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THE USE AND ABUSE OF INSECTICIDES ON CABBAGE IN BARBADOS

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ABSTRACT

Cabbage (Brassica oleracea L. var. capitata L.), an important crop throughout the world, is subject to major economic losses as a result of damage by a number of pests. The diamondback moth [Plutella xylostella (L.)], which is probably the most important of these, has developed resistance to all classes of commercial insecticides. Data are presented on the insecticides used in Barbados to control cabbage pests and how they are used. The practices are discussed in relation to the consumer, economics of production, biological control programmes in Barbados and the management of insecticide resistance in P. xylostella.

INTRODUCTION

Brader (1986) quoted World Health Organization estimates of 1,100,000 cases of pesticide poisoning in the world per year, of which 20,000 are lethal. According to Bramble (1989), it is estimated that, because of pesticide misuse in developing countries, there are 750,000 cases of poisoning and 10,000 deaths per year. This situation can be attributed to several factors. These include: a lack of training in the safe use of toxic chemicals, lack of concern for farmworker health by large landowners and, often, health care workers not being trained to recognize symptoms of pesticide poisoning (Bramble, 1989). In addition, in the tropics it is often impracticable to use protective clothing.

The U.S. National Wildlife Federation (NWF) is concerned by reports of massive fish kills and contamination of wildlife, especially animals at the top of the food chain (Bramble, 1989). In many areas the natural balance of predators and prey has been upset, particularly among insects. The NWF has also investigated pesticide residues in foods imported into the United States and, according to Bramble (1989), the pattern of high and illegal residues in imported foods is disquieting.

In some areas, pesticide use is so heavy that human health may be threatened in many ways. Bramble (1989) cites the heavy use of pesticides on the Central American cotton crop that has led to the resurgence of malaria and to beef cattle becoming contaminated.

According to Reichelderfer (1989), there is a well-accepted (but undocumented) relationship between countries' incomes and the effectiveness of national pesticide regulations. The higher a country's gross national product, the more likely it is that pesticide regulations exist and are enforced. Thus, rigorous pesticide regulation tends to be directly related to high levels of development. This enforces the view of Ruttan (1971, cited by Reichelderfer, 1989) and others that environmental quality is, in essence, a luxury good.

Gianessi and Elworth (1990) have pointed out recently that, even in the United States of America (USA), surprisingly little information is available on the actual use of agricultural chemicals. Many Americans and public policy-making officials assume that detailed data about the quantity of specific pesticides being sprayed on individual fruit and vegetable crops exists somewhere but they are seriously mistaken. Although, in the United States and other developed countries, mountains of safety test information are required to register, or re-register, a pesticide, comprehensive data on actual use is <u>not</u> available. In most of the states of the USA, where data are available, they only cover certain crops, pesticides, or types of applications and, according to Gianessi and Elworth (1990), most of these reports are out of date.

At the present time, farmers in Barbados are using large quantities of insecticides to control diamondback moth, <u>Plutella xylostella</u> (L.). These are often applied as elaborate "cocktails" of chemicals. This is not only a major cost of production but has led to concerns about residues remaining on the crop, especially in relation to praedial larceny, and the possibility of the ground water becoming contaminated.

The heavy reliance on chemicals could be in response to insecticide resistance in the pest (Gibbs et al., 1989) but is also a recipe to ensure the development, or continued development, of resistance. In other parts of the world, this moth has developed resistance to practically all classes of chemical insecticides. Sun et al. (1986) reported resistance to carbamates, DDT, organophosphorus compounds and pyrethroids. Particularly disturbing are: (1) the report from Taiwan that the greatest resistance, in that country, is to synthetic pyrethroids (Cheng, 1986); (2) the suggestion that there is resistance to formulations of <u>Bacillus thuringiensis</u> (Berl.) (Thuricide HP) in the area around Baguio City in the Philippines (Kirsch and Schmutterer, 1988); and (3) the reported resistance to insect growth regulators in Thailand (Cheng, 1988).

