MGCSA Environmental Stewardship Supplemental Information

EIQ What Does It Mean?

A Method to Measure the Environmental Impact of Pesticide

Introduction and Background

For several years, increased attention has been focused on integrated pest management (IPM) programs and alternative methods of pest control to reduce pesticide use in agricultural systems because of food safety issues, groundwater contamination, and increased environmental awareness. By definition, IPM is a pest management strategy that uses a combination of methods (sampling, thresholds, forecasts, biological and cultural controls, etc.) to manage pests without solely relying on chemical pesticides to produce a safe, economic crop. If, however, no other control measure is effective in preventing pest damage, a chemical pesticide is recommended. In past IPM programs, pesticides were generally chosen based on their efficacy or cost rather than on their potential environmental impact. Although some growers and pest management practitioners did take into account the effect of the pesticides on the applicator or beneficial natural enemies such as predatory mites when making pesticide recommendations, no formal method was available to assist them in making environmentally based pesticide choices. Because there is no easy method to assess pesticide impacts, each individual had to rely primarily on their own judgment to make these decisions. Some growers (organically approved growers) felt that only natural pesticides should be used in agricultural production systems because they are naturally occurring and are perceived to be less harmful to the environment. Other growers felt that any pesticide registered by the United States Environmental Protection Agency (US EPA) and used according to the label must be environmentally safe. In addition, IPM programs throughout the country use various methods (number of sprays, the amount of active ingredient or formulated product used per acre, dosage equivalents, etc.) to quantify pesticide use and environmental impact to compare different pest management strategies or programs. None of these methods estimates the environmental impact of specific pesticides.

Because of the EPA pesticide registration process, there is a wealth of toxicological and environmental impact data for most pesticides that are commonly used in agricultural systems. However, these data are not readily available or organized in a manner that is usable to the IPM practitioner. Therefore, the purpose of this bulletin is 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. This bulletin presents a method to calculate the environmental impact of most common fruit and vegetable pesticides (insecticides, acaricides, fungicides and herbicides) used in commercial agriculture. 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.

Methods

Extensive data are available on the environmental effects of specific pesticides, and the data used in this project were gathered from a variety of sources. The Extension Toxicology Network (EXTOXNET), a collaborative education project of the environ-mental toxicology and pesticide education departments of Cornell University, Michigan State University, Oregon State University, and the University of California, was the primary source used in developing the database (Hotchkiss et al. 1989). EXTOXNET conveys pesticide-related information on the health and environmental effects of approximately 100 pesticides.

A second source of information used was CHEM-NEWS of CENET, the Cornell Cooperative Extension Network. CHEM-NEWS is a computer program maintained by the Pesticide Man-agement and Education Program of Cornell University that contains approximately 310 US EPA - Pesticide Fact Sheets, describing health, ecological, and environmental effects of the pesticides that are required for the reregistration of these pesticides (Smith and Barnard 1992).

The impact of pesticides on arthropod natural enemies was determined by using the SELCTV database developed at Oregon State (Theiling and Croft 1988). These authors searched the literature and rated the effect of about 400 agrichemical pesticides on over 600 species of arthropod natural enemies, translating all pesticide/natural enemy response data to a scale ranging from one (0% effect) to five (90-100% effect).

Leaching, surface loss potentials (runoff), and soil half-life data of approximately 100 compounds are contained in the National Pesticide/Soils Database developed by the USDA Agricultural Research Service and Soil Conservation Service. This database was developed from the GLEAMS computer model that simulates leaching and surface loss potential for a large number of pesticides in various soils and uses statistical methods to evaluate the interactions between pesticide properties (solubility, adsorption coefficient, and half-life) and soil properties (surface horizon thickness, organic matter content, etc.). The variables that provided the best estimate of surface loss and leaching were then selected by this model and used to classify all pesticides into risk groups (large, medium, and small) according to their potential for leaching or surface loss. Bee toxicity was determined using tables by Morse (1989) in the 1989 New York State pesticide recommendations, which contain information on the relative toxicity of pesticides to honey bees from laboratory and field tests conducted at the University of California, Riverside from 1950 to 1980. More than 260 pesticides are listed in this reference.

In order to fill as many data gaps as possible, Material Safety Data Sheets (MSDS) and technical bulletins developed by the agricultural chemical industry were also used when available.

