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Review

Use of Environmental Impact Quotient in IPM Programmes in Asia

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The IPM Impact Assessment Series aims to provide guidance to impact assessment of Integrated Pest Management (IPM) projects and programmes.

This review was jointly commissioned by the FAO Global IPM Facility and the FAO Asia Regional IPM Programme.

The status of this Review is that of a Project Report prepared for GCP/INT/999/SWI on Pest and Pesticide Management Policy Development, and GCP/RAS/209/NOR and GCP/RAS/229/SWE on Vegetable IPM and Pesticide Risk Reduction in Asia. As such, it does not necessarily reflect the official view of FAO.

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Preface

In recent years, there has been an increased demand on IPM projects to examine their economic, environmental, health and social impacts, including their achievements in reducing pesticide related risks. One of the tools used for this purpose has been the Environmental Impact Quotient (EIQ) that was developed at Cornell University in 1992, and which provides an index of the environmental and health risks of pesticides.

Since 2000, the EIQ has been used in several IPM projects in Asia for different purposes ranging from impact assessment to pesticide selection. To analyze these experiences and to identify EIQ's strengths and weaknesses as a tool for pesticide risk reduction, FAO commissioned a study in March 2007 to review these applications of EIQ in Asia.

The draft report of this study served as one of the background papers for an international workshop on EIQ that was convened in Doson, Haiphong, Vietnam in April 2007. The purpose of the workshop was to review the use of EIQ in IPM programmes and to develop a set of guidelines for its future use in such programmes.

The report was then finalised after the workshop, incorporating some further information presented by participants. The document starts with a brief introduction of the concept of EIQ and its applications, and then describes its utilization in the FAO-EU IPM Programme for Cotton in Asia and the national IPM programmes in Vietnam, Thailand and Cambodia. The application of EIQ for impact assessment and IPM decision support is discussed and lessons learned are summarised. The final chapter was added after the workshop and presents the outcome of its delibrations and follow-on discussions on technical, operational and application issues related to the use of EIQ.

1. INTRODUCTION

1.1 Need for Pesticide Risk Assessment

The risk of pesticides to human health and the environment is widely recognized by pesticide users, consumers and policy-makers. To reduce these risks, many measures have been introduced to pest and pesticide management in order to lessen the harmful effects from these products. To assess the outcomes from these efforts, it is necessary to have indicators that are able to quantify the human and environmental risks of pesticides.

Pesticide risk is related to the hazard of the active ingredient, i.e. its inherent potential to cause harm, and the likelihood of exposure to the active ingredient to actually cause harm. Therefore risk assessments combine toxicity information with information about the use of a product and its spread through the environment.

The hazards of pesticides are either expressed in single parameters (e.g. WHO Classification of Pesticides by Hazards, or Pesticide Hazards to Honey Bees) or by rating systems that take into account multiple parameters. Actual pesticide risks are affected by a multitude of factors that are intensely interacting and, in most situations, difficult to measure. Facing the variety in hazards and the difficulties in measuring actual risks, comprehensive assessments of actual risks are often replaced by calculated assessment of theoretical risks. This involves assessment of impacts on specific risk indicators that measure the combination of hazard and exposure for one or several environmental compartments. The Environmental Impact Quotient (EIQ) is such an indicator.

All risk assessment systems assign arbitrary ratios and relative weights to the different parameters and environmental compartments. These assignments and ratings are inherently based on human judgment, and depending on the person and the context, results can vary widely. One should therefore always remember that indicators, as the name suggests, are intended to only provide an indication of the potential risk.

1.2 Risk Assessment in IPM Programmes

One of the measures to reduce pesticide related risks is Integrated Pest Management (IPM). Numerous studies have shown that IPM reduces the amount of pesticides used and contributes to the selection of less harmful products. To measure these effects, IPM programs have used various pesticide use indicators, e.g. number of sprays, amounts of active ingredient or formulated product, dosage equivalents, or expenditure on pesticides. However, none of these methods estimates the environmental impact or reduction of risk because they do not consider qualitative aspects of the products used. Thus quantifying changes in terms of risk reduction to the farmer, consumer and the environment would be useful to assess the success of IPM in particular and improvements to the environment and safety in general.

IPM programmes have to balance environmental, human health (consumer and worker) and economic risks. However, local circumstances determine the most appropriate strategy, including the choice of alternatives. The creation and transfer of knowledge and skills to farmers, combined with financial incentives, are conditions for adequate decision making to balance the various risks. In IPM programmes, individual or composite pesticide risk indicators potentially could be used for the following purposes:

- compare relative risks of different pest and pesticide management strategies;
- monitor trends in the progress and success of risk reduction policies;
- contribute to the development of economic instruments that consider the potential of individual pesticides to cause environmental damage (e.g. taxation schemes to discourage use of products that have considerable negative impact on the environment);
- contribute to the development of broad simplified criteria for ‘green’ labeling of agricultural produce and influence consumer opinion and market behavior;
- possibly play a limited role in pesticide risk education.

2. EIQ AS A TOOL FOR PESTICIDE RISK ASSESSMENT

2.1 Environmental impact quotient (EIQ)

The Environmental Impact Quotient (EIQ) was developed in 1992 at Cornell University in the US to organize the published environmental impact information of pesticides into a usable form to help growers and other IPM practitioners make more environmentally sound pesticide choices. It represents a method to calculate the environmental impact of pesticides, and the values obtained from these calculations can be used to compare different pesticides and pest management programs to ultimately determine which program or pesticide is likely to have the lower environmental impact. The method addresses a majority of the environmental concerns that are encountered in agricultural systems including farm worker, consumer, wildlife, health and safety (Kovach et al., 1992). Distinction is made between “EIQ values” and “Field Use EIQ”. The EIQ value is a figure calculated for a specific active ingredient. It serves as a basis for the calculation of the “Field Use EIQ”, which provides an indication of the potential environmental impact of specific pesticide formulations at the prescribed dosage. (This difference is further explained in section 2.2).

The EIQ value for a particular active ingredient is calculated according to a formula that includes parameters for toxicity (dermal, chronic, bird, bee, fish, beneficial arthropod), soil half-life, systemicity, leaching potential, and plant surface half-life are considered. Each of these parameters is given a rating of 1, 3 or 5 to reflect its potential to cause harm (Table 1). Six of these ratings are based on measured or known properties and five others on judgments according to low, moderate or severe impact.

Table 1: The parameters and rating system used to calculate the EIQ Value of active ingredients. (Kovach et al., 1992)

Variables	Symbol	Score 1	Score 3	Score 5
Long-term health effects	C	Little-none	Possible	Definite
Dermal toxicity (Rat LD_{50})	DT	>2000 mg/kg	200-2000 mg/kg	0-200 mg/kg
Bird toxicity (8 day LC_{50})	D	>1000 ppm	100-1000 ppm	1-100 ppm
Bee toxicity	Z	Non-toxic	Moderately toxic	Highly toxic
Beneficial. Arthr. Toxicity.	B	Low impact	Moderate	Severe impact
Fish toxicity (96 hr LC_{50})	F	>10 ppm	1-10 ppm	<1 ppm
Plant surface half-live	P	1-2 weeks pre-emerg. herbic.	2-4 weeks post-emerg. herbic.	>4 weeks
Soil residue half-live (TI/2)	S	<30 days	30-100 days	>100 days
Mode of Action	SY	Non-systemic; all herbicides	Systemic	
Leaching potential	L	Small	Medium	Large
Surface runoff potential	R	Small	Medium	Large

These eleven parameters are used to calculate eight environmental impact indicators by using algebraic equations that combine the numerical ratings with relative weights assigned to each of these effects: effect to applicators, pickers, consumers, ground water, fish, bees, and beneficial arthropods. These scores are then further aggregated to express the environmental impact on each of the three main compartments: farmer, consumer and environment. The final composite EIQ score is the average of the three scores and it is calculated for each pesticide active ingredient. The maximum possible EIQ score is 210, while the minimum score is 6.7.

Table 2: EIQ Components and Formula (based on Kovach et al., 1992)

EI Applicator: C x DT x 5

EI Picker: C x DT x P

EI Farm Worker = EI Sprayer + EI Picker

EI Consumer: C x (S + P)/2 x SY

EI Ground Water: L

EI Consumer = EI Consumer + EI Ground Water

EI Fish: F x R

EI Bird: D x (S + P)/2 x 3)

EI Honey Bee: Z x P x 3

EI Natural Enemies: B x P x 5

EI Ecology = EI Fish + EI Bird + EI Honey Bee + EI Natural Enemies

EIQ

(EI Farm Worker + EI Consumer + EI Ecology) /3

The EIQ Formula:

$$EIQ=\{C[(DT*5)+(DT* P)]+[(C *((S+P)/2)* SY)+(L)]+[(F*R)+(D*((S+P)/2)*3)+(Z*P*3)+(B*P*5)]\} /3$$

As shown in Fig. 1, the weight distribution is further affected by the final EIQ score. In the maximum possible EIQ value (=210; Fig. 1a), EI Ecology is reflected with 48%, followed by EI Farm Worker (40%) and EI Consumer (13%). For the minimum score (=6.7), these values change to 60%, 30% and 10% (Fig. 1b), respectively. As intended, the EIQ has a bias towards EI Ecology, and particularly towards the impact on natural enemies, which constitutes almost a quarter of its total value.

Fig. 1a: Relative EI Weights at maximum EIQ Score (210)

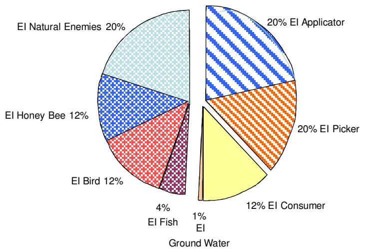
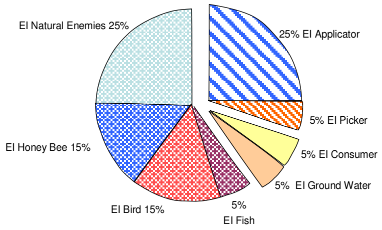


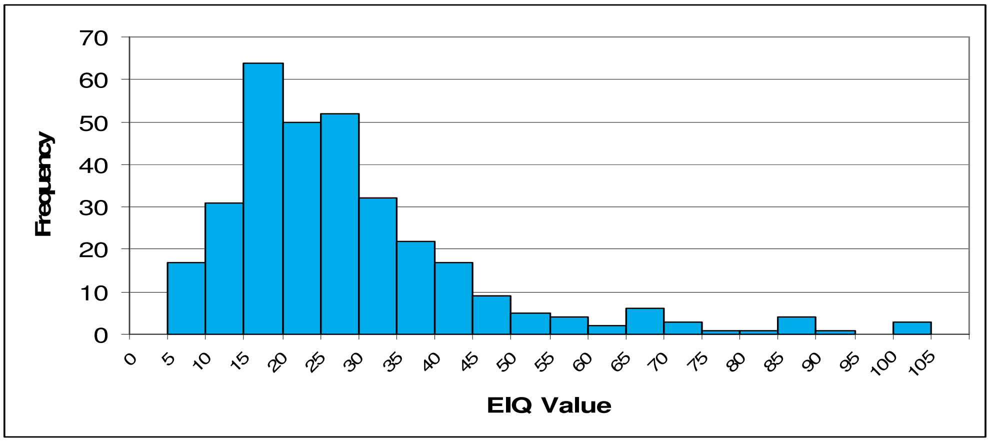
Fig. 1b: Relative EI Weights at minimum EIQ Score (6.7)



Lists of EIQ values have been published and periodically updated by Cornell University (http://www.nysipm.cornell.edu/publications/eiq/). These lists contain the EIQ value, as well as the EI scores for the individual components that make up the EIQ value.

Figure 2 provides the distribution of EIQ values for the 324 active ingredients for which an EIQ Value has been calculated. EIQ values range from 6.7 (e.g *Bacillus licheniformis*) to 104.5 (disulfoton), with most values between 10 and 35; only 6% are above 60. The figure reveals that the distribution is noticeably skewed with only very few active ingredients exceeding half the possible maximum value and none exceeding two-thirds of the possible maximum value.

Figure 2: EIQ Frequency Distribution of 324 Active Ingredients



Most of the information used for the EIQ calculation is available from pesticide manufacturers since provision of such information is required for pesticide registration. The Cornell EIQ values are based on data obtained from EXTOXNET, Pesticide Management and Education, SELCTV, the National Pesticide/Soils Database developed by the USDA Agricultural Research Service and Soil Conservation Service, the New York State Pesticide Recommendations, Material Safety Data Sheets (MSDS), and technical bulletins developed by the agricultural chemical industry.

It should be noted that only about half the published EIQ values are based on complete datasets required for its calculation; for the rest, one or more data are missing, in which case the value "2" is used in the formula. The information most frequently missing is toxicity data for natural enemies (80 cases, mostly for herbicides and fungicides), which are often not required for registration, but have the biggest weight in the EIQ formula. In a few cases, five or more data requirements are missing as for cryolite, pirimicarb, soap, sabadilla, ryania, and flusilazol. As a result, quite a number of these values are potentially inaccurate and may change as missing information becomes available. Missing data contribute to the "roughness" of EIQ as an indicator.

2.2 Field Use EIQ

Since the EIQ value is mainly a hazard indicator, additional calculations are required to obtain an indication of the pesticide risk. To account for exposure, a simple equation called the Field Use EIQ was developed. This rating is calculated by multiplying the table EIQ value for a specific chemical by the percent active ingredient in the formulation and its dosage rate per hectare or acre used (usually in liter or kilogram or pints or pounds of formulated product).

$$\text{Field Use EIQ} = \text{EIQ Value} \times \%\ \text{active ingredient} \times \text{Dosage Rate}$$

Furthermore, in principle, comparisons could be made between different pest management strategies by adding up the Field Use EIQ figures for each pesticide application throughout the season. The aggregate total Field Use EIQ figure reflects the potential environmental impact for the pest management strategy followed that season. It sometimes is also referred to as an indicator of "environmental load".

It is important to note that the "EIQ Value" refers to active ingredients and therefore cannot be used to compare hazard or risk of formulated products. In order to compare the EIQ of different products, one always needs to compare the "Field Use EIQ".

2.3 Further Development of EIQ since 1992

The original list of EIQ Values published by Cornell in 1992 contained 221 values. In the meantime, 103 new active ingredients have been added so that the present list (2007) contains 324 products. (http://northeastipm.org/ny/program_news/EIQ.html)

Besides adding new active ingredients, 124 EIQ scores have been updated as new data became available. Only 97 of the EIQ values available in 2007 were the original ones from 1992. In some cases, the changes were quite significant (see table 3 below):

Table 3: Most Significant Updates in EIQ values

Name	Old EIQ value	New EIQ value	Year of Change
bifenthrin	36	87.8	2003
isophenphon	32.3	66	2001
fipronil	54.1	90.1	2004
terbufos	32.3	66	2003
permethrin	56.4	88.7	2001
thiophanate	55.1	22.4	2004
2,4-D	56.3	18.7	2004
paraquat	70	31	2002
maneb	64.1	21.4	2003
mancozeb	62.3	14.6	2003
ziram	87.7	25.8	2001

The magnitude of these changes further illustrates the roughness of this indicator.

2.4 Applications of EIQ

The EIQ has been widely cited and is used in several states in the US and internationally (see table 4 below). Over 10,000 copies of the original hardcopy EIQ publication have been distributed upon request since 1992 and the EIQ website (http://nysipm.cornell.edu/publication/EIQ.html) gets about 400 visits per month.

Most of the reported EIQ applications have been in studies assessing the impact of IPM or evaluating different pest management strategies (Table 4; see Annex 1 for abstracts). In some cases, the EIQ has been modified and tailored for specific uses by selecting only particular components or groups of components.