In 1938, seven insect species were already resistant to insecticides. Fifty years later, close to 500 species were resistant (Brattsen, 1989). In the view of Brattsen (ibid.) of greater significance than the increase in number of resistant species is the increasing number of species that have multiple resistance or cross-resistance. Multiple resistance results from multiple co-occurring resistance mechanisms, such as insensitive acetylcholinesterase combined with enhanced detoxification by several enzymes, as in the case of resistance to organophosphates. It differs from cross-resistance, which is where different groups of insecticides interfere with a common target that has changed, e.g. cross-resistance to pyrethroids and DDT is most often attributed to an insensitive sodium channel (Brattsen, ibid.). Cross-resistance also occurs when a single enzyme detoxifies more than one class of insecticides.

The concept of resistance has changed over the years. It used to be that resistance in field-collected insects was compared with susceptibility in insect populations that had been kept isolated in insecticide-free conditions. Today, field strains are compared with a population that can be controlled with the recommended dose. This means that all field populations have acquired some degree of resistance; that the genetic constitution has been changed (in mostly unknown ways) of practically all insects that inhabit areas exposed to insecticides.

METHODS

A survey of 60 cabbage farmers in Barbados was carried out between September 1988 and June 1990. The questionnaire was designed to determine pest control practices and gather evidence suggestive of the presence of insecticide resistance in diamondback moth.

Data are also presented from a survey of Barbadian vegetable farmers conducted by Ferdinand (1988). Ferdinand's focus was on human and environmental health aspects of pesticide use. Of the 34 farmers interviewed 30 grew beans, 20 grew carrots and 19 grew cabbage.

RESULTS AND DISCUSSION

Many of the farmers surveyed reported that they had experienced heavy losses from their most recent cabbage crops. Losses of over 50% were not uncommon (Table 1).

From the survey it was found that a total of 18 different insecticides, were being used in attempts to control diamondback moth (Table 2). Pyrethroids and organophosphates were the most frequent types used and the most common product was Tambo, a combination of the pyrethroid Sherpa and the organophosphate Selecron.

The data in Table 2 are listed by individual products but more than a quarter of the farmers interviewed were using "cocktails" with up to four products. For example, Ferdinand (1988) found one farmer who had used the following "cocktail" on his most recent cabbage crop: two organophosphates (Lannate and Orthene), a carbamate (Padan), a pyrethroid (Decis) and a pyrethroid/organophosphate mixture (Tambo). It is possible that the use of "cocktails" is decreasing. In 1988, 17 of the 19 cabbage farmers interviewed by Ferdinand (1988) were using "cocktails". Of the other two, one was using the mixed product Tambo and the other used no insecticide.

The farmer using no insecticide was an elderly farmer who grows cabbage on a small scale and picks the insect larvae off by hand. This practice would be too expensive for large farmers and too time consuming for part-time farmers.

There was considerable variation in the number of applications per crop between farms and among insecticides (Table 3). Surprisingly, most of the farmers were spraying less frequently than the local Ministry of Agriculture's recommendation of two to three times per week (J.E. Jones, personal communication). Although most of the farmers interviewed reported that they used the insecticides at the manufacturers' recommended rates (Table 4), it must be noted that their "cocktails" often included more than one insecticide at the recommended rate.

The wide range in the number of applications means that there is also a wide range of production costs. Table 5 gives estimated insecticide costs for each of the insecticides listed in Table 2. The calculations are based on a typical cabbage plot of 0.25 ha and the recommended rate of application, although not all the farmers use this (Table 4). For those insecticides where the manufacturers give a range of recommended rates, the midpoint of the range was used. The labor costs were calculated at one sprayperson for one hour and no allowance has been made for the cost, depreciation or maintenance of spray equipment.

If one assumes that ten applications is typical, there is almost a four-fold difference in using the carbamate Padan rather than the organophosphate Malathion. Comparing five applications of Malathion with 15 applications of Padan, the latter is 11 times more expensive. Fifteen percent of the farmers using Padan actually make more than 15 applications per crop at a cost in excess of Bds $450 and are still not guaranteed to totally avoid any crop loss.

Table 1. Farmers' estimates of cabbage crop loss and the percentage of farms reporting each level of crop loss.

