There was some concern that the statements could be taken out of context and used against a product with some non US examples mentioned. Chuck Staetz reminded the group that there was an agreement in the central IRAC charter prohibiting using statements or data against a product and volunteered to distribute this agreement at the next meeting. Roger Leonard expressed some concern that resistance potential statements might not be adequate and that some products should change their labels to indicate suppression rather than control. It was agreed that the label statement discussion would continue at the Beltwide Conference.

Field Diagnostic Kits: There was a good discussion on the history and status of field kits to assist field personnel in detecting the presence or absence of resistance in resistance in field crops to provide guidance with insecticide selection. In Australia, a kit that was developed by Abbott is being distributed that distinguishes between H. armigera and H. punctigera eggs. There are apparently some efforts going on in the US for a similar kit for H. zea and H. virescens. There were some concerns about the liability the marketer of such kits would assume and also on the practicality and value of such kits. However, this was felt to be an area that still needed more investigation and one that was a good fit for a multi-company group such as IRAC to contribute to. A challenge was made to all members to continue investigating the area and provide additional reports.

2. Validation of non synthetic pyrethroid glass vials for adult monitoring:

Don Allemann reported on an extensive program that Ciba had on profenofos vials during 1993. They had several sources prepare vials and found a wide variability in the amount of recoverable profenofos and concluded that strict guidelines for quality control are a must. Profenofos was found to be extremely sensitive to temperature effects with significant loss at room temperatures at 6 days and the loss accelerates with an increase in temperature. Benzoic acid did not help with profenfos stability. However, the vials were stable when kept frozen and considerable data was collected across the Cotton Belt. There was considerable variability in the results but the variability was determined to be natural biological variability in susceptibility rather than pockets of resistance.

3. Insect Pest Situation During 1993 and Insecticide Use Strategies:

G. Burris, S. Micinski, and G. Elzen. In Louisiana, it was felt that the resistance management plan was well adhered to and that it worked well since populations were low. The top 5 pests were beet armyworm, boll weevils, tobacco budworms, plantbugs, and aphids. An informal survey of growers indicated that there is a perception that the performance of all compounds has decreased.

In Mississippi, thrips, boll weevils and locally heavy aphid populations were early season pests during 1993. There were high levels of plant bugs all season and resistance was mentioned as a possibility following control problems. There was a wide spread beet armyworm epidemic that caused sever injury to many fields.

Objective #1: To survey selected populations of tobacco budworm for changes in susceptibility levels to carbmate, cyclodiene, organophosphate and pyrethroid insecticides. J. Graves & G. Elzen.

The results to date from the extensive Louisiana survey were distributed and discussed by Dr. Graves. Although population levels were down and there were fewer treatments there was a general trend for slightly higher resistant levels in Louisiana during 1993. Dr. G. Elzen reported similar population levels in Washington Co. MS but that the observed resistant levels were lower than in 1992. AVT tests were compared with spray table tests at both Stoneville, MS and Winnsboro, LA. There was less resistance in AVT than with spray table tests which was believed to be due to the fact that the AVT doses are too high to detect low differences. With non SP compounds there was no early season survival but adult survival was up late season probably reflecting selection from beet armyworm treatments. The researchers felt that more work is needed in determining proper discriminating doses and that there is danger in using vial tests results for making insecticide recommendations particularly with OP's since the vial results are general averages of cotton and non cotton populations and may not be indicative of in-field targets. All remarks were qualified that these were in-progress results with little analysis.

Objective #2: To examine metabolic capacity and variation in neuronal sensitivity to organophosphate and pyrethroid insecticides in field collected tobacco budworms.

J. Otea reported his preliminary results where he observed 30% less penetration and high levels of MFO activity in the Macon Ridge Strain of H. virescens. However, the bulk of the resistance was attributed to a 10 fold reduction in nerve sensitivity. There was no target site resistance to OP's in early season samples. All late season samples were still being examined.

Objective #3: To evaluate the effect of insecticide use patterns on changes in tobacco budworm susceptibility to carbamates, organophosphates and pyrethroids. A large number of larvae were field collected then exposed to various insecticide selections using a modified spray table approach. There were differences observed and some cross class implications in response. Results are still being analyzed.

Objective #4: To refine tobacco budworm insecticide resistance management theory and practice based on results obtained under Objectives 1-3. No changes were made for 93.

Acaricide Subgroup: John Long of Rohm & Haas reported that he and other members of this committee as well as representatives from Merck have need to work jointly in miticide resistance projects. The subgroup would need to cover not only cotton but other crops as well. There was unanimous consensus that the group could work within IRAC US Cotton and meet earlier or later to cover other crops.