Table 4: Selection of Worldwide Uses of EIQ outside Asia *

Year	Location	Title
2001	Washington, USA	Sustainability of three apple production systems
2001	Ontario, Canada	Pesticide Risk Reduction on Crops in the Province of Ontario.
2002	Spain?	Evaluation of the Environmental Impact of the Pesticides Applied in Processing Tomato Cropping.
2003	Georgia, USA	Reduction of Pesticide Risk in Georgia Peaches, 1991-2001
2003	Ohio, USA	Environmental Impact Quotient Analysis of Pesticide Use in North Central Ohio - 1999 & 2003
2004	Global	Assessing the environmental impact of changes in pesticide use on transgenic crops.
2005	New England, USA	New England-wide Demonstration of an Integrated Pest Management (IPM) System for Apples and Consumer Education in IPM as a Pollution-prevention Strategy
2005	Canada	Influence of herbicide-resistant canola on the environmental impact of weed management
2005	Global	GM Crops: The Global Economic and Environmental Impact - The First Nine Years 1996-2004
2005	USA	Central Coast Vineyard Team's 2005 Strategy
2006	Australia	Environmental impact of conventional and Bt insecticidal cotton expressing one and two Cry genes in Australia
2006	Scandinavia	Biotechnology as a tool for plant breeding
?	Quebec, Canada	Organic vs Integrated Production of Apples in Northeastern North America: Measured Outcomes of Two Different Approaches for Reducing the Environmental Impact of Pesticides

* see Annex 1 for links and references

The use of EIQ as a decision support tool appears to be quite limited. One example found was the New York State Integrated Crop and Pest Management Guidelines for Commercial Vegetable Production (Reiners and Petzoldt, 2006; http://www.nysaes.cornell.edu/recommends/) in which a Field Use EIQ value, based on label instruction for dosage, is reported for every pesticide registered for use against a particular pest, together with its pre-harvest and re-entry intervals (e.g. for field tomatoes: http://www.nysaes.cornell.edu/recommends/27frameset.html). By comparing the Field Use EIQ values as a quick reference for a rough indication of potential environmental impact, it is suggested that growers can include environmental considerations in their decision making without having to make calculations. However, one still has to consider the number of applications, as some products may require more frequent treatments than others, which would have a major effect on the environmental load.

In Europe, the EIQ has been reported to be used as a tool for IPM production in Norway, where farmers are encouraged to calculate the EIQ to determine the relative environmental load of plant protection strategies in different crops from year to year. Bioforsk provides a website where such calculations can be made. However, the EIQ values given were not always the latest updated figures published by Cornell. Like the countries mentioned in table 4, Norway uses a different indicator for national pesticide policy purposes.

2.5 Other Pesticide Risk Assessment Models

Besides the EIQ, different indicator models for calculation of environmental risks exist. Levitan et al. (1995) listed 51 pesticide risk indicators. The Cornell University's Environmental Risk Analysis Program describes in detail eight more widely used pesticide risk indicators and assessment systems, including EIQ (http://www.aftresearch.org/ipm/risk/index.php; see Annex 2). As seen in Table 5, each indicator uses different sets of data, though some data are used by all.

Since different assessment models take different approaches to incorporating indicators of exposure, and assign greater weight to different aspects of the environment, different results are obtained. When comparing the most hazardous pesticides generated by three different composite models, Levitan (1997; Table 6) found only 2,4 D, trifluralin and dimethoate on more than one list. The reason is that two of the models (UC and EIQ) focus on agricultural pesticide uses, but the EIQ is particularly sensitive to impacts on beneficial insects and farm workers. In contrast, the CHEMS1 was developed for screening all chemicals. The rank order of pesticides depends in part upon the components of the analysis--the pesticides considered, the variables assessed, the choice of specific measurable endpoints as the indicators of impacts on these variables; the mathematical structure of the model, including relative weighting of variables and scoring of results; the method for filling data gaps; and whether usage data are factored into the equation (i.e., a ranking by hazard or by hazard potential/risk). Differences in outcomes among the models underscore how arbitrary these models are.

Table 5: Data Sources Used in Different Pesticide Risk Indicators

	EPRIP	EYP	PERI	SYNOPS	SyPEP	EIQ	CHEMS1	MATF
Pesticide Application Rate	x	x	x	x	x	x	x	x
Pesticide Toxicity Values	x	x	x	x	x	x	x	x
Pesticide Chemical Properties	x	x	x	x	x	x	x	x
Field Size	x	x	x	x	x	x	x	x
Soil Data	x	x		x				
Weather Data	x	x		x	x			
Bodies of Water	x			x	x			
Health Impacts of Pesticide						x	x	x
Impact on Pesticide Resistance								x
Amount of a.i. pre-existing in environment							x	

EPRIP=Environmental Potential Risk Indicator for Pesticides, Italy; EYP=Environmental Yardstick for Pesticides, Netherlands; PERI=Pesticide Environmental Risk Indicator, Sweden; SYNOPS=German environmental indicator model; SyPEP=System for Predicting the Environmental Impact of Pesticides, Belgium; EIQ=Environmental Impact Quotient, USA; CHEMS1=Chemical Hazard Evaluation for Management Strategies; MATF=Multi-Attribute Toxicity Factor, USA

Table 6: Comparison of "most hazardous" pesticides, as ranked by three assessment systems (Levitan, 1997)

Chems1 (Swanson et al. 1997; emphasis on aquatic species, incl. bioaccumulation)	**UC-Model** (Pease et al., 1996; emphasis on human health)	**EIQ** (Kovach et al., 1992; emphasis on terrestrial species, incl. birds)
1. terbufos	1. methomyl	1. disulfoton
2. **trifluralin**	2. aldicarb	2. parathion
3. HCB	3. carbofuran	3. propoxur
4. anthracene	4. **2,4-D**	4. oxydemeton-m
5. chlorothalonil	5. mevinphos	5. fenamiphos
6. **2,4-D**	6. **dimethoate**	6. **dimethoate**
7. 1,3 dichloropropene	7. **trifluralin**	7. paraquat

A study by van Bol et al. (2002) listed 95 different pesticide indicators, including use and risk indicators. Many of these only assess the active ingredient's physico-chemical properties or the pesticide risks on a single environmental compartment, e.g. humans, or specific flora and fauna species. The Field Use EIQ was listed as one of 31 comprehensive Pesticide Impact Assessment Systems, while the EIQ and its individual components were included under pesticide hazard indicators.

With the increasing interest in pesticide risk reduction, many models are refined and further developed. In 1997, an OECD workshop on pesticide risk indicators developed and agreed to a set of principles for their development (OECD, 1997). The *Concerted Action on Pesticide Environmental Risk indicators* (CAPER) project compared and evaluated eight pesticide indicators that were developed within the European Union (Reus et al., 1999). EIQ, which had been developed in the USA, was not among these eight. Based on a European Directive (91/414/EC), the *Pesticide Occupational and Environmental Risk* (POCER) indicator was developed which consists of ten modules reflecting the risk for persons arising from occupational, non-dietary exposure and the risk to the environment (Vercruysse and Steurbaut, 2001).

In 2004, the EU-Commission started a new *Harmonised Environmental Indicators for Pesticide Risk* (HAIR; www.rivm.nl/rvs/overige/risbeoor/Modellen/HAIR.jsp) project. The primary aim of that project is to develop and integrate European scientific expertise on the use, emissions, environmental fate, and the impact of plant protection products in agro-ecosystems in order to provide a harmonised European approach for the assessment of fate and impact of these products. The main expected output of the project is a harmonised environmental risk indicator. The proposed tool will calculate the emissions of plant protection products and the resulting acute and chronic ecotoxicological consequences for aquatic and terrestrial organisms, for groundwater, for public health, and for workers. The proposed indicator should apply to the entire European territory, and this implies the consideration of variability of soil, crop, climate, agricultural practice, land use and pesticide use. The proposed indicator should operate on different scales, from the catchment regional level up to the European level. At the European level highly aggregated and integrated indicators are required, while at the regional level there is a need for support in the selection of substances to control pests. Inherently, this harmonized indicator will be more accurate than the EIQ model, but also more complicated.

2.6 Views on reliability and usefulness of EIQ

A number of flaws in the EIQ have been pointed out by Dushoff et al. (1994) in the journal American Entomologist. In addition to problems with scaling, weighting of effects, and inert ingredients, those authors point out that "...even benign substances are given ... an EIQ of at least 6.7." because the lowest value given in the rating system of 1-5 is 1 which may lead to non-toxic products used at a higher rate having a higher rating than a toxic product used once. By way of illustrating an extreme example, "...if water were considered a pesticide, it would have an EIQ of 9.3. This means that 20 lbs per acre of water would be considered worse than a 1 lb application of parathion..."

Another example using actual orchard pesticides can be seen in a comparison of the Field Use EIQ for dormant oil (EIQ of 37.7) and a 25 WP formulation of permethrin (EIQ of 56.4). For permethrin, used at 5 oz. per 100 gal. and applying 300 gal. per acre (or 0.9 lbs. per acre), this results in an Field Use EIQ of 13 (56.4 x 0.25 x 0.9 lbs). This is obviously much lower than the field use rating of 226 for oil used at a rate of 2 gal. per 100 gal. and applying 300 gal. per acre (37.7 x 1 x 6 gal), because oil is 100% active ingredient, and is used at a much higher per-acre rate. Since oil is used during the dormant period, however, its environmental impact on beneficial insects would be minimal.

It was pointed out that the EIQ ranks arthropod toxicity higher than chronic toxicity to humans; it overrates systemic pesticides with a long plant half-life; it does not take into account inert ingredients in pesticides by giving them a rating of 0 while the most benign substance would have at least 6.7; finally, it does not account long-term damage to nerve and immune system.

The authors concluded that “flaws in both the formula and its conceptual underpinnings serve to make the information provided misleading. We recommend that EIQ … not be used to evaluate field applications of pesticides. Further, current understanding of pesticides and their effects is not sufficient to allow the environmental effects of a pesticide to be captured by a single number.”

Other authors pointed out that the EIQ model does not consider some important factors that can influence the impact of pesticides. For example, the model and field use rating formula do not consider the susceptibility of local natural enemies of pests. Values based on research on natural enemies in US orchards may thus not necessarily be accurate for natural enemies in Asian rice fields. Toxicity to bees and natural enemies may not be relevant if the product is applied at a time that there is no activity of bees or natural enemies. Differences in pest pressure, environmental conditions, and grower management style often govern both the choice of pesticides and their application frequency and thus the resulting environmental load.

In spite of the flaws in the EIQ, it is also being noted that no indicator is perfect and that EIQ is relatively user friendly.

A detailed review of potential and limitations of EIQ, including points that emerged from the experience of its use in IPM programmes in Asia, is provided in Chapters 6 and 7

3. USE OF EIQ IN THE COTTON IPM PROGRAMME

Between 2000 and 2004, the *FAO-EU IPM Programme for Cotton in Asia* (Cotton IPM Programme) implemented about 3,600 IPM Farmer Field Schools (FFS) for more than 90,000 farmers in Bangladesh, China, India, Pakistan, Philippines and Vietnam. To assess the impact of these training activities, impact assessment studies were conducted at seven sites, i.e. one in each country and three in China. The Programme's impact on pesticide reduction was monitored in terms of number of applications and dose applied. In addition, it was decided to test the EIQ as a means to assess the environmental risks of different pest management strategies. No EIQ training was given to farmers or FFS facilitators during the course of the project.

The Programme was introduced to the EIQ model by the NORAD funded project "IPM in Vegetables in Vietnam" in 2001. Calculation of the Field Use EIQ followed the method described by Kovach et al. (1992) based on the list of updated EIQ values posted in 2003 (Kovach et al., 2003). Values for pesticides missing from this list were calculated using pesticide datasheets available from EcoToxNet, USEPA, WHO/FAO or PAN Pesticide Database. Field Use EIQ values were calculated by project staff or consultants using an Excel based computer programme developed by the project. This application only required users to enter a pesticide's trade or common name, its formulation percentage, dose rate and number of sprays. It then automatically looked up the EIQ values for the active ingredient from an electronic table and calculated the Field Use EIQ as well as the individual EI values for farmers, consumers and the environment. No specific training was given to the project staff for that purpose.

Since calculation of the EIQ was not included as a standard practice in all impact assessment studies, no overall figure is available for the project's impact on risk reduction. Instead, separate case studies were conducted in the different countries to test the usefulness of the EIQ indicator. Most studies compared IPM and conventional farmer practice (non-IPM) plots during FFS. Only two impact assessment studies included EIQ calculations. Details are provided in Table 7.

Table 7: Use of EIQ in the FAO-EU IPM Programme for Cotton in Asia

Bangladesh
- Case studies of 37 FFS in 2002-03, comparing IPM and farmer practice plots
- Case studies of 52 FFS in 2003, comparing IPM and farmer practice plots

China
- Case studies of FFS in Shandong , comparing IPM and farmer practice plots

India
- Case studies of 117 FFS plots in Andra Pradesh, Karnataka and Maharashtra
- Impact study of 37 post-FFS farmer field practices relative to control fields
- Comparative study of organic, IPM and conventional cotton production

Pakistan
- Case studies of 90 FFS in 2003, comparing IPM and farmer practice plots
- Impact study with 190 respondents of which 78 were FFS participants. The farmers were interviewed one year after FFS training in 2003, and responses were compared with pre-training baseline data from 2001.

Philippines
- Case studies of 24 FFS in Iloilo, Negros, South Cotabato, Cotaboto and Sarangani in 2003, comparing IPM and farmer practice plots

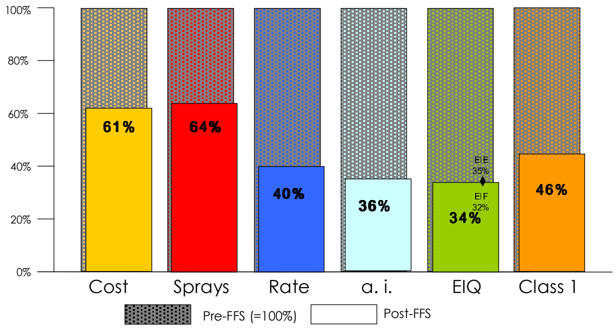
Vietnam
- Review of EIQ and calculation of missing pesticide EIQ values

3.1 Comparison of EIQ with other indicators related to pesticide use or risk

Pesticide reduction results from the Pakistan impact assessment study (Fig. 3) showed pesticide cost and number of sprays in 2003 at 61% and 64% of the pre-training values from 2001, respectively, while the dose rate was reduced to 40% and the amount of active ingredients used was 36%. The pesticide risk as measured by Field Use EIQ was the furthest reduced to 34%. This figure was lower than the use reduction of products containing Class 1 compounds (46%), suggesting that the relative reduction of environmental risks exceeded that of poisoning risks.

Fig. 3: Pesticide Reduction Indicators

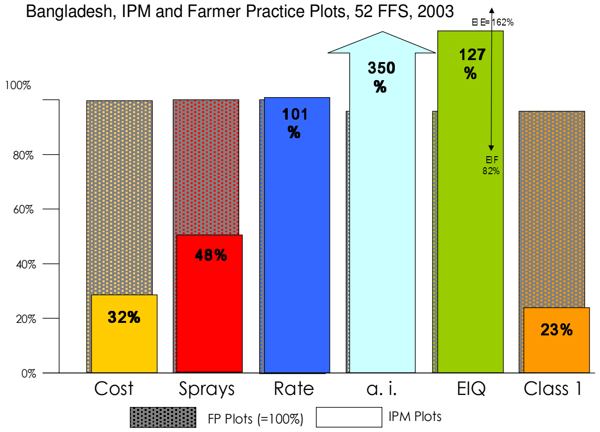
Pakistan, Impact Assessment Study, 78 farmers, 2003 post-FFS farmer fields relative to 2001 practices and control



However, this relatively uniform pattern was not repeated in the outcome of some other studies. Data from Bangladesh FFS plots (Fig. 4) for instance showed the biggest reductions in terms of Class 1 compounds, cost and number of sprays, while the dose rate was unchanged. However, the amount of active ingredient showed a considerable increase to 350% of the control. Total Field Use EIQ values rose to 127% due to a 162% increase of the EI Ecology index. These surprising results derived from the intensive use of insecticidal soap which is normally considered a cheap and non-toxic alternative to chemical pesticides. However, since it is applied at high spray volumes and less diluted than pesticides, the total amount of 'active ingredient' was increased, and so was the Field Use EIQ by multiplying the low soap EIQ (19.5) with the high dosage rate.

Fig. 4: Pesticide Reduction Indicators

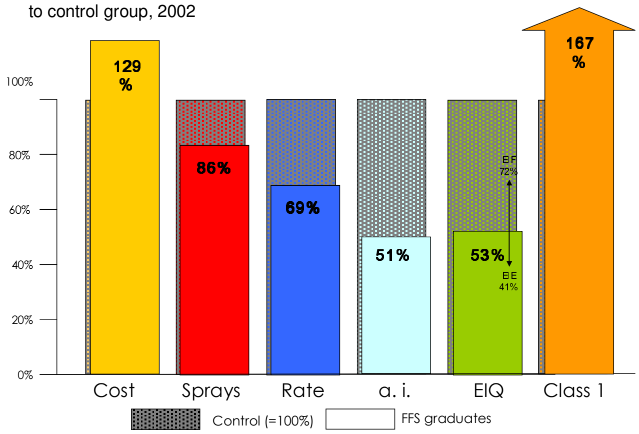
Bangladesh, IPM and Farmer Practice Plots, 52 FFS, 2003



A different pattern emerged from the India impact assessment study (Fig. 5), where farmers reduced the number of sprays, dose rate and amount of active ingredients, but increased their pest control costs and use of pesticides containing Class 1 compounds. However, pesticide risk as measured by Field Use EIQ, was reduced to 53% of the control value, with a larger reduction of the EI Ecology component (down to 41% of the control) than the EI Farmer component (down to 72% of the control).