Estimated % Crop Loss	% Farms
0 - 5	22
5 - 10	8
10 - 25	15
25 - 50	12
50 - 75	5
75 -100	38

Table 2. Insecticides used to control diamondback moth on cabbage and the percentage of farms using them. (Bio = biological, Car = carbamate, OP = organophosphate, Pyr = pyrethroid).

Insecticide	Type	% Farms
Ambush	Pyr	16
Decis	Pyr	2
Diazinon	OP	10
Dipel	Bio	12
Ekalux	OP	2
Hostathion	OP	1
Karate	Pyr	2
Lannate	Car	3
Malathion	OP	2
Marshall	Car	2
Orthene	OP	5
Padan	Car	11
Payoff	Pyr	2
Perfekthion	OP	2
Sevin	Car	1
Sherpa	Pyr	6
Systoate	OP	2
Tambo	OP/Pyr	19

Table 3. Number of insecticide applications per cabbage crop and, for each insecticide, the percentage of farmers making these numbers of applications.

Insecticide	% Farms making these numbers of applications			
	1-5	6-10	11-15	>15
Ambush	29	25	17	29
Decis	50	50	0	0
Diazinon	19	31	25	25
Dipel	19	19	24	38
Ekalux	0	67	33	0
Hostathion	50	0	50	0
Karate	0	34	33	33
Lannate	40	40	0	20
Malathion	50	50	0	0
Marshall	100	0	0	0
Orthene	45	33	11	11
Padan	32	32	21	15
Payoff	0	33	34	33
Perfekthion	25	25	25	25
Sevin	50	0	50	0
Sherpa	55	27	0	18
Systoate	0	50	0	50
Tambo	22	25	31	22

Table 4. Percentage of farmers using each insecticide at the manufacturers' recommended rates (RR) and lesser and greater rates of application.

Insecticide	% Farmers using insecticide at		
	<RR	RR	>RR
Ambush	11	39	50
Decis	0	100	0
Diazinon	12	75	13
Dipel	5	75	20
Ekalux	0	100	0
Hostathion	100	0	0
Karate	0	67	33
Lannate	0	100	0
Malathion	25	50	25
Marshall	0	100	0
Orthene	33	67	0
Padan	50	50	0
Payoff	0	67	33
Perfekthion	0	100	0
Sevin	0	100	0
Sherpa	9	55	36
Systoate	50	0	50
Tambo	41	53	6
All insecticides	21	61	18

Ferdinand (1988) found that 85% of the vegetable farmers interviewed used some protective clothing during spraying and that all those that did not had been farming for over five years. However, when they were questioned about what they wore for different types of spraying activity, only about one quarter were found to be taking adequate precautions.

Under the prevailing wind regime of Barbados where wind speeds tend to increase during the day and decrease in the late afternoon, to minimize drift, and conform to government regulations, spraying should ideally be done before 7;00 A.M. or after 4;00 P.M.. However, Ferdinand (1988) found that one third of the farmers interviewed sprayed between 7;00 A.M. and noon (Table 6). These were either plantation farmers, or others who hired labour to do the spraying, and this time period represents hours of work. In the case of plantations, when the spraying allocation is done, the workers are free to return home.

Of the vegetable farmers interviewed by Ferdinand in 1988, 30% said that they considered both wind and rain before spraying (Table 6). Both of these factors are very important in gaining full benefit from the use of insecticide. Rain shortly before spraying will increase loss of insecticide by runoff from plant leaves, effecting a reduced application of the non-contact insecticides. Rain after spraying, by washing the leaves, may reduce the uptake of systemics and reduce the concentration of these in plant sap. In either case, the result is the exposure of the pests to sublethal doses, a recipe for the development of insecticide resistance in the pest population.

Rain and wind will lead to increased amounts of insecticide reaching the soil surface, increasing the potential for them to be leached into Barbados' underground aquifer which is a source of both potable and irrigation water. Although 40% of the cabbage farmers interviewed in the current study are using pyrethroids or dipel, which have no mammalian toxicity, many are using them in conjunction with carbamates and organophosphates. Another consideration is that, although much of the insecticide may be adsorbed on to clay particles in the soil, little is known about the degradation of these chemicals under tropical conditions. Their decomposition has been found to be influenced by a number of factors including moisture, temperature, soil type, adsorption, the level of soil nutrients and biological activity (Freed, 1980). Therefore, testing under temperate conditions may provide little information of value in the tropics because of unique soil types and typically low levels of soil nutrients and biological activity. Also, the breakdown products of the chemicals are not always known and may themselves be toxic.