Acaricide Subgroup: John Long of Rohm & Haas reported that he and other members of this committee as well as representatives from Merck have need to work jointly in miticide resistance projects. The subgroup would need to cover not only cotton but other crops as well. There was unanimous consensus that the group could work within IRAC US Cotton and meet earlier or later to cover other crops.

Section 18 Discussion: W. Mullins related an experience where his company was denied a Section 18 that was requested based on a concern for resistance to current compounds since the criteria of documented 10 fold resistance accompanied by field failures had not been met. He suggested that we invite EPA to discuss the current criteria since they don't address the value of using new compounds early to prevent the complete loss of existing compounds to resistance.

G.D. Thompson
DowElanco
Vice Chairman/Secretary
Wayside, MS

ALS-Inhibitor Resistance Working Group (AIRWG) Meeting Minutes

The ALS/AHAS-Inhibitor Herbicide Resistance Working Group (AIRWG) Meeting held in St. Louis, Missouri, on September 15th and 16th, 1993, was attended by 12 academics and 17 technical representatives from industry. The first day of the meeting included reports from academics followed by brainstorming sessions on how to deal with short- and long term resistance management.

Academic Session, September 15, 1993

Reports of resistant weeds in Georgia

- ALS-inhibitor resistant prickly sida (Sida spinosa); also known as teaweed
- DNA-resistant goosegrass (Eleusine indica), especially on golf courses; may also be less sensitive to dithiopyr
- ACCase-inhibitor resistant annual ryegrass (Lolium sp.) and Johnsongrass (Sorghum halepense); ryegrass was selected on the GA Experimental Station
- MSMA-resistant cocklebur (Xanthium strumarium); not spreading; only seen in continuous cotton
- 2,4-D-resistant cocklebur claimed but NOT documented; Bridges et al. will investigate this winter
- Paraquat-resistant coffee senna (Cassia occidentalis)

Greatest concern is the possibility of ALS-inhibitor resistance in Johnsongrass, especially in no-till corn where nicrosulfuron or primisulfuron are used every year. Believes that resistance is manageable on an on-farm basis, in contrast with western U.S. where large regions are infested with resistance. The RWM (resistance weed management) strategy proposed is to minimize exposure to selection pressure.

Perceived problems for RWM by academics:

- Limiting the use (and therefore the selection pressure) of a product that is cheap, effective, and easy to use

- Hard to implement the cleaning up of escapes with glyphosate
- No action taken until problem occurs
- Recommendations between university extension and industry are not the same - key to effective management is to have the same recommendations

Believes that all RWM strategies must reduce selection pressure: Are crop rotations useful? Are tank mixtures useful?

Dr. David Bridges
University of Georgia
United States

Currently, no resistance to ALS-inhibitor herbicides in Ontario

Triazine resistance is prevalent

- Nine weed species since 1974
- Managed via broader rotations, herbicide rotation, and monitoring (using fluorescence test)

Ideas for RWM (no proof that these will work):

- Conservation tillage
- Burn-down herbicide treatments
- Herbicide banding
- Strip cropping, i.e., intensify rotations within a farm
- Use germinants
- IWM (Integrated Weed Management)

Dr. Clarence
Swanton University of Guelph
Canada

Views the management of resistant weeds and naturally tolerant weeds identically. Similarly, views prevention and cure of resistance as being nearly the same concept. More concerned about problem weeds in short term than resistant weeds. (A.)

Triazine resistance in WI:

- First resistance noted in 1978
- Exceeds one million acres
- Exclusively in dairy regions

In areas where triazine resistance exists, 88% of acreage sees triazine herbicides; in other words, farmers are not dependent on triazines alone. Currently, get no questions about resistance because triazine resistance is managed.

ACCase-resistant giant foxtail (Setaria faberi) and crabgrass (Digitaria sp.) are now present in WI. Like triazine resistance, ACCase resistance is an on-farm problem and can be managed.

Typical practices used in WI to help manage resistance:

- Herbicide combinations (>70% of farmers use this practice)
- Crop rotations (>70%)
- Herbicide rotations (>70%)
- Row cultivation (>70%)
- Tillage (50%)
- Split herbicide treatments (38%)

Emphasizes IWM in WI because:

- Altrazine and alachlor shows up in ground water; therefore, must reduce herbicide use
- Conservation tillage
- Profitability

Tank mixes have had varying degrees of effectiveness

Need alternative controls, especially for possible future resistance to nicrosulfuron or primisulfuron in Johnsongrass.

An experiment was performed to estimate the potential for ALS-inhibitor resistance in Johnsongrass. Nicrosulfuron was applied two times per year for three years, and the seeds were collected. To date, no resistance has been observed.