Fig. 5: Pesticide Reduction Indicators

India, Impact Assessment Study, 37 post-FFS farmer fields relative to control group, 2002



This comparison of different indicators shows that each indicator measures something unique that is not equally expressed in other values. Only the combination of different indicators gives a full portrayal of the make-up of pesticide risk reduction. However, the total amount of pesticides applied is probably the one factor that has most influence on other parameters, including environmental risk.

Generally, the case studies showed that reductions in Field Use EIQ often exceeded those of sprays, dose rate and cost, indicating that the reduction in pesticide related risks often exceeded other parameters. Anomalies, like the effect of soap on EIQ, however, make the indicator less reliable.

In India, another study compared different environmental indicators with regards to their potential to determine environmental impacts of IPM and organic cotton production (Mancini, 2006). The tested indicators were Field Use EIQ, Global Warming Potential (GWP), Acidification Potential (AP), Eutrophication Potential (EP) and Universal Soil Loss Equation (USLE). Results showed that organic farming systems had a far lower impact on the environment than the other cotton farming systems. The indicators that resulted in the most pronounced differentiation of the systems were the Field Use EIQ and Eutrophication Potential. The major reason for this difference can be ascribed to the different uses of mineral fertilizers and pesticides and the burning of organic material in conventional and IPM systems.

3.2 Farmer Field School Case Studies

Most of the pesticide risk reduction assessments were conducted as case studies, comparing FFS IPM and farmer practice plots. Since these studies were closely supervised by FFS facilitators, results were likely better than would have been obtained from actual farmer fields. Generally, no pesticides containing Class 1 compounds are used in FFS on the IPM plots, and often the number of sprays is reduced to near zero.

For example, in Pakistan, out of 90 FFS-IPM plots, only 5 were reported as having been sprayed once, while the rest supposedly had no pesticide treatments at all. The average total pesticide load on the IPM plots was therefore only 28 ml/ha (Table 8). In comparison, farmer practice plots received an average of 2.27 applications with a total load of 2,800 ml/ha of pesticides, out of which 1,085 ml/ha were products containing Class 1 compounds. As a result, the Field Use EIQ was reduced by 100% to almost zero in the FFS plots. Even with a high margin of error, these data indicate a high reduction of pesticide risk.

Table 8: Comparison of 90 FFS IPM and farmer practice plots (FP) in Pakistan

Category	Number of pesticide applications	Pesticide dose (ml/ha)	Class 1 (ml/ha)	Field Use EIQ	Yield (Kg/ha)	Gross Margin
IPM-plot	.05	28	0	0	1768	506
Farmer-plot	2.27	2800	1085	55	1582	342
% difference	-98%	-99%	-100%	-100%	+12%	+48%

Similar results were obtained from other countries whereby the absolute changes reported are more important indicators of risk reduction than the relative changes.

Table 9: Comparison of 37 FFS IPM and farmer practice plots (FP) in Bangladesh in 2002-03

Category	Number of pesticide applications	Pesticide dose (ml/ha)	Field Use EIQ
Farmer-plot	2.1	1118	19.5
IPM-plot	0.16	94	1.6
% difference	-92%	-92%	-92%

Table 10: Comparison of 117 FFS IPM and farmer practice plots (FP) in 3 States in India in 2003

Category	Number of pesticide applications	Pesticide dose (ml/ha)	Field Use EIQ
Farmer-plot	5.54	(not reported)	123
IPM-plot	1.42	(not reported)	3.0
% difference	-74%	(not reported)	-97%

Table 11: Comparison of FFS IPM and farmer practice plots (FP) in Shandong, China

Category	Number of pesticide applications	Pesticide dose (ml/ha)	Field Use EIQ
Farmer-plot	32	29,100	1951
IPM-plot	8	9,900	284
% difference	-75%	-66%	-85%

Table 12: Comparison of 24 FFS IPM and farmer practice plots (FP) in 5 provinces in the Philippines in 2003

Category	Number of pesticide applications	Pesticide dose (ml/ha)	Field Use EIQ
Farmer-plot	3.83	1,803	39
IPM-plot	0.63	317	8.1
% difference	-84%	-82%	-79%

In most of the above cases, the pesticide risk reduction as expressed by Field Use EIQ was similar or better than the reduction in pesticide use.

A comparison of conventional, IPM and organic cotton pest management systems in India showed totalled Field Use EIQ of 257, 62 and 0 per ton of raw cotton, respectively (Mancini, 2006). In the conventionally managed farming systems, the insecticide monocrotophos contributed on average 37% to the total Field Use EIQ. Next were the insecticides chlorpyrifos (14%) and endosulfan (12%). The 75% lower EIQ index for IPM system was mainly due to reduced pesticide use and selection of insecticides belonging to lower hazard classes such as imidacloprid, acephate, and spinosad. Organic farms had a total Field Use EIQ of zero because no pesticides were used. However, locally-produced plant extracts (like neem oil) may have been applied, although this was not noticed during the study. If they had, they would need to be included in an EIQ calculation.

The term "pesticide" often only refers to synthetic chemical products and excludes non-synthetic pest control measures such as bio-pesticides, sulfur, soaps or oils. Even though these products are relatively safe for humans, their environmental impacts could be substantial, particularly when used at high dose rates as it is often the case for soaps and oils. If these products can kill pests, they can also kill predators and parasites. Therefore, they should be included in environmental risk evaluations of different pest management schemes because of the potential negative environmental impact of pest management strategies that use large quantities of natural products. However, a problem with EIQ is that it does not have a zero rating. As a result, the risk of harmless products become overrated. This then can get further distorted if multiplied with high volumes. Other aspects like timing and mobility of natural enemies also need to be considered when determining the pesticide risks to the environment.

3.3 Impact Assessment Studies

While farmer field school studies show the potential risk reduction through IPM, impact studies assess the actual reduction as a result of FFS training. To assess the project’s impact, FFS participants were compared with non-FFS farmers from the same village (exposed farmers) and farmers in villages where no FFS had taken place (control farmers). During the baseline survey in 2002 after the formation of the FFS groups, farmers were asked to recall their cotton production practices from 2001. In the year after the FFS training, i.e. in 2003, all farmers were visited several times during the cotton season to collect the impact data on the post-FFS practices.

In Pakistan, EIQ results were reported as total Field Use EIQ, as well as grouped for EI Farmer, EI Environment/Ecology and EI Consumer. As illustrated in Table 13, figures showed an average 50% reduction of relative risk on FFS farms as compared to a 75% increase on control farms where both total pesticides and the use of products containing Class 1 compounds increased between 2001 and 2003 (Khan et al. 2004). Calculations in Table 14 of the statistical significance of these results show that the measured changes in EIQ and use of products containing Class 1 compounds among FFS farmers were highly significant; however, the reduction of risk as measured by Field Use EIQ was much bigger than the reduction in use of products containing Class 1 compounds.

Table 13: Hazards of pesticide use and potential impacts on environment and human health in Pakistan

Year	Types	N	Class-1 (ml/ha)		Total Field Use EIQ*		Field Use Farmers EI		Field Use Ecology EI		Field Use Consumer EI	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2001	FFS	78	2828	1802	194	168	176	182	365	298	41	39
	Exposed	59	2757	1994	162	158	133	125	322	360	31	28
	Control	53	2790	1631	196	147	178	175	370	247	39	37
	Overall	190	2795	1810	185	159	164	165	354	304	38	36
	Sig.		0.904		0.437		0.241		0.651		0.306	
2003	FFS	78	1292	1225	98	94	83	82	191	197	20	19
	Exposed	59	1831	1640	157	237	135	227	303	442	32	51
	Control	53	3488	2666	337	378	267	389	682	706	62	84
	Overall	190	2072	2055	183	264	150	257	363	505	35	57
	Sig.		0.000		0.000		0.000		0.000		0.000	

* Total field EIQ is equal to sum total of farmers EI, Ecology EI and Consumer EI divided by 3

Table 14: Change in Hazard of pesticide use and potential impacts on environment and human health in Pakistan

Types	Class I pesticides-		Total Field Use EIQ		Field Use Farmers EI		Field Use Ecology EI		Field Use Consumer EI	
	T-Test Sig.	% Change	T-Test Sig.	% Change	T-Test Sig.	% Change	T-Test Sig.	% Change	T-Test Sig.	% Change
FFS	0.000	-54	0.000	-98	0.000	-113	0.000	-91	0.000	-102
Exposed	0.009	-34	0.985	-4	0.847	2	0.898	-6	0.893	0
Control	0.121	25	0.014	42	0.139	33	0.003	46	0.079	37
Overall	0.000	-26	0.990	-1	0.599	-9	0.764	3	0.727	-6

An analysis of the correlation of changes in the Field Use EIQ with socio-economic attributes and practices (Table 15) showed a strong association with FFS attendance and the resulting changes in pesticide use, attitude toward the environment and decision making scores. The EIQ changes were not correlated with age or education of farmers. There was also a high correlation between EIQ and observed biodiversity scores, indicating that EIQ was indeed an indicator of observable environmental changes.

Table 15: Correlation matrixes of socio-economic and environment attributes at FFS farms

Attributes	Attendance (%)	Decision maker age (years)	Decision maker education (years)	Observed biodiversity score (%)	Attitude towards environment score (%)	Total pesticide dose (ml/ha)	Field Use EIQ score	Decision making score (5)
Attendance (%)	1.000	-0.132	0.145	0.126	0.246*	-0.240*	-0.253*	0.245*
Decision maker age (years)	-0.132	1.000	-0.507**	-0.355**	-0.087	0.332**	0.142	-0.085
Decision maker education (years)	0.145	-0.507**	1.000	0.348**	0.136	-0.214	-0.102	0.270*
Observed biodiversity score (%)	0.126	-0.355**	0.348**	1.000	0.366**	-0.451**	-0.379**	0.287*
Attitude towards environment score (%)	0.246*	-0.087	0.136	0.366**	1.000	-0.241*	-0.305**	0.378**
Total pesticide dose (ml/ha)	-0.240*	0.332**	-0.214	-0.451**	-0.241*	1.000	0.733**	-0.273*
Field Use EIQ score	-0.253*	0.142	-0.102	-0.379**	-0.305**	0.733**	1.000	-0.382**
Decision making score (5)	0.245*	-0.085	0.270*	0.287*	0.378**	-0.273*	-0.382**	1.000

** Correlation is significant at the 0.01 levels. * Correlation is significant at the 0.05 levels.

Thus, lower Field Use EIQ scores are an outcome of improved decision-making power of farmers, pesticide use reduction, positive attitude towards environment and strong beliefs in ecological pest suppression for plant protection.

Calculated on a per hectare basis, the total Field Use EIQ was reduced by 66% as compared to the baseline values.

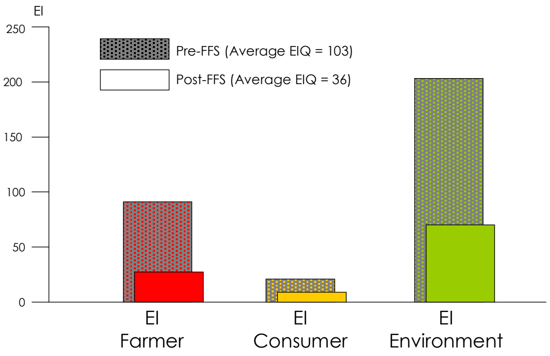
Table 16: Comparison of Field Use EI values and Field Use EIQ from Pakistan per hectare

	Field Use EI Farmer	Field Use EI Consumer	Field Use EI Ecology	Field Use EIQ
Pakistan (78 FFS participants)				
Pre-FFS	89	21	199	105
Post-FFS	30	7.1	72	36
Average % reduction	***-67%***	***-66%***	***-64%***	***-66%***

A comparative analysis of the 3 EIQ components shows that the risk was nearly equally reduced in each component by an average of 66%, While the number of sprays was only reduced by 36%, this reduction in risk was mainly due to a much lower use of methamidophos and endosulfan after the IPM-FFS training.

Fig. 6: IPM Impact on EIQ Reduction

Pakistan Impact Assessment Study, average of 78 FFS farmer fields



This pattern, however, was different in some other countries. In India, a slightly different picture presented itself for 37 FFS graduates that were compared with 30 control farmers:

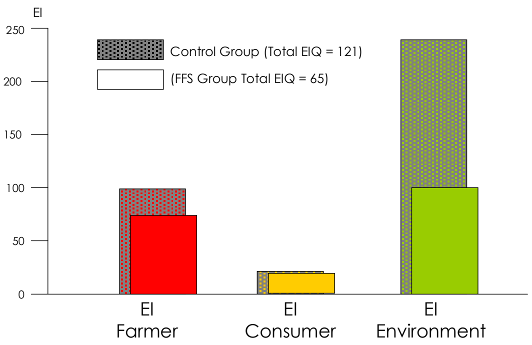
Table 17: Comparison of Field Use EI values and Field Use EIQ from India

	Field Use EI Farmer	Field Use EI Consumer	Field Use EI Ecology	Field Use EIQ
India (post-FFS values for 37 FFS participants and 30 control farmers)				
Control Farmers	101	22	244	122
FFS graduates	80	21	102	68
Average % reduction	***-21%***	***-5%***	***-58%***	***-44%***

The above results from India showed that the replacement of endosulfan and quinalphos with neem and NPV in the IPM plot primarily reduced pesticide risks in the environmental components. Due to the continued use of monocrotophos and acephate, which accounted for the larger share of the overall risk to farmers, the reduction in farmer risk was only reduced by 21%, while the consumer risk was largely unchanged. Obviously, the consumer risk is less relevant for cotton than for vegetables.

Fig. 7: IPM Impact on EIQ Reduction

India Impact Assessment Study, average of 37 FFS graduate and 30 control farmer fields



These examples illustrate that a differentiation of the total Field Use EIQ into the individual components can provide additional information about relative changes within risk components compared to just a single index figure. However, these figures explicitly cannot be used to compare the level of risk between the different components. The values for different EIQ components in the tables, or the relative heights of the columns in the graph, reflect a combination of parameters quantifying risk and the manner in which these parameters are being weighed within the EIQ formula. Differences between components are to a large extent caused by differences in weight assigned to different components by the authors of the EIQ formula. As such, these figures can not be interpreted as absolute figures that allow comparison.

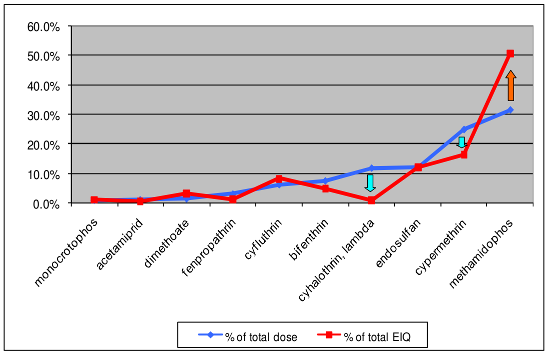
Nevertheless, taking into consideration the above, profiles may to some extent help identify attention areas for targeted risk management strategies and corrective measures. For instance, if the EI environment component of the Field Use EIQ for a season of pesticides use stands out as much higher than the average, one could try to identify which pesticides are causing this deviation and try to reduce the use of these pesticides.

By comparing the percent of total dosage with the percent of total Field Use EIQ values for individual pesticides, typical cotton pesticides like monocrotophos or methamidophos were clearly recognized as the biggest contributors to high total Field Use EIQ figures, while neem or other biopesticide products contribute proportionally less.

Fig. 8: EIQ Product Profile

Pakistan, average of 78 post-FFS farmer fields

ranked by increasing dose rate

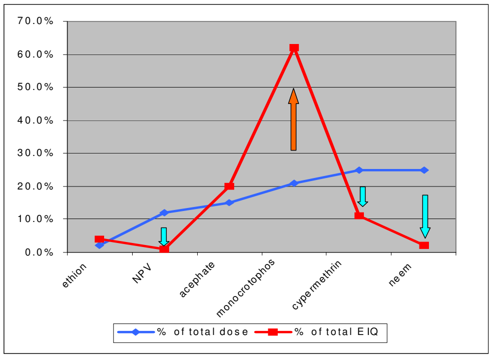


For example, in Pakistan (Fig. 8) methamidophos made up 32% of the total quantity of pesticides applied, but contributed 51% to the total Field Use EIQ. On the other hand, lambda-cyhalothrin was 12% of the total dose, but contributed only 1% to the total Field Use EIQ.