Insecticides which enter the soil can also have a number of secondary effects. These may include killing soil insects and microorganisms that play important roles in nutrient cycling and adverse effects on microbial nitrogen fixation and, although not involved with cabbage, vesicular-arbuscular mycorrhizal fungi.

When Ferdinand (1988) asked vegetable farmers whether pesticides could cause adverse effects on the environment, just over three quarters said yes with the proportion who answered in the affirmative increasing with level of education (Table 7). Interestingly, all those who answered no had only received a primary school education.

Many of the farmers interviewed by Ferdinand (1988) believed that the use of insecticides to control diamondback moth on cabbage had lead to increased infestations by other pests on neighboring crops. This necessitated the use of more chemicals on those crops. Obviously, these pests were previously controlled by natural enemies and their populations have been reduced by the pesticides applied to cabbage. That 12% of the farmers, in the current survey, are using the bacterial insecticide Dipel is a welcome feature. Dipel, a formulation of Bacillus thuringiensis, is mainly effective against Lepidoptera and therefore should not affect the complex of natural enemies most of which are Hymenoptera. Of course, it will affect those beneficial lepidopterans that pollinate crops harvested as fruit.

According to Hill (1983) development of resistance to insecticides by pests may be rapid in the tropics because of greater biological productivity. It is generally recognized that 10-15 generations are required in most insect species for resistance to manifest itself (Hill, ibid.). Thus, with continuous breeding of pest species with overlapping generations, insecticide resistance can rapidly develop in the tropics. In the case of diamondback moth, which produces as many as 30 overlapping generations per year in Barbados (Jones, 1985), it would be expected that any population exposed to the same chemical control agent for four to six months would exhibit reduced susceptibility due to developing resistance.

The current survey shows that farmers are getting unacceptable crop losses despite the use of a wide arsenal of insecticides. This in itself suggests that these are ineffective at achieving the desired level of control. Failure of insecticidal control can be due to a number of factors including weather conditions at the time of spraying and the proficiency of those doing the spraying. Although these factors may contribute to the problem, it appears that insecticidal resistance in diamondback moth plays a major causative role in crop loss.

Table 5. Insecticide costs related to the number of insecticide applications per cabbage crop. The figures are quoted in Barbados dollars (Bds $ 1.00 = US $ 0.50). The costs are based on application at the recommended rate on a typical plot of 0.25 ha, labour at Bds $ 4.00 per application which represents one sprayperson for 1 hr and insecticides at July 1990 retail prices.

Insecticide	Number of applications per crop			
	1	5	10	15
Ambush	9.80	49.00	98.00	147.00
Decis	17.27	86.35	172.70	259.05
Diazinon	12.22	61.10	122.20	183.30
Dipel	17.10	85.50	171.00	256.50
Ekalux	23.30	116.50	233.00	349.50
Hostathion	12.45	62.25	124.50	186.75
Karate	15.00	75.00	150.00	225.00
Lannate	9.62	48.10	96.20	144.30
Malathion	8.31	41.55	83.10	124.65
Marshall *	55.47	277.35	554.70	832.05
Orthene	25.25	126.25	252.50	378.75
Padan	29.95	149.75	299.50	449.25
Payoff	16.43	82.15	164.30	246.45
Perfekthion	12.59	62.95	125.90	188.85
Sevin	18.27	91.35	182.70	274.05
Sherpa	14.90	74.50	149.00	223.50
Systoate	15.46	77.30	154.60	231.90
Tambo	17.21	86.05	172.21	258.15

* Marshall should only be used up to a maximum of 3 times per crop.

Table 6. The proportion of farmers spraying at different times and taking rain and/or wind into consideration before spraying (data from Ferdinand, 1988).

Factor	Time of Spraying			Total
	Before 7.00 a.m. and/or after 4.00 p.m.	Between 7.00 a.m. and 12.00 noon	Anytime	
Rain	26	12	6	44
Wind	6	6	3	15
Both	15	12	3	30
Neither	9	3	-	12
Total	56	33	12	100

Table 7. The proportion of vegetable farmers in Barbados answering yes, no or don't know to whether pesticides could adversely affect the environment related to education level (Ferdinand, 1988).