A six-year study will evaluate IWM practices for RWM use. Ten thousand wild-proso millet (Panicum miliaceum) seeds will be planted in the center of a large plot and different IWM methods will be tested for their effect on the spread of millet seed over six years. Harvey did not want to use resistant weed biotypes for the study so instead chose the proso millet.

Dr. Gordon
Harvey University of Wisconsin
United States

Views the management of resistant weeds and naturally tolerant weeds identically. Similarly, views prevention and cure of resistance as being nearly the same concept. More concerned about problem weeds in short term than resistant weeds. (B.)

Seven to eight weeds have resistance to one or more herbicides including annual grasses, wild oats (Avena fatua), green foxtail (Setaria veridis), wild mustard (Brassica kaber), and kochia (Kochia scoparia) resulting in a near-crisis situation in the western Canadian provinces. In communicating about resistance, university and extension personnel have worked hard to simplify the language regarding resistance.

Eight groups of herbicide-resistant weeds exist. Some of the groups include:

Group 1: ACCase-inhibitor resistant weeds

- Wild oats, green foxtail
- Seventy percent of acreage in western Canada has an ACCase-inhibitor herbicide applied.

Also, western Canadian is dependent on ACCase inhibitors for soil conservation management.

Group 2: ALS-inhibitor resistant weeds

- Common chickweed (Stellaria media), kochia, Russian thistle (Salsola iberica), wild mustard.
- Control of resistant wild mustard required two applications of dichlorprop/2,4-D because the weed population was so high.

Group 3: Mitotic inhibitor resistance

- Green foxtail

Group 4: Growth regulators (2,4-D, dicamba)
Group 8: Triallate/difenzoquat

- Wild mustard

Groups 1 and 3:

- Green foxtail

The initial RWM program was to promote herbicide rotation by employing a one-in-three use rule. Imidazolinone-resistant canola will be available for use within one or two years. If used judiciously, this resistant crop may be useful in herbicide rotations.

Dr. Ian Morrison
University of Manitoba
Canada

Insecticide resistance cost growers between $400 million and $1.4 billion annually

Four mechanisms of insecticide resistance

- Behavioral e.g., repellency (not a situation encountered in weeds)
- Penetration i.e., a change in the exoskeleton
- Target- site e.g., acetyl CoA esterase sensitivity to carbamates
- Metabolism: three systems identified include hydrolases, glutathione transferases, and mixed-function oxidases

Resistant management principles

- Diversify mortality
- Reduce selection pressure
- Encourage susceptibility
- Monitor
- Establish policy and communications

CO potato beetle

- Very large year to year variation in size of problem
- Resistant to every insecticide used for its control
- On average, a new insecticide works for two years
- If resistance is present, the economic cost of control is increased by 50%

Crop rotation with regard to insecticide resistance

- Crop rotation forces beetles to move to alternate hosts
- Volunteer crops provide a refuge during treatment

IOPRM goals are aligned to facilitate communications via the Pesticide Newsletter and the resistance workshop held annually at MSU.

Long residual insecticides select for polygenic mutants; subsequently, if a large insecticidal dose is applied to this population, then a resistant insect results often having one major gene responsible for resistance along with two or three other minor genes.

Dr. Joel Wierenga
Insecticide Resistance Representative
Michigan State University
B-11 Pesticide Research Center
East Lansing, MI 48824

General components of resistant fungicide management

- Reduce selection pressure by reducing disease pressure (i.e., keep orchards clean)
- Reduce selection time by limiting use as a single compound
- Reduce frequency of resistance and selectable isolates; this works only if the fungus has broad sensitivity and the population can be controlled by increasing doses; i.e., the spectrum increases with lower doses

According to Koeller, the first component was a very good strategy, the second component was not useful, and the third component was the most important.

Dr. Wolfram Koeller
Fungicide Resistance Representative
Cornell University
United States

General components of resistant fungicide management

A new, rapid diagnosis for ALS-inhibitor resistant weeds employing the simultaneous use of ALS and KARI (ketol-acid reductoisomerase) inhibitors was described. In addition to results described in the Weed Technology paper, Cliff presented results on whether metabolism-based resistance would be detected. This experiment was performed using elaf disks of soybean and lambsquarters, both of which metabolize flumetsulam, and velvetleaf which does not. As expected, the test is specific for target-site resistance and would not identify soybean as resistant to ALS-inhibitors.

Dr. Clifford Gerwick
DowElanco

Report on Break-Out Sessions

Two areas were agreed upon as topics for break-out discussions: short-term and long-term strategies regarding RWM.