Fig. 9: EIQ Product Profile

India, average of 37 post-FFS farmer samples

ranked by % formulated dose



Similarly, in India (Fig. 9) monochrotophos use amounted to 21% of the total pesticide dose, but made up 62% of the total Field Use EIQ. Neem and NPV products, on the other hand, were 37% of the total quantity, but contributed only 3% to the environmental risk.

3.4 Critical Assessment

The use of EIQ in the Cotton IPM Programme was limited to impact assessment. It supplemented data on pesticide use reduction and case studies that determined effects of pesticides on the health of applicators and on biodiversity. Results of EIQ comparisons were presented as case studies or as part of the statistical analysis of panel data in addition to other data showing the project’s impact on pesticide reduction. In some instances, Field Use EIQ values were able to point out particular risk considerations with the types of pesticides used.

In none of the member countries was EIQ used for training facilitators or farmers, and it was never used in FFS for decision-making. EIQ calculations were done by a few specialized staff by means of a computer spreadsheet application developed by the project, called “EIQEasy”, which retrieved the EIQ values from an electronic table and assisted in the calculation of the Field Use EIQ.

The biggest problem encountered by the Cotton IPM Programme was the missing EIQ values, e.g. for monocrotophos, quinalphos or NPV. EIQ values for these and other products were calculated by project officers from data sheets and added to the EIQ database even though not all the required information was available for these products. Furthermore, calculations were based on a widely circulated incorrect version of the EIQ formula (e.g. Levitan 1997) which had the factor “C” missing from the EI Picker calculation. Even though the EIQ data published by Cornell University were unaffected, the uncorrected formula was occasionally used to calculate new EIQ values, resulting in slightly lower EI Farmer values for some active ingredients. The size of the error did not affect the overall IPM Programme outcomes and conclusions. Tables presented in this report have been corrected.

Pesticide formulation and use data collected during the impact studies and FFS were generally adequate to calculate the Field Use EIQ because the information was collected by trained enumerators or FFS facilitators throughout the cotton growing season.

Comparisons of Field Use EIQ with Class I pesticides may have been slightly distorted because the latter concerned pesticides that contained Class I compounds rather than formulated products that fall in Class I. As such, some products may have been counted as Class I products, while these actually may have been in Class II.

4. USE OF EIQ IN THE VEGETABLE IPM PROGRAMME IN VIETNAM

The NORAD funded project "Integrated Pest Management (IPM) in Vegetables in Vietnam" was implemented from 2000 to 2003 by the Plant Protection Centre of the Norwegian Crop Research Institute (NCRI or PlanteForsk[1]) and the Vietnamese Plant Protection Department with the objective of reducing risks for human and environmental health by strengthening IPM in vegetable production. Much of the work was done in close collaboration with FAO's "Regional Programme for Community IPM in Asia", and for Phase II (2005-2007) of the Norwegian project, the donor requested that its activities were integrated into the FAO's Regional Vegetable IPM Programme through a subcontract arrangement.

4.1 Project History and Development

Phase I

One of the objectives of the Norwegian project was to develop and implement a decision support system for vegetable farmers. For this purpose, the assessment of environmental risks of pesticide use was initiated, and the EIQ model was selected as risk indicator and introduced to farmers, authorities and extension workers as a tool to choose pesticide management strategies having the least environmental load.

To draw a baseline for the risk level of pesticide use in vegetable production, the total Field Use EIQ was calculated in 2000 in a thesis titled "Pesticide Use and Risk Calculations (Environmental Impact Quotient) on Vegetables in Hanoi Province, Vietnam". The study investigated the pesticide environmental load on tomato and eggplant crops and compared farmers who participated in FFS (IPM farmers) with farmers who did not (non-IPM farmers). (Tran Thi Ngoc Phuong, 2001). EIQ calculations showed reduced load of pesticide to the environment for the group of farmers using IPM strategies compared to the group with no training in IPM (Table 18). In addition, data revealed that non-FFS farmers took mostly unauthorised or banned pesticides.

Table 18: Total Field Use EIQ from IPM and non-IPM Farmers in Hanoi Province, Vietnam

	Average and Range of Field Use EIQs	
Crop	IPM Farmers	Non-IPM Farmers
Tomato	617 (282-1,241)	2,654 (220-6,842)
Eggplant	426 (138-1,167)	1,491 (150-3,292)

The study concluded that: "even though the environmental impacts of pesticides cannot be described fully with a single parameter, it may be useful for farmers' decision making when choosing the least risky pesticide". Furthermore, it was suggested that it could also be used to monitor and evaluate policy measures and regulations, or for adding taxes to more harmful pesticides to make them more expensive and thus discourage their use. The study recommended the development of a database on pesticides in Vietnam that should be easy to understand and use for farmers.

It also was realized that due to the weaknesses of risk indicators, more research and development was needed. One of the biggest problems with the use of the EIQ was missing or incomplete EIQ values. EIQ values were not available for many of the pesticides used in Vietnam

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[1] In 2006 the institute's name was changed into "BioForsk" or Norwegian Institute for Agricultural and Environmental Research (NIAER) including the Division for Plant Health and Norwegian Plant Protection

and had to be calculated. Available EIQ values were often incomplete because of missing data especially regarding the environmental effects (e.i. beneficials) of pesticides.

Data presented at the Vietnamese-Norwegian Workshop on Biological Control of Crop Pests in 2002 analyzed the reduction of pesticides from 247 FFS conducted in 16 communes in the peri-urban areas of Hanoi between 1999 and 2001. This data was collected by Agricultural Development Denmark Asia (ADDA) in cooperation with the Vietnamese Farmers Union. Results showed that through FFS training in IPM, the number of pesticide applications in tomato, cabbage and beans were reduced by an average of 50%. However, in terms of Field Use EIQ value, the average reduction was almost 80%, indicating an additional effect of FFS on the dosage applied and the selection of less toxic pesticides (Eklo et al. 2003).

An introductory course for Master Trainers started in August 2001 in Hanoi. This was the first attempt to introduce EIQ as a part of FFS training in Vietnam (Eklo, 2002). Based on the experience from this workshop, the National IPM Programme developed a field guide for "Evaluating the Impact of Pesticides to Human Health and the Environment by EIQ" with training exercises for (1) EIQ formula and EIQ calculation method, (2) guidance to data investigation and collection, and (3) data synthesis and EIQ calculation at the end of the cropping season. Based on the field guide, EIQ was introduced to IPM farmers in a pilot study in three provinces (involving 30 farmers in each province). The results of IPM farmers were compared with those of non-IPM farmers. The findings of this study were presented at the 4th SETAC World Congress in 2004 (Eklo and Dung, 2004) and indicated that the environmental load expressed in EIQ was lower in IPM than non-IPM fields[2].

Around the same time, an officer of the Cotton IPM Programme calculated more EIQ values for pesticides used in Vietnam that were not on the Cornell list and made recommendations to update the field guide with exercises on health studies, calculation of EIQ for unlisted products, and pesticide effects on plant growth (Rikke Peterson, 2003).

At the end of Phase I, the Norwegian project concluded that "measurements with the pesticide risk indicator EIQ have shown that introduction of IPM in vegetable crop production in the Hanoi area has considerable effects in reducing pesticide environmental risks". Comparison of the EIQ results with the number of pesticide applications made clear that apart from reducing the number of pesticide applications the FFS-IPM training also contributed to risk reduction through reduced dosage and selection of less hazardous pesticides.

Even though all improvements in pesticide use measured by EIQ were the result of regular IPM-FFS training in which EIQ was not yet included, the Norwegian project stated that "the use of EIQ had an impact on the dosage applied and the selection of less toxic pesticides." Furthermore, it was reported that "the introduction of EIQ in IPM training gave farmers a new understanding of pesticide use in vegetable production" and the "risk indicator model (EIQ) has proved to be a convenient tool for farmers and the authorities to reduce health and environmental load of pesticides." It was concluded that "FFS can be improved by including new educational tools in FFS, e.g. the EIQ model."

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[2] (Abstract No. 499 in: http://www.setac.org/htdocs/files/FourthSETACWorldCongressAbstract%20Book.pdf).

Phase II

Planning for Phase II of the Norwegian project was based in part on the expectation that with "introducing EIQ as a tool of IPM, further [pesticide] reduction would be possible." Consequently, the plans for 2005 to 2007 included a broad-scale "implementation of EIQ" in 6 provinces in Vietnam. Specifically, EIQ-related activities were included in three project objectives as quoted from the 2005 project document prepared by NCRI:

> "Objective 4: Pesticide Risk Indicator Model (EIQ):
> Develop and implement a model among farmers to choose the best management practice to reduce impact of pesticides and risks for health and environment in vegetable production in the most important areas.
> Outputs: (1) In four provinces, an autonomous extension service corps with necessary knowledge to implement a decision support system in Vietnam; an updated document of the EIQ model is available for farmer training materials"; and (2) "report of risk trend on pesticide use in Cambodia based on data from FFS."
>
> "Objective 1: Biodiversity:
> Research on the biology of insect pests and their natural enemies, and on effects of pesticides to strengthen IPM and reduce the negative effect of pesticides on biodiversity in agricultural areas.
> Output: New data will be important for improving the use of the EIQ model. By the end of 2007 new data on the effect of selected pesticides on about 10 species of natural enemies will be included in the EIQ model. Results will be available for training material towards the end of 2007."
>
> "Objective 3: Pesticide Resistance:
> To obtain documentation on pesticide resistance in leafminers and spider mites in vegetable crops. To stop overuse of pesticides due to resistance. To start a system for pesticide resistance monitoring.
> Output: Improve and develop EIQ model with data for resistance. Standard protocols and resistance management guidelines will be available and can be included in FFS training materials at the end of 2007."

Another objective for the project phase (but not specifically mentioned in connection with EIQ) was a field study of pesticide residues in long beans and leaf mustard from IPM and non-IPM farmers in three provinces.

The pesticides tested for the biodiversity objective are presented in Table 19. As shown, data on toxicity to beneficials (B) that are required for the calculation of EIQ values were already available for all but two of the ten compounds. The relevance of this work therefore was to determine to what extent data concerning effects on natural enemies from the USA, as used for the Cornell list, would differ from those on natural enemies in Vietnam. This would provide an indication of possible errors regarding the assumption that values originating from the US are equally valid under tropical conditions in Vietnam. The report of this research was not yet available at the time of writing this review. Similar deviations may exist for other parameters that make up the EIQ, such as leaching and pesticide residue half-life.

Table 19: Products tested for their effect on natural enemies in Vietnam

Pesticide active ingredient	Missing data for EIQ (see Table 1 for Code)
Herbicides	
fluazifop-buthyl	E,M,O,B
simazine	none
Fungicides	
fosetyl aluminium	none
chlorothalonil	B
Insecticides	
chlofenapyr	none
spinosad	none
imidacloprid	P
abamectin	none
fipronil	none
Bacillus thuringiensis	none

Research on pesticide resistance is expected to help advise vegetable growers to stop the use of environmentally unfavorable pyrethroids against the leafminers and turn to newer and less harmful compounds. This information would be given in addition to EIQ information as pesticide resistance is not a parameter in the EIQ formula.

For the "implementation of EIQ" during Phase II, the Norwegian project planned an extensive training programme on EIQ (Section 4.2) and a number of associated studies (section 4.3). These activities were implemented by PPD under technical guidance of Bioforsk**.**

4.2 EIQ Training

The topic of EIQ was included in two training courses for master trainers and 14 training courses for trainers that were attended by a total of 521 participants from 13 provinces. In addition, a 2-day EIQ workshop was held for 20 directors of PPSD and senior staff from 7 provinces.

Farmers from six FFS in intensive vegetable farming areas were trained in three weekly sessions on EIQ before the start of the regular programme. The purpose of this training was to enable farmers to select less risky pesticides for use on IPM plots in the FFS. Furthermore, 450 farmers who had already graduated from FFS were also trained in EIQ. The training of farmers was based on a field guide on "Evaluation of Pesticide Effects on Human Health and the Environment by Using EIQ" from 2002, which was reorganized in 2006. The topics covered in the field guide were: Areas affected by pesticide risk; EIQ formula and practice on using EIQ table; calculation of Field Use EIQ; data collection and processing.

4.3 EIQ Studies

Three provinces (Ha Noi, Ha Tay, and Lam Dong) carried out surveys in 2006 and 2007 which collected information on fertilizer and pesticide use and expenses that farmer respondents recorded information in production diaries. Data were used to compare economics and EIQ of

IPM farmers with non-IPM farmers.

Process:

1. Train 20 trainers/farmers in EIQ for 3 days and select 10 as surveyors.
2. Select 40 farmers (20 IPM/Safe-Vegetable, 20 non-IPM as control) and train them to keep record on pesticides used, dose, and area sprayed, as well as information for economic analysis (Half-day training, incl. practice in keeping record and economic analysis).
3. Weekly visits to farmers by surveyors to assist farmers in calculating inputs and summarizing data.
4. End of season: surveyors collect information on calculate Field Use EIQ and evaluate economic results.
5. Presentation of results to the commune and follow-up (e.g. weaknesses in program, policy, banned products, etc.).

In general, survey results showed that:

- Non-IPM farmers have higher pesticide use, mainly insecticides and fungicides.
- IPM farmers had higher costs for fertilizers. This was due to the use of more compost and micro-nutrients, less nitrogenous fertilizers, and more potassium.
- IPM farmers had higher economic profits as a result of reduced pesticide use and (sometimes) higher yields.
- Non-IPM farmers had higher Field Use EIQ totals.

Field studies were carried out in four provinces (Ha Noi, Ha Tay, Hai Phong and Lam Dong). In addition to information on fertilizer and pesticide use and expenses, information was also collected on population densities of natural enemies and pests in IPM and non-IPM plots.

Objective:

Increase farmer’s ability to evaluate pesticide impacts through EIQ.

Increase farmer’s ability to manage crops and pests in a safe and effective manner.

Process: (17 weekly sessions)

1. Selection of 10 key/outstanding farmers, a 1000 m^2 study field and a study crop.
2. Training of farmers in EIQ (3 weekly sessions).
3. Weekly observations and data collection on EIQ plot and control plot (11 sessions).
4. Report writing (2 sessions).
5. Field day and presentation of results (1 session):
    a. Weekly natural enemies and pest situation
    b. Pesticide applications:
        i. number of sprays (herbicide, insecticide, fungicide, total)
        ii. Field Use EIQ values (farmer, consumer, environment, total)
    c. Fertilizer applications (organic, N, P, K in kg/ha/season)
    d. Economic analysis:
        i. inputs: labour, seeds, fertilizer, pesticides, other
        ii. yield and income

In general, the field studies showed that:

- Pest densities were the same or higher in non-IPM plots.
- IPM farmers used less pesticides (although in some areas both non-IPM and IPM farmers used the same kind of pesticides).
- Non-IPM farmers had higher Field Use EIQ totals.
- IPM farmers had higher economic profits as a result of reduced pesticide use that also reduced labour costs and better water management.
- Non-IPM farmers used more nitrogenous fertilizers that led to more insect pests and consequently higher pesticide use.

4.4 Availability of EIQ values

Bioforsk was not aware that many of the Cornell EIQ values had been updated and that new values had become available. As a result, the project continued to use old values, possibly leading to wrong choices because changes could be quite significant. For example, the old EIQ value for fipronil was 54.1, while the new one is 90.1, or the old value for mancozeb was 62.3, while the new value is 14.6. Furthermore, additional EIQ values had become available that were not used. For instance, in 2001 EIQ values were calculated for 8 products widely used in Vietnam (Tran Thi Ngoc Phuong, 2001), and the Cotton IPM projects added another 10 EIQ values in 2003 (Rikke Peterson, 2003). Some of these values later had to be corrected because they were based on a publication of the EIQ formula that contained an error. In 2007, a total of 342 EIQ values was available. 221 of these were used by the vegetable IPM project in Vietnam. There were only about 18 active ingredients used in Vietnam for which no EIQ values were available. However, for all these products data sheets exist (in addition to the dossiers submitted for registration), based on which working values of EIQ could be calculated, even with some data missing. Thus, it would be possible to make complete Field Use EIQ calculations. Problems still arise when farmers cannot read the labels because they are in Chinese or Thai; in most cases, however, the active ingredient and the percent of formulation are normally legible. Unknown products could still be included in the EIQ calculations with a proxy value (= 27.3, assuming missing data for all properties) which then would be multiplied by the dose to obtain a Field Use EIQ estimate. Such a procedure, however, increases the margin of error of the risk estimate.