Education Level	% Yes	% Don't Know	% No
Primary	67	13	20
Secondary	83	17	0
Tertiary	86	14	0
Total	77	15	9

The results of preliminary screening tests of diamondback moth for insecticide resistance showed that it was common in Barbados. In tests with seven different insecticides on 15 different populations, on no occasion were all of the adult diamondback moths exposed killed (Gibbs et al., 1989). High survival rates with Selecron and Sherpa, the components of Tambo, the most commonly used insecticide, are particularly worrying.

For some pests biological control is a viable alternative to insecticides. Unfortunately Jones (1985), after a detailed study of the use of the braconid wasp Apanteles plutellae, a parasite of the diamondback moth, was forced to conclude that insecticides were the only viable control option.

The data presented in this paper suggest that, with the heavy use of insecticides, the environment for the development of resistance exists in Barbados and that resistance is in fact developing. Although the screening tests with the same insecticide on diamondback moth collected from different farms showed varying levels of mortality (Gibbs et al., 1989), these need to be viewed against the background that this is a highly mobile pest and populations can cover areas in excess of five thousand hectares (Cheng, 1981). Thus practices on one farm which discourage the development of resistance are pointless if other farms are doing nothing.

Cheng (1988) stated that alternating insecticides is better than using mixtures, because diamondback moth can develop multiple resistance through the use of mixtures. He further reported that, as a countermeasure to resistance, in Taiwan a limited number of insecticides are alternated during the spray season with each insecticide being used no more than twice in succession.

Pest management strategies that lead to the development of insecticide resistance depreciate the value of the crop protection input. Resistance in pest populations to insecticides for which there are no readily available substitutes may defeat the very purpose of the crop protection activities and can even result in increased crop losses (Brader, 1986; Reichelderfer, 1989).

Increased use of pesticides in developing economies has been associated with an increased incidence of acute pesticide poisonings and potential for chronic health effects, as well as contamination of food and water supplies. These adverse effects of pesticide use, as Reichelderfer (1989) has stated, can become constraints on agricultural development. Acute and chronic health effects reduce the productivity of the urban labour force and limit economic growth of the nation.

The heavy use of insecticides on cabbage in Barbados and the lack of facilities to examine fresh produce for chemical residues poses the question of safety to the consumer. Although Ferdinand (1988) found that most of the farmers interviewed were very aware of the need for an adequate lag-time between last application and harvest and that most of them were conforming to the manufacturers' recommendations, there are still some important concerns: (1) praedial larceny is not uncommon in Barbados and the larcenist is unlikely to be aware of the spraying history or to care about it, (2) recommended lag-times are often no better than guesstimates and may have to be revised, e.g. the doubling of the lag-time for the organophosphate Diazinon (Frank et al., 1987), (3) the recent introduction to Barbados of the carbamate Marshall, which has a very high persistence, and thus a very long lag-time, and (4) economic pressures on the farmer to sell. Often when supermarket rings a farmer and asks if he has any cabbage to sell, the farmer is often faced with the moral dilemma of losing a sale or selling before the lag-time has elapsed. This pressure is greatest at those times of the year when several farmers have cabbage crops nearing harvest and on the least educated farmers who depend on the sale of produce for most of their income.

Brader (1986) estimated that in developing countries where pest control measures are applied, these can reach 30% of production costs. This results from higher pest incidence, generally higher pesticide costs than in the industrialized countries and a low level of crop productivity. The data presented in this paper show that, for the cabbage crop in Barbados, insecticide costs are often the major cost of production.

Brader (ibid.) gave three criteria that define appropriate pest control technology. These are: (1) the technology should provide optimum control results both in the short and the long term, (2) it should be economically justifiable in a given agricultural production system, and (3) it should not present undue hazards to the users, the public or the environment. In addition, as Goodell (1989) has emphazised, chemical control requires elaborate and persistent extension programmes. Arguably, the insecticide situation on cabbages in Barbados meets none of these criteria.

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