Long-term research which would aid future RWM included the study of combinations, herbicide rates, effect of government programs, negative cross-resistance, etc. Test systems using kochia, cocklebur, and green foxtail were suggested (two broadleaf weeds in grass and broadleaf crops, and a grass weed). The study of both ALS resistance and ACCase resistance simultaneously may be useful in elucidating more encompassing RWM strategies as well as being more appealing for funding via organizations such as HRAC. It was proposed that an approximately five page document highlighting proposed research be prepared by academics, reviewed by AIRWG members, and presented to HRAC for input regarding content and possible funding. Hopefully, initial industry financing would provide a basis for obtaining matching grants from organizations such as the Center for IPM in North Carolina.

The other discussion topic, short-term strategies and research, dealt with short-term strategies within the 3 to 4 year range. Very little consensus was found regarding several topics including weeds at risk, regional differences, validation of resistance models, and strategies. There was, however, a fair bit of agreement around more understandable labels, the importance of selection pressure, and rotation of modes of action.

The importance of prevention, definitions of resistance, rotation of modes of action, use of tillage where appropriate, and equipment clean-up were mentioned as some of the important messages that need to be communicated to the grower.

Also suggested was to involve the WSSA in compiling the resistance literature available from various companies and universities. This issue will be brought up at the next meeting of the WSSA herbicide resistance group.

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WRCC-60: Science and Management of Pesticides Resistance Meeting

The next meeting of WRCC-60 will be on Monday and Tuesday, April 18-19, 1994, immediately preceeding and in conjunction with the Second National IPM Symposium/Workshop at the Riviera Hotel in Las Vegas, Nevada. The WRCC-60 meeting will consist of three half-day sessions, and will be a comprehensive review of the status of research on insecticide, herbicide, and fungicide resistance. Participants will include Experiment Station and USDA scientists, other academic researchs, staff of regulatory agencies, industry scientists and representatives of industry action groups.

For more information, contact the WRCC-60 Chairman, David G. Heckel, Department of Biological Sciences, Clemson University, Clemson SC 29634. Phone (803)656-3585 FAX (803)656-0435 E-Mail DHECKEL@CLEMSON.CLEMSON.EDU.

The IPM Symposium/Workshop will begin Tuesday afternoon, April 19, and /continue through Friday, April 22. Registration materials will be available in January 1994; for more information contact the symposium organizer Ronald J. Kuhr, Department of Entomology, Box 7613, North Carolina State University, Raleigh, NC 27695-7613. There are plenary sessions, workshops, and 22 poster sessions on various aspects of IPM, including Pesticide Impact Assessment (NAPIAP), Pest Resistance Management and IPM, and Minor Use Registration (IR-4). WRCC-60 attendees are encouraged to submit a poster to one of these sessions. The abstract deadline is January 15, 1994.

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Management of *Bemisia tabaci* Symposia

The SCI Pesticides Group will hold a meeting January 25, 1994 on Management of Bemisia tabaci in Belgrave Square, London. This meeting will feature talks given by Mr. M. Cahill of the Rothamsted Experimental Station, Harpenden, UK concerning Managing resistance in Bemisia tabaci and Dr. A. Rami Horowitz of The Volcani Center, Bet-Dagan, Israel concern ing Managing resistance in Bemisia tabaci in Israel. For more information and/or registration forms write to: SCI Conference Secretariat 14/15 Belgrave Square London SW1X8PS ENGLAND

Global Pest Resistance Management Summer Institute

The second annual Global Pest Resistance Management Summer Institute will be held at Michigan State University July 5 15, 1994. The Summer Institute is a 2-week formal training program designed to teach the concepts of pest resistance management. This is accomplished through a rigorous schedule of classroom instruction, hands-on laboratory exercises, informal discussions, and global networking project development. Each participant is provided with critical literature, resistance monitoring kits, networking capabilities, and hands-on resistance management experience. Ten Departments and Academic Units particpate in presenting an in-depth, multi-disciplinary examination of resistance management. Enrollment is limited to 30 scientists. The registration deadline is May 1, 1994.

For more information contact: Dr. Joel Wierenga Pesticide Research Center Michigan State University East Lansing, MI 48824 UNITED STATES Telephone (517)355-1768 FAX (517)353-5598 E-Mail:wierenga@pilot.msu.edu or Dr. Mark E. Whalon Department of Entomology and Pesticide Research Center Michigan State University East Lansing, MI 48824 UNITED STATES Telephone (517)353-9425 FAX (517)353-5598 E-Mail: 22513MEW@MSU.edu

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Announcements

This is the first RESISTANT PEST MANAGEMENT NEWSLETTER that I have produced. It has been both a pleasure and a challenge for me to put this newsletter together. Please direct future coorespondance to the address below.

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