4.5 National Review

A total of four national EIQ workshops were conducted between 2002 and 2007 to plan and review these activities. Following the national review workshop in 2007, the utilization of EIQ in the Vietnam IPM programme was assessed as follows by the National IPM Coordinator (adapted from Dung, 2007):

Potential:

- Working with EIQ helped both farmers and technical officers to better understand negative effects of pesticides, including fungicides, on human health and the environment. Farmers understood the eight targets areas being affected by pesticides and the effect levels for those targets: Farm worker (Applicator, Harvester); Consumer (who eats vegetable products); Groundwater (who use groundwater); and Ecology (fish, birds, bees, predators).

This knowledge would contribute to farmer awareness about pesticide risks, which is considered a useful addition to the FFS-IPM curriculum.

- Although EIQ can not substitute for key selection criteria, such as efficacy, acute human toxicity, avoidance of MRL issues, and effects on natural enemies of the pest concerned, it possibly can play an additional role in the preparation of short lists for pesticides selected as least risky for use under the National Safe Vegetable Programme in Vietnam.
- When it is required to use pesticides, Field Use EIQ information might to some extent help farmers select, from the MARD list of pesticides permitted for use on vegetables, those pesticides with the least effects on the targets most relevant to their situation.
- In impact assessment, expression of pesticide risk reduction in Field Use EIQ provides a better indication than reduced number of sprays or reduced expenditure on pesticides, because it reflects effects of both use reduction and better selection of less hazardous products.
- End-of-season reviews of Field Use EIQ can possibly provide useful feed back for further improvement of the effectiveness of IPM Programme in Vegetable.
- EIQ can possibly also be applied to review different pest management scenarios for other crops, including tea and fruit trees.
- Through Field Use EIQ, as a measurement for impact assessment of IPM activities, authorities and farmers better understand the constraints related to pesticide use and the importance of IPM in addressing such constrains.

Constraints:

- EIQ is not necessarily a good indicator for safety of vegetables, as it averages out residue risks against user and environmental risks. In EIQ, consumer risks are weighed relatively low compared to environmental risk.
- The EIQ formula does not reflect the risk of not respecting pre-harvest intervals for pesticide use.
- Variations in quality and consistency of record keeping by farmers reduce the reliability of Field Use EIQ calculations.
- EIQ values are not available for all pesticides sold in Vietnam (especially illegal imports from China), so it is difficult to make comparisons.
- More complete EIQ values (fewer data gaps) are required if EIQ is to be used as an additional tool to contribute to further prioritization of pesticides from the MARD list of pesticides approved for use on vegetables.

4.6 Critical assessment

The EIQ became an important part of the vegetable IPM programme in Vietnam. Not only was it used as a management tool to assess the project's impact on pesticide risk reduction, but it also became a subject of widespread training to farmers for the purpose of pesticide selection. The latter raised concerns in FAO, notably regarding the suitability of EIQ as a tool for pesticide selection and the associated investment to integrate EIQ into farmer field schools. Concerns were underscored by the finding that due to lack of critical oversight on the side of the Norwegian project, all training and EIQ calculations had used outdated EIQ values, likely resulting in erroneous comparisons. Training materials contained inaccuracies and provided inappropriate messages about certain pesticides. Some reports started referring to EIQ plots instead of IPM plots. Above all, it seemed that the Norwegian project had insufficiently informed the government of Vietnam about the limitations of the model.

As a result, discussions were ongoing about the use of EIQ as a criterion for proper pesticide use in safe vegetables, or even Good Agricultural Practice in safe vegetable production. In safe vegetables, the main criterion is to have pesticide residues below MRL. As consumer risk constitutes only a small proportion of the EIQ value, it would not be suitable to use EIQ of applied pesticides as a criterion for safe vegetable production. Furthermore, important factors such as respecting pre-harvest intervals are not reflected, which might give low EIQ figures a false sense of safety. Selection of pesticides for safe vegetable production is to be based on a number of criteria with cut-off points on applicator safety, efficacy, risk of residues, effects on natural enemies. The strategy of the Vietnam PPD, to develop a list of pesticides that are in principle suitable for use on vegetables, or even better a short list of preferred products to choose from, seems to make much more sense than to train farmers in using EIQ (with all its limitations and risk of over-interpretation) to work it out for themselves.

In conclusion, the pilot work on EIQ in Vietnam has been of great importance to help better understand the potential and limitations of EIQ. It has generated lessons learned that are not only relevant for Vietnam, but also for IPM programmes in other countries that are contemplating the use of EIQ. It demonstrated the usefulness of EIQ as an additional parameter for impact assessment. It also illustrated the risk of over-valuing a risk indicator and the temptation to use it for purposes it is not suitable for. As a result of the international workshop (Chapter 7), Vietnam shifted towards the development of a broader pesticide risk reduction module for FFS, of which EIQ is just one element for awareness raising about diversity of risks, rather than the centre-piece.

5. USE OF EIQ IN OTHER ASIAN COUNTRIES

5.1 Thailand

In Thailand, an impact assessment study on IPM in rice analyzed a set of panel data collected over a period of over four years in five pilot FFS project sites. Field Use EIQ was used to quantify environmental and health risk reduction achieved by IPM in addition to effects on expenditure on pesticides.

Results showed that FFS-IPM farmers significantly reduced their pesticide use in gram active ingredient by 41.7 % after the training, while no significant reduction was observed between the groups on non-participating farmers in the same and control villages. Due to the pesticide reduction two other parameters linked to pesticide use, i.e. farmer net benefit and EIQ also showed significant differences. The difference in the EIQ, however, is also influenced by a change in the type of pesticide used. After the training, FFS farmers opted for less toxic pesticides to reduce their health risks.

Missing EIQ values was an important limitation to the use of EIQ for impact assessment and may have affected the accuracy of this exercise.

5.2 Cambodia

Two IPM impact assessment studies have been carried out in Cambodia, one by DANIDA on rice in 2003 and one by the FAO Intercountry Vegetable IPM Programme on vegetable crops in 2003 and 2004. Though risk assessment through EIQ was not included in the studies, attempts were made to calculate the Field Use EIQ afterwards based on existing data from the earlier impact assessment work.

However, calculation of the Field Use EIQ was constrained by the fact that the survey pesticide data not always clearly identified the products used. Not only were many farmers illiterate and did not know the name of the pesticides they were using, many of the pesticides originated from neighbouring countries and the label information was written in Thai, Vietnamese or Chinese. Attempts to record the names of the pesticides used by farmers often resulted in misspelled and incomprehensible names. In addition, some of the product names did not correspond with internationally known products of the same name, and in other instances, names like “dimethyl phosphate” or “dimethyl carbomoyl” may have been made up by local formulators.

With the help of a reference book that contains pictures of pesticide labels found in Cambodia, it was possible to identify or guess most of the pesticides used by the surveyed farmers. Unfortunately, the book only identified the active ingredients in the packages, not its concentration in the formulation. However, since most products come in typical concentrations, such as 50% for parathion, 35% for endosulfan, 80% for carbaryl, 2.5% for deltamethrin, etc., it was possible to calculate indicative Field Use EIQ values by assuming the most likely percentage of active ingredients for unknown formulations. Unknown products that could not be deduced were included in the field use EIQ calculations with a placeholder EIQ value of 27.3 and a 50% formulation.

Considering these constraints, preliminary results for IPM on rice indicated that the Field Use EIQ reduction was similar to the reduction in dose and cost, but not as great as the reduction in use of products containing WHO Class 1 compounds, which was one of the main objectives of the IPM training.

Table 20: Pesticide Reduction in the Cambodian Rice IPM Programme

Rice IPM	FFS	%	Exposed	%	Control	%
Total area (ha)	138		164		163	
Sprayed area	85	51	116	79	130	100
# applications per season	1.65	62	2.57	96	2.68	100
kg/l per ha	0.62	49	0.98	77	1.26	100
Pest Control Cost (Riel/ha)	12,681	50	18,514	73	25,337	100
WHO Class 1 (cases)	42.0	41	58.6	57	102.3	100
Total Field Use EIQ	93	53	139	79	175	100
Field Use EI Farmer	110	54	173	84	202	100
Field Use EI Consumer	24	60	34	85	40	100
Field Use EI Environment	145	51	211	74	284	100

6. DISCUSSION AND CONCLUSIONS

Experience worldwide shows that pesticide risk indicator models will be important tools in the future for measuring and documenting progress in conversion towards more environmental-friendly plant production and in pesticide risk reduction. Use of risk indicators is bridging the gap between agriculture, health and the environment by quantifying health and environmental risk of agricultural production and thus measuring the quality of the crops and crop production in a new manner. High sophistication of a model tends to limit its application, especially in developing countries, while simplicity tends to increase inaccuracy. Transparent, easily understood and user-friendly systems, however, will be important and essential to a widespread use. Accordingly, relatively simple models like EIQ represent a possible tool in assessing progress in pesticide risk reduction in situations where a rough estimate would constitute a positive first step pending a more comprehensive risk management system. However, as with most models and indicators, one should be aware that the connection between changes in EIQ and actual improvement in environmental impact remains theoretical as long as such changes have not been validated against measured actual effects. Although the Field Use EIQ takes into account some exposure parameters, one should remain aware that exposure scenarios are fragmented and may not necessarily be relevant for the situation at hand.

In fact, the term Environmental Impact Quotient somehow seems inappropriate as it actually combines potential impact on the environment, consumers and farmer. Although the Cornell literature refers to EIQ as an indicator for environmental impact, it is more a general risk indicator with an emphasis on Environment.

General references to EIQ refer to the “Field Use EIQ” rather than the “EIQ Value”. However, this sometimes seems to get mixed up.

6.1 Limitations of the EIQ

Like all pesticide risk assessment systems, the EIQ has strengths and weaknesses. It is widely appreciated for its relative simplicity and ability to give useful though crude estimates of pesticide risks. However, there is a danger of over-interpreting the numbers that are generated by the model, particularly since many scores are based on incomplete datasets.

The EIQ model was developed in the US and the manner in which the various components are expressed and weighed against each other reflects concerns about risks in the US, which are not necessarily the same in Asian countries.

One of the biggest weaknesses of the EIQ is the often missing data for natural enemy toxicity, which is given the biggest weight in the formula, thereby introducing considerable inaccuracy. However, other risk assessment systems that also include the impact on natural enemies would share the same limitation.

In addition, the impact of pesticides on beneficial organisms other than just arthropods is not reflected in the EIQ index. Currently, little information is available about impacts of a diverse array of pesticides on beneficial fungi, including commercially available ones as *Trichoderma harzianum* and *Beauvaria bassiana* or on bacteria such as *Bacillus subtilis*.

A number of plant protection products, including pesticides widely used in developing countries but no longer registered in the USA, some modern products, or specialized products such as fruit thinners or certified organic products are not on the Cornell EIQ list. This often hampers the assessment of different plant protection strategies. An exchange of newly calculated EIQ values among EIQ users would be very helpful.

Although the EIQ Model does take into account the potential environmental impact of high-volume low-toxicity products such as oil and soap, it does not reflect these very accurately because of the absence of zero or near zero values in the scoring system. As a result, the risk of such products may get over-rated. This concerns several of the products that IPM Programmes may be promoting as alternatives for chemical pesticides.

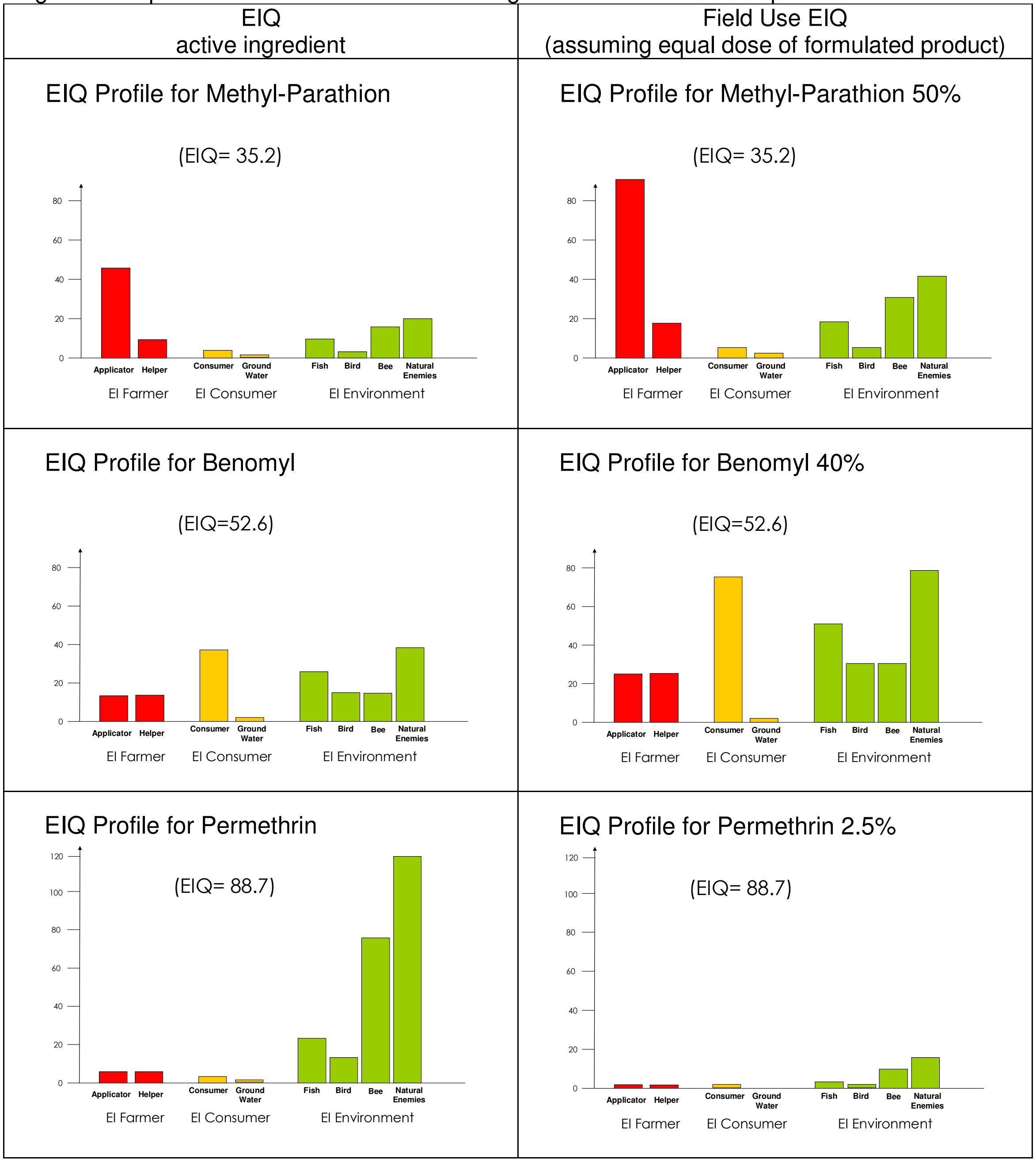
Because the single EIQ value lumps together very diverse aspects (i.e. occupational risks, food safety and environmental contamination) it will not be useful if one is interested in a specific risk, such as for instance consumer risk, risk to fish, or pesticide resistance. In those cases, it would be more appropriate to focus on a narrower range of impact (e.g. only on human health or on non-target, aquatic species) to determine practical cut-off points for unacceptable risks related to the situation at hand.

Likewise, the total Field Use EIQ value may not always be useful when assessing specific pest control strategies, including IPM, because some important use and timing aspects are not considered. For example, adherence to the pre-harvest safety interval may be much more important to reducing consumer risk than the selection of a low-EIQ pesticide, particularly since the EI Consumer constitutes only 10-22% of the total EIQ index. Therefore, it might be risky and sometimes misleading to base program assessments entirely on EIQ scores. The EIQ cannot substitute for good IPM thinking and a proper agro-ecosystem analysis, and additional context information is necessary when presenting EIQ results.

Profiles

Break down of EIQ Field Use into its components can provide an indication of relative differences in risk scores on individual EIQ components for different pesticides. In order to make such comparisons one would need to look at Field Use EIQ figures, as shown in Fig. 10 below. When comparing three active ingredients, methyl-parathion poses a relatively high risk to applicators, benomyl to consumers and permethrin to bees and natural enemies. However, among the formulated products, permethrin poses the least risk due to its low concentration, despite of its high EIQ rating. These comparisons emphasize the need to calculate the Field Use EIQ figures when assessing risk and not to rely on the EIQ values.

Fig. 10: Comparison of EIQ Profiles for active ingredients and formulated products



As indicated above, these profiles can only be used for comparison of relative differences in risk scores on specific components (Farmer, Consumer, Environment) for different formulated products. They can not be used to compare risks to different components for a single product, because the authors of the formula assigned different weights to different components to construct an indicator that serves a specific purpose. Such weight attribution is always arbitrary and based on assumptions. This does not matter when one combines several factors in one formula that is applied in the same manner for all products. It means, however, that one cannot dissect the formula into different components and then draw conclusions on differences in scores between components.

With good understanding of the above limitations, the comparison of EIQ field use profiles of different products or crop protection strategies may help identify specific risk areas that have scope for improvement. These could then be further analysed, which could lead to specific measures to further reduce specific risks.

As such, profiles may draw attention to important risk areas that can be overlooked by other risk assessments procedures that focus primarily on acute mammalian toxicity.

Use of EIQ in IPM Programmes

The purpose for which EIQ has been used in IPM programmes falls into two categories:

1. Assessments, usually made at the end of a season, either in form of impact assessment studies, field studies or surveys
2. IPM tool for decision making on pesticide risk reduction

These are discussed below.

6.2 Use of EIQ for Impact Assessment

Pesticide use reduction can be measured in many ways, most commonly as number of applications, quantity (kg or litre per hectare) of active ingredient or quantity of formulated product. All these measures, however, say nothing about the quality of the products used.

A qualitative measure would be, for example, the reduction of the use of products that fall in WHO Hazard Class I. While this measure would show reduced acute risk to the applicator, it does not take into account risks to consumers or the environment, nor chronic risk to the applicator. Therefore, IPM Programmes in Asia used EIQ as a more complete measure of pesticide risk.

Table 21: Indicators for pesticide use, hazard or risk

Indicators	What it measures	Limitations\Comments
Number of applications	Pesticide use	Does not indicate quality of products used; more a measure of labour
Quantity (kg or litre) of formulated product applied per hectare	Pesticide use	A more quantitative measure than number of applications, but does not indicate quality of products used
Quantity (kg or litre) active ingredient applied per hectare	Pesticide use	A more accurate measurement than just the quantity of applied product, but does not indicate the quality of products used. Does not reflect the overall volume of product and the frequency of pesticide use. E.g.: switching from OPs to pyrethroids will show up as pesticide reduction, even when spraying intensity has increased.
Number of applications with products containing WHO hazard class I active ingredient	Pesticide hazard to farmers	Incorrect parameter. It is the hazard class of the formulated product that counts, not the hazard class of the pure active ingredient. .
Number of applications with formulated products falling in WHO hazard class I	Pesticide hazard to farmers	Useful for showing a shift to products with lower acute health risk to farmers. Does not include chronic health hazards or environmental hazards.
Field Use EIQ	Pesticide risk to farmers, consumers and the environment	Expresses both reduction in pesticide use and selection of less hazardous products. Provides a broader but rough indication of potential impact. Does not take into account actual exposure and other factors such as timing.

While appearing useful for impact assessment, one could nevertheless ask the question: When does EIQ actually give added value to the quantitative pesticide reduction figures, and is the additional effort for calculating Field Use EIQ values justified? For example, when the number of applications decreased but the same products were used, the environmental risk would logically decrease proportionally; in this case, calculating the EIQ would not give any new information.

The usefulness of EIQ may also depend on the stage of an IPM programme and the extent to which pesticide applications are still deemed as essential part of any ecology-based IPM set of ‘best practices’ for a given crop under a given crop production situation. For example, in an intensive pesticide use situation, IPM may be able to reduce the number of applications initially from 15 to 5. In this case, the reduction in quantity appears to be an adequate success indicator.

In most cases, Field Use EIQ values would not make this figure more impressive. However, for a further reduction from 5 to 3 applications, the EIQ might be more impressive if it can show an improved quality of pest control products used.

As shown in table 22, use of EIQ in impact assessment makes most sense when there are little or no changes in the quantity of pesticides, but improvements or deteriorations in the quality of products, whereby low hazard products are considered to be of higher quality.

Table 22: Most useful circumstances for application of EIQ

Hazard **Quantity**	more toxic	same	less toxic
more	--	+/-	+/-
same	---	+/-	+++
less	+/-	+/-	++

Shaded areas indicate most useful circumstances for application of EIQ; + indicates areas where EIQ can show positive impacts, and – indicates areas where the impacts would be negative to the objectives of IPM; +/- indicates areas where the EIQ would add no or little new information.

Use of EIQ as a parameter for impact assessment therefore can be a useful addition to parameters that measure quantitative pesticide reduction if there are improvements in the quality of pesticides selected.

However, as the EIQ is a composite indicator that combines risks to farmers, consumers and the environment, it may be less suitable if one is specifically interested in potential impact on human health or on specific risk to the environment.

Regarding impact on health of pesticide users, data on actual poisoning sign and symptoms are the most suitable form for evaluating pesticide effects on human health. However, since signs and symptoms are often unspecific, it is necessary to correlate these data with toxicological characteristics of products used to establish a plausible cause-effect relationship. These characteristics can be found on the label, on material safety data sheets or in online databases, such as the WHO\IPCS Intox Databank. The EIQ value is not a suitable measure for the impact of health because it includes other data than human health. Without actual poisoning information it would be difficult to establish a convincing case of pesticide effects on human health. However, when that information is not available, reduction in WHO toxicity class or in the EI Farmer and EI Consumer components of the Field Use EIQ could be used to indicate potential positive effects on human health, but these values alone are not sufficient for evaluating pesticide effects.

Similar to human toxicity, use of the EI Ecology component of the Field Use EIQ would not be sufficient for evaluating pesticide effects on the environment. This would best be done by showing changes in ecosystem functions and population densities, particularly of beneficial insects, as is done in IPM field studies. However, experience has also shown that it is very difficult to come up with significant changes in population densities in these studies. Credible results of pesticide effects on the environment may require more sophisticated and elaborate studies. In this case, changes in the EI Ecology Component of the Field Use EIQ may be a useful tool to indicate possible effects on the environment, but it cannot substitute for actual results, particularly since the EI Ecology only takes into account reference species of fish, bird, bee and beneficial insects toxicity that may not accurately reflect the impact on specific local species. However, in the absence of a better alternative, the Field Use EIQ appears to be useful as a rough indicator of potential impact of pesticides on the environment.

Conclusions

The selected case studies from the Cotton IPM Programme showed that reduction in Field Use EIQ exceeded reduction in commonly used indicators for pesticide use (number of applications, dosage rate and cost), indicating that IPM often reduces risks more than would be evident from reduction in pesticide use indicators. Nevertheless, the dosage rate of pesticide applications is probably still the primary factor that affects environmental risk because it affects the possibility of exposure and contamination.

While the EIQ seems useful as a rough environmental indicator, the ultimate impact of IPM on biodiversity still needs to be documented separately. Case studies have shown significant increases in natural enemy populations and predator-pest ratios in IPM plots, as well as an increase in the total number of species, substantiating the positive impacts of IPM on the environment, as also indicated by pesticide use reduction figures and changes in Field Use EIQ.

Field Use EIQ profiles showing the individual farm worker, consumer and environmental risk components sometimes may be useful for illustrating relative changes <u>within</u> the different components, but cannot be used to compare risk <u>between</u> different components without taking into account the different weighing of components in the formula. A comparison of the ‘percent of dose’ and ‘percent of EIQ’ values for all pesticides used in an application scheme can help identify those products that contribute disproportional to their quantity to the environmental risk as shown in Fig. 8 and 9.

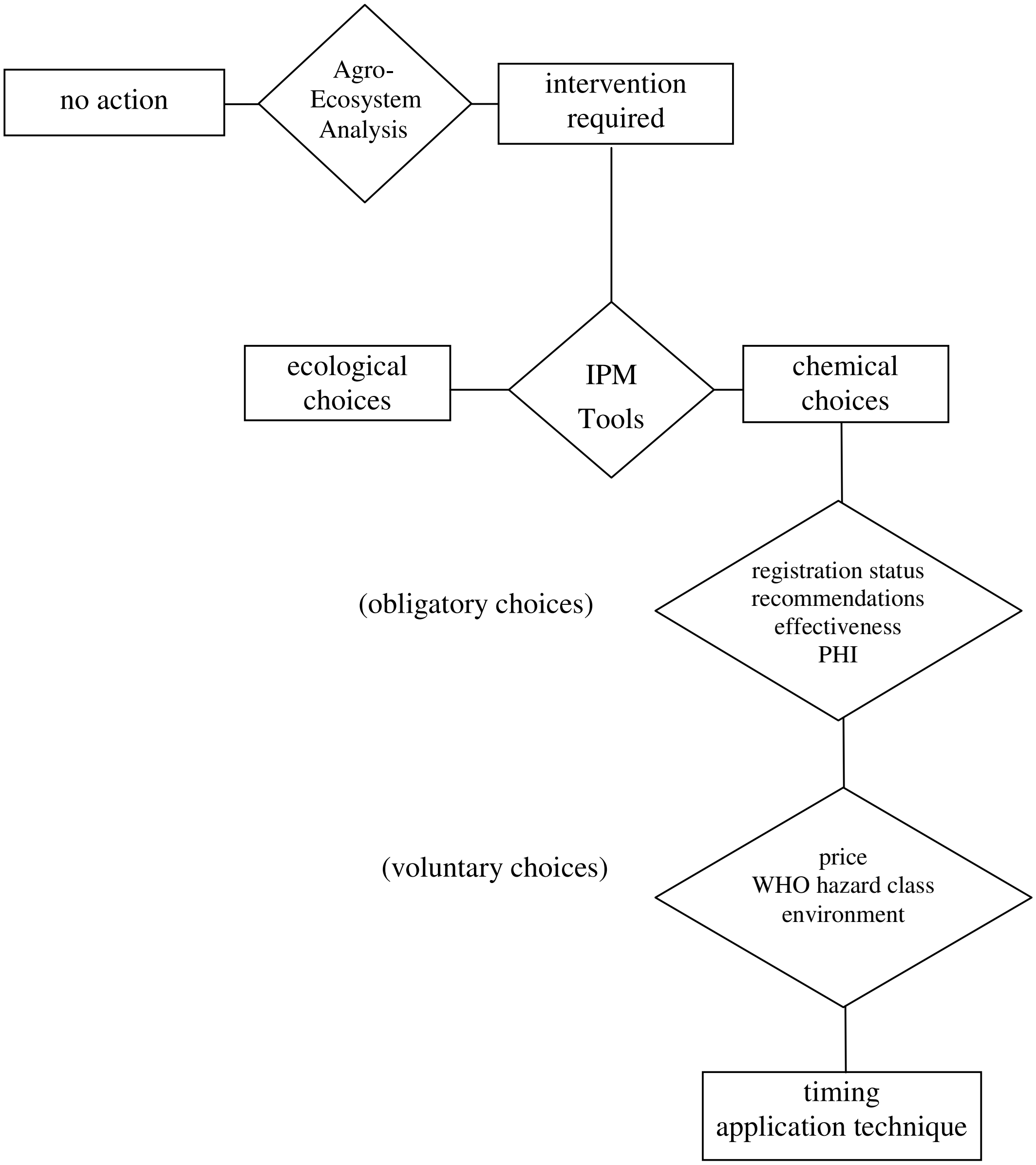
Since solvents are a major component of pesticide formulations, their effect on the environment would also need to be included. While considered less toxic to humans, the effect of these "inert" ingredients on the environment may be considerable.

6.3 Use of EIQ for IPM Decision Support for Pesticide Risk Reduction

IPM promotes pest management decision-taking based on a sound analysis of the agro-ecosystem. If the results indicate that an intervention is warranted, farmers should first consider the different IPM tools at their disposal. Only after rejecting other tools, chemical intervention should be taken as the last resort. When faced with choosing a pesticide, farmers’ first concern is most likely that of efficacy against the identified pest problem, particularly if pesticide resistance might have developed. Next, farmers will probably consider price, toxicity and required waiting period before harvest when making a choice. Toxicity for fish can be a consideration if fish is part of their production system, such as in paddy rice, or if their fields border water that is used to rear or catch fish.

The proper sequence of decisions is depicted in figure 11 below:

Fig. 11: Farmer Decision Tree



This analysis shows that IPM decision-taking is complex and that primary decisions relate to pest management. The possible role of EIQ in this process is limited to environmental considerations related to selection of pesticides in the voluntary choices box after all earlier considerations have been made. Even then, specific concerns may be more important. For instance a farmer growing paddy rice would be more interested in considering actual fish toxicity of the products concerned.

While the usefulness of EIQ for impact assessment purposes has been established, its use as a decision support tool in IPM is still unproven. At best, it can help with broad evaluation of different pest management approaches or in identifying certain pesticides that should be further scrutinised. It is not suitable as a tool for farmers to determine what specific pesticide to use.

7. INTERNATIONAL WORKSHOP ON EIQ

An international workshop was convened by FAO and the Vietnam IPM Programme at Doson in Haiphong, Vietnam from 19 to 21 April 2007. The objective of the gathering was to review experiences with the application of EIQ in IPM programmes and to contribute to a guidance document for use of EIQ in IPM projects. The meeting was attended by 16 participants involved in environmental and health monitoring from ongoing programmes in Vietnam, Cambodia, Thailand, China, and Lebanon, resource persons from Norway, USA and Thailand, and FAO staff from Rome, Bangkok and Vietnam.

Chapters 1-6 of a draft version of this report served as a background document to the workshop. These were finalized after the workshop. Chapter 7 was added to reflect the findings and conclusions of the workshop and follow-on discussions on some specific issues. The outcome is summarised below:

<u>General observations regarding the EIQ Model</u>:

- The index was developed in North America to assist in decision making and assessment of IPM on fruits and vegetables in order to protect the environment. It originated in the context of a highly sophisticated pesticide evaluation and registration system that strongly regulates the use of pesticides in agriculture to protect farm workers and consumers against health risks and prohibits dangerous products from the market. This context is drastically different from the situation in many developing countries where highly toxic products are still widely available and people’s lives are at risk because of weak regulatory controls, misuse and lack of education.
- For the sake of simplicity and user-friendliness, the model traded off accuracy and specificity .
- Data gaps (e.g. for arthropod or chronic toxicity) in about half the calculated values contribute to the inaccuracy of the index;
- Data used for the calculation of EIQ values take into consideration impacts on beneficial arthropods, bees, birds and fish. The effects on the species used for these calculations are not necessarily representative for the effects on species common in Asia. The same applies to leaching potential in soil and residue half-life, which are likely to be different in a humid tropical climate.
- The EIQ is a rough index that generalizes potential pesticide risks based on chemical properties; it was not designed to estimate or measure actual pesticide risks in a given situation or setting.
- While the index is appreciated for pointing out potential pesticide impact on the environment, it assigns 60% of its value to this sector, 30% to occupational health and 10% to consumer protection. However, the distribution of weight to sub-sectors cannot be generalized and

depends on local situations and priorities.

- The single EIQ Value averages out the effect of the three components that make up the value. As such, the EIQ is not suitable as indicator for “safe vegetable programmes” because the EI Consumer component makes up only 10-23% of the total EIQ value and may get averaged out against other components. Further, the EI Consumer component does not reflect risks associated with non-observance of pre-harvest intervals, which is a key factor for safe vegetable programmes.
- Modification of the EIQ model has many implications and therefore is not desirable. In order to maintain comparability, all EIQ values would need to be recalculated and data for these recalculations need to be available. For instance inclusion of effects on a local fish species only makes sense if the effect is measured for all pesticides used in the country concerned. The same applies to incorporation of information related to pesticide resistance. The EIQ model requires that the same data are available for all pesticides that are being compared. If it is nevertheless decided to adjust the model, consider building a beta (modification in process) model by replacing individual components with more accurate indicators.

The following more specific technical points were identified:

- The Field Use EIQ does not reflect actual exposure pathways, which are often site specific, and the main factor that determine risks in a given situations.
- Specific EIQ calculations are based on assumptions which often not reflect local realities, e.g. it assumes consumer risks through groundwater contamination while in many instances surface water is the main water source; or, in another example, risk to honey bees has been found to be directly related to spray exposure and not to pesticide half-life as assumed in the EIQ;
- Leaching potentials vary strongly depending on soil, climate and irrigation practices, but the EIQ only uses a single, general score;
- Environmental effects are often location-specific (e.g. a particular natural enemy, fish, etc.) which cannot be generalized;
- The EIQ index implies a linear relationship between the index number and potential benefits, while in reality changes are often influenced by threshold values (e.g. biodiversity, human health, etc.); even significant reductions in EIQ may not represent actual risk improvements; likewise, low EIQ values may still hold substantial risks when a product is used widely and frequently, or if its used inappropriately.
- The model does not assign a “zero” score for non-toxic, harmless products; this potentially results in unwarranted high Field Use EIQ for some benign products used in IPM;
- The model does not reflect the importance of timing, including observance of pre-harvest intervals, which greatly affect pesticide risks;
- The model has not been verified to be correlated with actually measured effects and there are no set standards for the quality of data or the validation of its results. As such, EIQ data cannot be linked to actual human and environmental effects in the field without further verification.

- EIQ calculations cannot substitute for actual health or environmental impact monitoring.
- There is a high risk of indicating potential harm where there is none (false positives) or indicating a product to be relatively harmless when it poses a serious risk (false negatives).

<u>Use of the EIQ model in impact assessment</u>

- Field Use EIQ is particularly useful in impact assessment to include effects of improvements in pesticide selection, which are not reflected in general pesticide use indicators;
- EIQ is useful as retrospective impact assessment tool if no specific studies on health or environmental impact have been done;
- However, it is important to recognize that EIQ is an index that reflects a generalized potential risk and it is not a direct measure of impact;
- Based on project objectives, other impact indicators should be considered to complement EIQ, e.g. WHO pesticide hazard classes, poisoning signs and symptoms, etc.;
- Field Use EIQ may be used at the end of a season or in rigorous, multi-year impact assessment studies to assess relative achievements of farmer groups on programme/policy level. Because it can be applied to every participant in a study for who pesticide use data are available it can show frequency distributions of potential impacts for very large number of farmers. It can be used for rigorous statistical analysis, e.g., through the double delta approach.
- Comparison of Field Use EIQ profiles for different pest management strategies can play a role in identification of risk components that have scope for further risk reduction.
- Impact assessment requires solid farm records about pesticide use, preferably recorded continuously during the season and not collected as recall information at the end;
- Collection of accurate field data for impact assessment is often a challenge. Even though the EIQ is only a rough indicator, the data used for its calculation should be as accurate as possible. Field projects using EIQ as a parameter for impact assessment faced the following practical problems that complicated calculation of Field Use EIQ data and added to the margin of error:
    - Product not identifiable (e.g.: label information missing, label in foreign language, made-up names, etc.).
    - Misspelled and incomprehensive names in farmer records.
    - Inaccurate assessment of dosage (volume used, area treated), particularly with self-made mixtures.
    - Incomplete records (entries missing).
    - EIQ value is not available for the pesticide.
    - The type of crops grown by farmers change between base-line and impact measurement and, as such, affect pesticide use pattern and Field Use EIQ.

- Whenever possible, validate changes in Field Use EIQ by crosschecking them with case studies on health and environmental effects of pesticide use (e.g.: signs and symptoms; residues; biodiversity, natural enemies, etc.). Such validation is important if changes in Field Use EIQ are to be presented as positive effects on the environment.

Practical recommendations for the use of EIQ in impact assessment

If the model is used for impact assessment, high quality of data should be ensured, which requires good preparation and training of facilitators to assist farmers in the recording of information.

- Before collecting pesticide use data, the active ingredients of all trade names should be known. Picture books with pesticide labels have proven useful to identify the products used by farmers.
- EIQ values should be available for all major pesticides used. Where missing, EIQ values should be calculated by using available pesticide data sheets, even with some information missing.
- Project staff needs to check data, and if necessary verify and correct these, before they are used for EIQ calculations.
- If one has to work with recall data, the recommended dose (as on the label) may be used as a proxy if field use data are incomplete.

Use of the EIQ Model in farmer education

- Use of EIQ in farmer education can easily lead to over-interpretation of figures and therefore only has a limited role to play in farmer training on pesticide risks:
  - Showing some examples of Field Use EIQ figures broken down into 3 or 8 components, may help understand diversity of risk. However, breakdowns in components can easily be over-interpreted as farmers may find it difficult to understand the implications of different weighing of the various components. If used at all, such breakdowns should be used very carefully and it should explicitly be explained that one cannot compare the values for the 3 or 8 components with each other. When comparing different products, one should explicitly look at break down of Field Use EIQ and not the break down of the EIQ Value.

    After introduction of the Globally Harmonised System (GHS) for the labelling of chemicals one could look at GHS risk classifications of products. Eventually, these will also be reflected in pictogrammes on the package.
  - When used as part of an end-of-season review, EIQ indexes could be useful to show general progress in risk reduction trends over time or to show the position of a farmer group within a larger distribution of pesticide users.

- EIQ is not a suitable tool for pesticide selection by farmers.

- Farmers should not be expected to calculate Field Use EIQ themselves if EIQ is included as a parameter for impact assessment.

Selected Abstracts and Links

Dushoff, Jonathan, Brian Cardwell, and Charles L. Mohler.
Evaluating the Environmental Effect the Pesticides: A Critique of the Environmental Impact Quotient.
American Entomologist 40 (3), 1994

“The environmental impact quotient (EIQ) developed by Kovach et al. is an effort to fill an important gap: the need to provide growers and others with easy-to-use information about the adverse effects of pesticides. However, flaws in both the formula and its conceptual underpinnings serve to make the information provide misleading. Although Kovach et al. provides a great deal of information and many interesting ideas, we recommend that EIQ presented there not be used to evaluate field applications of pesticides. Further, current understanding of pesticides and their effects is not sufficient to allow the environment al effects of a pesticide to be captured by a single number. We discuss alternate ways to provide growers and policymakers with usable information about pesticides”

Canada, British Columbia
The Fruit Leader, Vol. 3(2) July 1994

Used to compare the environmental impact between products in order to select the least harmful control strategy.

Old program: $ 1,259 EIQ 3982
IPM program: $841 EIQ 2372

The EIQ model does not consider some important factors that can influence the impact of pesticides. For example, the model and field use rating formula do not consider the susceptibility of local natural enemies of pests. Thus a product may be less harmful in one region than another because important predators are tolerant to the rate applied. Timing of application can also affect the impact of a product has on natural enemies. Petroleum oils and insecticides applied during dormant and delayed dormant will have much less impact than if applied later because most natural enemies are not yet active.

The model is not perfect but it is the best attempt to quantify the potential environmental impact. Comparisons can be made between control products and strategies to select the least harmful alternative.

John P. Reganold, Jerry D. Glover, Preston K. Andrews and Herbert R. Hinman
Sustainability of three apple production systems
Nature **410**, 926-930 (19 April 2001)

Environmental impact assessment
We determined environmental impact ratings for each farming system using an index developed by Stemilt Growers, Inc. of Wenatchee, Washington, as part of their 'Responsible Choice' program Similar to Cornell University's Environmental Impact Quotient but updated to include fruit thinners and certified organic products, the index takes into account chemical efficacy, potential worker and consumer exposure, leaching potential, soil sorption index, chemical half-life and the effects of chemicals on beneficial organisms, all based on toxicological studies and chemical characteristics of each product. The active ingredient of each pesticide and the dose and frequency of application were used to calculate the environmental impact ratings.

G.J. Gallivan, G.A. Surgeoner and J. Kovach.
Pesticide Risk Reduction on Crops in the Province of Ontario.
J. Environ. Qual. 30:798-813 (2001)

Between 1983 and 1998, total usage (as measured by active ingredient) decreased by 38.5%, and risk declined by 39.5%. Between 1983 and 1993, pesticide reductions resulted in:
29% reduction in the overall environmental impact of agricultural pesticides
21% reduction in the environmental impact per hectare of crop land
32% reduction in the environmental impact per tonne of food produced, reflecting both the reduction in pesticide use and an increase in productivity
41% reduction in the risk to farmworkers
28% reduction in the risk to consumers
21% reduction in the risk to environment
Note: of the twenty-seven pesticides with high environmental impact ratings that were in use in 1983, eleven were no longer in use in 1993.

R. Bues, M. Dadomo, J.P. Lyannaz, G. Di Lucca, J.I. Macua Gonzales, H. Prieto Losada, Y. Dumas.
Evaluation of the Environmental Impact of the Pesticides Applied in Processing Tomato Cropping.
ISHS Acta Horticulturae 613: VIII Intern. Symposium on the Processing Tomato, 2002

Among several proposed methods, none being exhaustive, the rating system of the “Environmental Impact Quotient” (EIQ) allows a relatively simple evaluation of the non-intentional impact of different pesticide spray programmes on the environment. Significant differences in EIQ values between treatment programmes were observed. The analysis showed that the strongest impact resulted from fungicides, particularly copper and sulphur. Although the range of variations was large, there was no close correlation between the EIQ values calculated and the number of pesticide sprays. The impact of pesticides on farm workers and consumers varied according to the treatment programmes, but was lower than on non-human organisms. These results should be taken into consideration to adapt spray decision rules within the scope of integrated production of processing tomato.

Scherm, Harald.
Reduction of Pesticide Risk in Georgia Peaches, 1991-2001
Southeastern Regional Peach Newsletter, Volume 3, No. 4 September 2003

When interpreting EIQ values, it must be borne in mind that these are relative numbers that aid in the comparison among years or active ingredients; they do not tell us anything about the absolute risk (e.g. number of pesticide-associated bee kills per year)

Results: Total pesticide risk, expressed as EIQ points per acre, has decreased by about one-fifth since 1991. Most of the decrease in EIQ since 1991 was due to reductions in risks to farm worker health, for which a decline by almost 50% was observed. This corresponds to the period when use of lime sulfur, a caustic fungicide with relatively high risk to applicators, was discontinued.

Conclusions: Since 1991, potential pesticide risk, estimated with the EIQ, has decreased by 20% per acre and by 35% per pound of produced fruit, although the overall amount of pesticide a.i. applied per acre has remained constant. The largest drop (close to 50%) was observed in risks to farm worker health, whereas potential risks to consumers, birds and bees have remained largely constant since 1991. EIQ estimates of risks to consumer health are relatively low (constituting no more than 13% of the total EIQ per acre) compare with those for the three other risk categories considered in this analysis. Potential impacts on birds and bees account for about 60% of the EIQ total in 2001; this highlights the importance of using application technologies that minimize potential exposure of these organisms.

Ted Gastier, Huron County Extension

Environmental Impact Quotient Analysis of Pesticide Use in North Central Ohio - 1999 & 2003

Ohio Fruit ICM News Volume 7, No. 47 December 4, 2003

A better EIQ model was created in 1999 for apples excluding ziram and Polyram which lowered the EIQ rating from 1600 to 586 and lowered season costs of materials by $10.50 per acre. For peaches, a better EIQ model without ziram and sulfur yielded an EIQ rating of 595 at an additional cost of $5.20 per acre. By considering EIQs, IPM practitioners can incorporate environmental concerns, along with efficacy and cost, into the pesticide decision making process.

Vincent Van Bol, Sara Claeys, Philippe Debongnie, Jordan Godfriaux, Luc Pussemier, Walter Steurbaut and Henri Maraite

PESTICIDE INDICATORS

Pesticide Outlook, 2003

http://www.rsc.org/delivery/_ArticleLinking/DisplayArticleForFree.cfm?doi=b308507b&JournalCode=PO

The article describes the development of indicators for use by public authorities in their pesticide assessment with a view to reductions in such use and argued that the adequacy of a pesticide risk indicator for a global assessment increases in proportion to the reduction of its adequacy for a specific assessment. Consequently, for a pesticide risk assessment at regional level, it could be interesting to work with both a “global” indicator, for the over-all impact, and a “specific” indicator for the most relevant combinations of a.s., use pattern, and environmental compartment.

The “global” indicator would have the following characteristics:

- it would include parameters only on the amount of active substances used (based on active substances sales), persistence and chronic toxicity (e.g., the American CTPU or the Belgian SEQglobal (Spread EQuivalent) (De Smet and Steurbaut, 2002);
- it would be used at regional level for inter-annual and inter-regional comparisons, mainly for policy purposes ;
- precautions would be taken to avoid using this indicator at local level (farm, field), as is unfortunately the case for the FA indicator in Denmark.

The “specific” indicator would have the following characteristics:

- it would be based on several (10–15) pesticide risk indicators specific for particular aspects (farm worker risk, consumer risk, water organisms, resistance induction of target organisms, etc.), as in the case of the Danish IL, the Norwegian CERI or the Belgian POCER-1 indicators ;
- risk assessment of the particular aspects should be aggregated in a traceable procedure in order to determine the implications for human health, farmer interest and environment, as in the case of POCER-2 developed in Belgium (Maraite, 2002) ;
- it would be used mainly at farm or field level to support any IPM improvement for sustainable development or quality label evaluation purposes.

Of course, one of the problems encountered in the use of all pesticide indicators is the large number of pesticide active substances and the even larger number of pesticide formulations. It is anticipated that these numbers will be significantly reduced by the on-going re-registration process in the framework of EU Directive 91/414.

Eklo, O.M., Dung, N.T.

The pesticide risk indicator model Environmental Impact Quotient (EIQ) used in vegetable production in Vietnam.

Fourth SETAC World Congress, 25th Annual Meeting in North America: WA8 Global Perspectives: Pesticide Risk Assessment in Developing Countries, 2004

http://abstracts.co.allenpress.com/pweb/setac2004/document/?ID=41931

ABSTRACT-

In four provinces of Vietnam the pesticide risk indicator model Environmental impact quotient (EIQ) has been introduced. The objective of the project was (1) to guide farmers using EIQ index to help choosing a less harmful pesticide to human and environment in vegetable production (2) to help farmers using EIQ index for assessing the effect of pesticides on human health and environment and (3) to gain experience from practical use of risk indicator models as a tool for farmers. Trainers from Plant Protection Sub-Departments (PPSD) at each province were responsible for the introduction of the EIQ model in Farmer Field Schools (FFS) with 30 farmers participating in each FFS. In the selected provinces, field plots in two crops from 15 IPM-farmers and 15 Non-IPM farmers (Farmer plot-FP) were followed during the growing season, September to December 2002. During the FFS, trainers and farmers discussed about objects affected by pesticide use and introduction of formula and method to calculate EIQ. Trainers guided farmers to practice the EIQ calculative table, to calculate and use field EIQ, to assess the effect of pesticides used on human and environment, and to guide and practice methods of collecting data. The main results from the exercise showed that the yield of IPM field was higher than FP. The EIQ at IPM field was lower than FP and thereby both economizing of expenses and less affecting the environment. After farmers training with IPM and EIQ, farmers gained new knowledge; changing their mind when using pesticides and decreasing the environmental load and risks in vegetable production.

Kleter, G.A. Kuiper, H.A.

Assessing the environmental impact of changes in pesticide use on transgenic crops.

Wageningen University, 2004

http://library.wur.nl/frontis/transgenic_crops/03a_kleter.pdf

Environmental indicators for pesticides may aid in comparing the outcomes of such assays in terms of environmental impact. Previously we applied one indicator, the Environmental Impact Quotient, to pesticide-use data for commercial biotech crops from a recent survey by NCFAP and found that, by this method, the impact paralleled the decreased use of pesticides. The output of many environmental indicators, while lending themselves to comparison of pesticides, is abstract and there may be a need for specific indicators that lend themselves for comparison with other agricultural factors or that are expressed in more tangible terms, e.g., monetary indicators. IUPAC recently initiated a project on the assessment of the environmental impact of altered pesticide use on transgenic crops, with the aim of providing input for risk–benefit analysis of the adoption of genetically modified crops. In conclusion, the use of appropriate environmental indicators enables the assessment of the economic and environmental effects of agricultural biotechnology, including that of altered pesticide use.

Conclusion: As discussed above, there is a need to translate the figures on altered pesticide-use practices during cultivation of GM crops (including data from surveys like those of the

USDA-ERS and NCFAP) into terms of impact on the environment. To this end, environmental indicators may prove instrumental in quantifying such impacts of pesticides. In our previous work, we employed the EIQ, which has the advantage that it is generally applicable, that EIQs have been established for a great number of pesticide active ingredients, and that farm worker, consumer and ecology components have been incorporated. Whereas the outcomes enable a comparison between different pesticide regimes, these results are rather abstract and may not be amenable to comparison with other issues in agriculture.

Terrance M. Hurley

Comment on Kleter and Kuiper: Environmental fate and impact considerations related to the use of transgenic crops

http://library.wur.nl/frontis/transgenic_crops/03b_hurley.pdf

To the extent that pt or ht crops result in the use of more active ingredient of a less hazardous pesticide, the results of this type of analysis can be misleading. Kleter and Kuiper rectify this shortcoming by using the Environmental Impact Quotient (EIQ, Kovach et al. 1992) to weight the kilograms of a pesticide used by measures of its hazard to human health and the environment. While their methodology represents an improvement over previous efforts, their analysis can still be criticized as biased in favour of transgenic crops. The bias comes from their treatment of Bt crops. Implicitly, their analysis assumes the EIQ for Bt crops is 0, which indicates no risk to human health or the environment. Kovach et al. (1992) does not report an EIQ for the toxins expressed by Bt crops. However, it does report an EIQ for Dipel, which is a spray formulation of toxins similar to those in Bt crops. While the Bt toxins are generally rated as less hazardous than most alternatives, they are not hazard-free. To avoid claims of bias, Kleter and Kuiper should explicitly include toxins present in Bt crops in accounting the effect of Bt crops on pesticide use and hazard.

BRIMNER Theresa A.; GALLIVAN Gordon James ; STEPHENSON Gerald R.;

Influence of herbicide-resistant canola on the environmental impact of weed management

Pest management science, vol. 61, n^{o}1, pp. 47-52 2005

The growth of herbicide-resistant canola varieties increased from 10% of the canola area in Canada in 1996, when the technology was first introduced, to 80% in 2000. From 1995 to 2000, the amount of herbicide active ingredient applied per hectare of canola declined by 42.8% and the Environmental Impact (EI) per hectare, calculated using the Environmental Impact Quotient for individual herbicides and the amounts of active ingredients applied, declined 36.8%. The amount of herbicide active ingredient per hectare applied to conventional canola was consistently higher than that applied to herbicide-resistant canola each year between 1996 and 2000. Similarly, the EI of herbicide use per hectare in conventional canola was higher than that of herbicide-resistant canola during the same time period. Since 1996, herbicide use has shifted from broadcast applications of soil-active herbicides to post-emergence applications of herbicides with broad-spectrum foliar activity. The decline in herbicide use and EI since the introduction of herbicide-resistant varieties was due to increased use of chemicals with lower application rates, a reduced number of applications and a decreased need for herbicide combinations.

Graham Brookes and Peter Barfoot

GM Crops: The Global Economic and Environmental Impact - The First Nine Years 1996-2004

AgBioForum, Volume 8 // Number 2 & 3 // Article 15, 187-196, 2005

2005 represents the tenth planting season since genetically modified (GM) crops were first grown in 1996. This milestone provides the opportunity to critically assess the impact this technology is having on global agriculture. This study examines specific global economic impacts on farm income and environmental impacts of the technology with respect to pesticide usage and greenhouse gas emissions for each of the countries where GM crops have been grown since 1996. The analysis shows that there have been substantial net economic benefits at the farm level amounting to a cumulative total of $27 billion. The technology has reduced pesticide spraying by 172 million kg and has reduced the environmental footprint associated with pesticide use by 14%. The technology has also significantly reduced the release of greenhouse gas emissions from agriculture, which is equivalent to removing five million cars from the roads.

William M. Coli, Craig S. Hollingworth, James F. Dill, Alan T. Eaton, Heather Faubert, Lorraine M. Los

New England-wide Demonstration of an Integrated Pest Management (IPM) System for Apples and Consumer Education in IPM as a Pollution-prevention Strategy

Fruit Notes, 2005 ;

http://www.umass.edu/fruitadvisor/fruitnotes/a3-622.htm

Environmental Impact Quotient (EIQ).

Although each of the measures described above (i.e. numbers of sprays applied, dosage equivalents applied, and harvest residues) gives some information on potential reduction in environmental and other pollution, the actual measurement of such reductions is another matter. In addition to the fact that there is no agreement on the best techniques for measuring environmental impacts of pesticides, environmental testing of any sort is very expensive and demands the utmost care in sample collection and analysis….

….Hence, with all the provisions noted above, the EIQ for each of the blocks in our demonstration is presented. If nothing else, the EIQ numbers point out that IPM is not a "one size fits all" strategy, and that differences in pest pressure, environmental conditions, and grower management style often govern both the choice of pesticides and their application frequency.

For example, while fungicides contributed the largest portion of the EIQ number in five out of six IPM blocks, one site in New Hampshire, which used a new insecticide (imadacloprid) which is very safe to predator mites but highly toxic to bees, had a much higher insecticide/acaricide EIQ than any of the other blocks. This probably does not actually represent greater environmental damage, however, because imidacloprid is applied after petals have fallen, and bees are no longer foraging in fruit trees. Nonetheless, use of the material results in a substantially higher EIQ rating.

Total EIQ numbers ranged from as low at 50% of the comparison traditional block to as high as 87% of that block, once again pointing out the normal differences among blocks for reasons described above. Ideally, had it been possible to set up a comparison block in each state which would have been subjected to the same weather and pest pressure, such comparisons would have had a much stronger biological basis, and their validity would have been strengthened

USEPA, Pesticide Environmental Stewardship Program

Central Coast Vineyard Team's 2005 Strategy

http://www.epa.gov/oppbppd1/PESP/strategies/2005/ccvt05.htm

CCVT also used the Cornell Environmental Impact Quotient as a method to evaluate pesticide risk. The EIQ for a specific active ingredient is determined based on impact on beneficials, water quality, workers, food, etc. It represents a way to “weight” various active ingredients based on relative risk. The total risk is calculated by multiplying the pounds applied times the EIQ for a given active ingredient.

Average EIQ per acre for non-BIFS blocks increased from 90.46 to 154.49 from 2002 – 2004. This was 100 – 200% higher than the average EIQ per acre for their BIFS counterparts for the same period (Figure 6).

Throughout the project period, BIFS growers reduced their EIQ per block acre for FQPA I materials, while their non-BIFS grower increased their EIQ for FQPA I materials. For FQPA II materials, BIFS growers decreased their EIQ from 2003 to 2004 and the non-BIFS growers showed a steady increase over the three year period. In each case, BIFS growers had lower EIQ’s attributed to FQPA materials than the non-BIFS growers (Figure 8).

When considering specific materials, BIFS growers reduced their EIQ from FQPA I pre-emergent herbicides over the project period. This reduction can be attributed to reductions in the use of simazine and oryzalin. During the same period, use of oxyflourfen remained stable (Figure 9). These reductions can be attributed to reduced rates, reduced bandwidths, or elimination of the materials altogether.

BIFS growers also reduced their EIQ for FQPA I contact herbicides (paraquat dichloride) during the project, as opposed to the non-BIFS growers which increased their average EIQ for paraquat in each year (Figure 10). Again, these reductions can be attributed to fewer passes, reduced rates, mechanical cultivation/suckering, and use of non-FQPA I materials

Mealybug control generally drove high EIQ values because of the traditional treatments of chlorpyrifos and diazinon. For all but one BIFS block, EIQ for mealybug control reduced over the project period. In the case of CHA and CHB, they were not treating for mealybug by the end of the project. The most marked reductions in EIQ for mealybug control were for BNC, SJN, and WLF. In addition, BIFS blocks’ average EIQ decreased from 31 to 14 during the project period, as opposed to their non-BIFS counter parts which increased from 26 to 36 during the same period (Figure 11)

In each case, the reductions can be attributed to successful use of reduced risk materials (i.e., buprofezen and imidacloprid) and through improved monitoring and improved application timing. The mealybug issue provided excellent opportunities to share challenges and successes with mealybug control between BIFS growers and was an important factor in the successful adoption of reduced risk practices by other BIFS growers.

Univ. of California

Sustainable Agriculture Research and Education Program

http://www.sarep.ucdavis.edu/newsltr/v15n3/sa-8.htm

John Reganold, professor in the crop and soil sciences department at Washington State University, Pullman, discussed his work with organic, conventional and integrated apple production systems in Washington State, where he found the organic apples to be firmer and slightly sweeter than those produced in either the conventional or integrated systems. This multidisciplinary study included economists and engineers; the economists calculated the breakeven point for organic production at six to nine years, compared to eight to 15 years and nine to 17 years for conventional and integrated production, assuming a 50 percent price premium on the organic with the range related to the russetting challenges in all three systems. His study used the Environmental Impact Quotient developed at Cornell, and found that organic production had the lowest (best) score. The study combined all data collected, developed a sustainability ranking and found that organic production ranked first in environmental and economic sustainability, with integrated production second, and conventional third

Oliver G. G. Knox, Greg A. Constable , Bruce Pyke and V. V. S. R. Gupta
Environmental impact of conventional and Bt insecticidal cotton expressing one and two Cry genes in Australia
Australian Journal of Agricultural Research 57(5) 501–509, 2006

Abstract
Genetically modified Bt cotton, expressing the Cry1Ac protein for specific insecticidal activity against economically significant lepidopteran pests, has been available commercially in Australia since 1996. This technology has been improved and superseded by the addition of a second gene, allowing new varieties to express both the Cry1Ac the Cry2Ab proteins.

Bt cotton offers several advantages to the grower, mainly through reduced insecticide spray requirements. The environmental benefits of reduced insecticide usage are assessed in this paper using the environmental impact quotient (EIQ). The assessment included consideration of the impact of the expressed transgenic proteins Cry1Ac and Cry2Ab. EIQ values of the Cry1Ac and Cry2Ab proteins were calculated at 9.9 and 7.9, respectively. Bt protein expression, plant biomass, insecticide application records, constituent of active ingredient, and insecticide EIQ values were used to produce an environmental impact (EI) value for insecticide use (kg a.i./ha) for conventional non-GM and single- and 2-gene Bt cotton for the 1997–98 to 2003–04 seasons. Inclusion of the Cry proteins in the assessment increased the EI values for Bt cotton by only 2%. The average insecticide EI value, for 2002–03 and 2003–04 seasons, for conventional cotton was 135 kg a.i./ha, whereas for the 2-gene Bt variety it was only 28 kg a.i./ha. Results of the EI evaluation indicate that, due to changes in insecticidal choice and reduction in usage, there was a reduction of >64% in EI from growing Bt cotton compared with conventional non-GM cotton in Australia

BIOTECHNOLOGY FACTS,
Office of the United States Trade Representative, Feb. 2006

Pesticide Reduction: According to the National Center for Food and Agricultural Policy (NCFAP), adoption of biotech in the United States reduced pesticide use in crops in 2004 by 62 million pounds. This is an additional 15.6 million pounds in reduced pesticide use compared to 2003, and reflects a 34 percent increase in pesticide reduction. Further, according to ISAAA, the cumulative reduction in pesticides for the period 1996 to 2004 was estimated at 172,500 metric tons, which is the equivalent to a 14% reduction in the associated environmental impact of pesticide use on these crops, as measured by the Environmental Impact Quotient – a composite measure based on the various factors contributing to the net environmental impact of an individual active ingredient. http://www.isaaa.org/

Suwanna Praneetvatakul and Hermann Waibel
Farm Level and Environmental Impacts of Farmer Field Schools in Thailand
Working Paper No. 7, Development and Agricultural Economics, Faculty of Economics and Management, University of Hannover, Germany, 2006

Due to the pesticide reduction the two other parameters linked to pesticide use, i.e. farmer net benefit and EIQ also showed significant differences. The difference in the EIQ however is also influenced by a change in the type of pesticide used, i.e. FFS farmers after the training opted for less toxic pesticides.

Results show that farmers who participated in the Farmer Field School retain their knowledge and continue to practice improved IPM practices. Growth rates of pesticide expenditures and environmental impact are significantly reduced by the FFS training both in the short and long term. On the other hand farmers not trained in FFS tend to continue non-judicious ways of using chemical pesticides.

PA Apple and Peach Pest Management
http://paipm.cas.psu.edu/NewsReleases/applepeach.html
16 July 2006
“According to the Environmental Impact Quotient developed at Cornell University, the environmental impact of reduced risk IPM programs would be 5.3 times safer than the programs they are replacing.”

Gerald Chouinard
Organic vs Integrated Production of Apples in Northeastern North America: Measured Outcomes of Two Different Approaches for Reducing the Environmental Impact of Pesticides

In North America as in most other regions of the world, numerous policies aiming to reduce the use of pesticides were implemented in the past 20 years with variable success. Among encountered problems, the debatable choice of an indicator to measure the progress of these programs can be pointed out. We used data collected since 1977 in a series of apple orchards in Quebec, Canada as an example to demonstrate a decline of the environmental impact of spray programs used in this region against insects and mites. During this period, the average field value of the modified Environmental Impact Quotient (mEIQ) decreased by 66%. A decrease was not necessary noticed, however, when other indicators were used, or when comparing with simulated organic farming practices. mEIQ or other novel risk indicators are nevertheless useful tools to facilitate the classification of pesticide applications and to develop appropriate recommendations in apple IFP programs currently under development in Canada and elsewhere.

M. Alsheikh
Biotechnology as a tool for plant breeding
BIOINN Konferansen, Hamar, 2006
http://www.bioinn.no/sitefiles/10/dokumenter/pdf/Konferanser/2006/MuathAlsheikhBIOIINSept06.pdf

The presentation reported that biotechnology has resulted in:
- 14% decrease in environmental impact quotient (EIQ).
- 172,000 metric tons decrease in pesticide applications.

Treasury Board of Canada
Building Public Confidence in Pesticide Regulation and Improving Access to Pest Management Products
http://www.tbs-sct.gc.ca/rma/eppi-ibdrp/hrdb-rhbd/bpcpr-rcprp/2004-2005_e.asp

Comparison analysis of Environmental Impact Quotient (EIQ) and Norway indicator (v.2) based on Ontario data sent to Pest Management Advisory Council (PMAC), first draft of Canadian customization for human health component of pesticide risk indicator prepared.

Annex 2:

List of Pesticide Risk Indicator Models

(http://www.aftresearch.org/ipm/risk/)

- **CHEMS1** : The "Chemical Hazard Evaluation for Management Strategies" environmental indicator model utilizes a ranking methodology to calculate hazards to human health and the environment. The model considers the environmental impact of chemicals on air, soil, groundwater and surface water. When calculating environmental impact, this model takes into account preexisting levels of the chemical in the environment due to industrial uses.
- **EIQ** : The "Environmental Impact Quotient" environmental indicator relies on a ranking methodology to assess the environmental and health risks of a particular pesticide application scheme. This model uses toxicology data and chemical parameter information to calculate risk to farm workers, consumers and terrestrial organisms.
- **EPRIP** : Developed in Italy, the "Environmental Potential Risk Indicator for Pesticides" calculates a predicted environmental concentration in groundwater, surface water, soil, and air. This predicted environmental concentration is the level of the pesticide's active ingredient in the environment after application. Once calculated, the predicted environmental concentration is divided by toxicology information to arrive at a potential risk score.
- **EYP** : The "Environmental Yardstick for Pesticides" environmental indicator model calculates the predicted environmental concentration of a pesticide's active ingredient in surface water and soil. For groundwater concentrations, this Dutch model relies on either the PESTLA or PEARL leaching simulation program. Once calculated, these predicted environmental concentrations are divided by toxicology information to arrive at an "Environmental Impact Point" score.
- **MATF** : The "Multi-Attribute Toxicity Factor" environmental indicator model uses a modified ranking methodology to calculate toxicity factor values for acute mammalian risk, chronic mammalian risk, ecological impacts, and impacts on beneficial organisms. These toxicity factor values are based on human health risk data, toxicological data, and chemical parameter information. Once calculated, these toxicity factor values are multiplied by the application rate of the pesticide's active ingredient to arrive at final toxicity units. Researchers designed this model for Wisconsin potatoes as part of a collaborative effort between the University of Wisconsin, the Wisconsin Potato and Vegetable Growers Association, and the World Wildlife Fund (UW/WPVGA/WWF).
- **PERI** : The "Pesticide Environmental Risk Indicator" originated in Sweden. This model uses a ranking methodology to assess the environmental risk from pesticide applications for groundwater, surface water, and air. Researchers designed this model as part of a system of indicators that could be used by farmers to record and evaluate potential environmental risk over time as part of an ISO 14001 certification process.
- **SYNOPS_2** : This German environmental indicator model assesses the potential environmental risk of a pesticide application strategy. SYNOPS_2 calculates a predicted environmental concentration of a pesticide's active ingredient in soil, air, and surface water. This model also calculates a predicted environmental concentration for groundwater with the PELMO leaching program. For soil and surface water, these concentrations are then divided by toxicology information to arrive at a risk score.
- **SyPEP :** Belgian researchers developed the "System for Predicting the Environmental Impact of Pesticides" environmental indicator model. This model calculates a predicted environmental concentration of a pesticide's active ingredient in groundwater and surface water. Toxicology information is then divided by this predicted environmental concentration. The resulting value is ranked and classified as a "toxicity exposure ratio."

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