Health and environmental factors that addressed some of the common concerns expressed by farm workers, consumers, pest management practitioners, and other environmentalists were evaluated and are listed in Figure 1 (1Mb pdf file). To simplify the interpretation of the data, the toxicity of the active ingredient of each pesticide and the effect on each environmental factor evaluated were grouped into low, medium, or high toxicity categories and rated on a scale from one to five, with one having a minimal impact on the environment or of a low toxicity and five considered to be highly toxic or having a major negative effect on the environment.

Figure I. A diagram showing the individual environmental factors that were evaluated in developing the environmental impact quotient of pesticides (EIQ) model.

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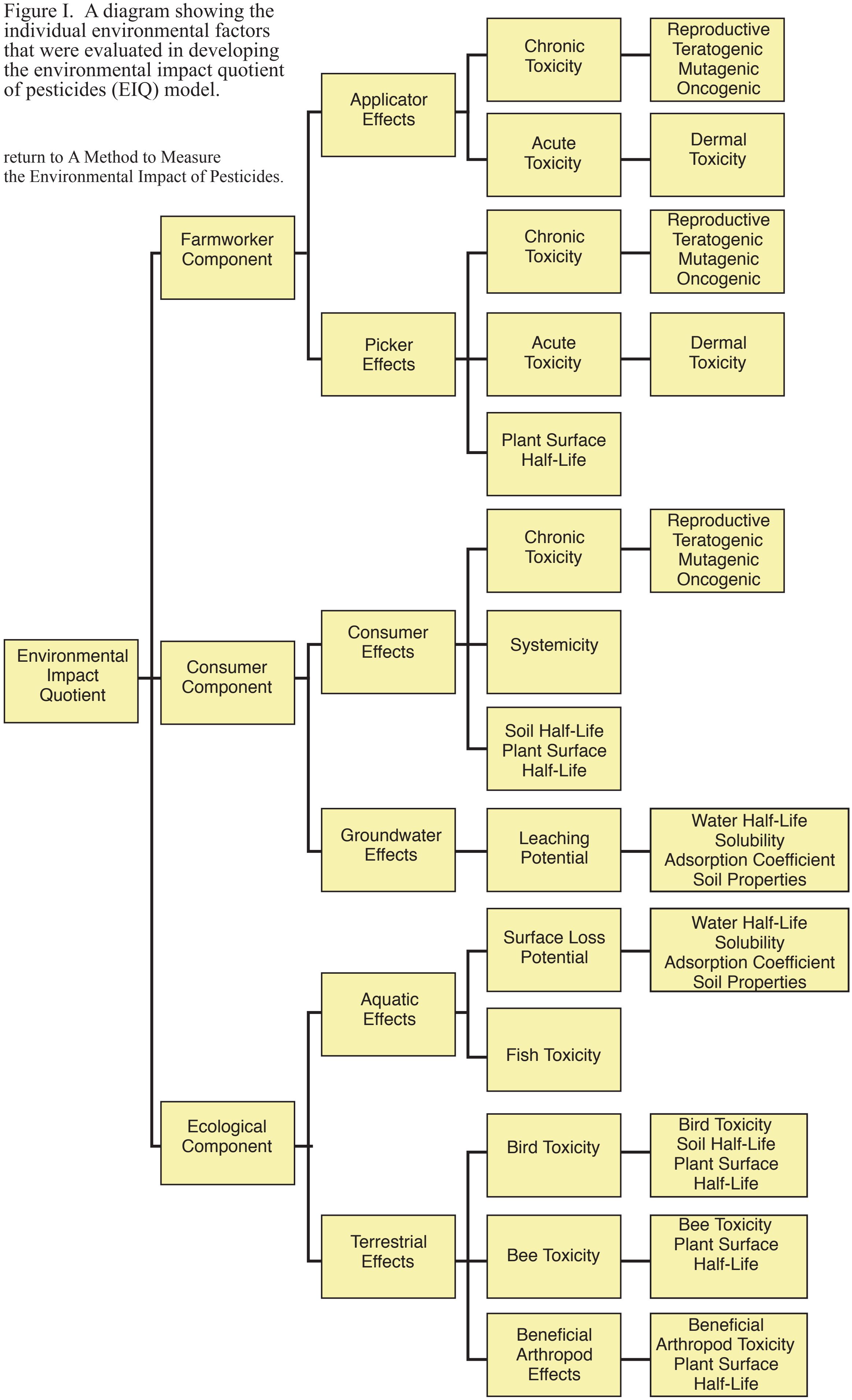

Table 1 lists the specific ratings for the individual factors evaluated. All pesticides were evaluated using the same criteria except for the mode of action and plant surface persistence of herbicides. Because herbicides are generally systemic in nature and are not normally applied to food crops we decided to consider this class of compounds differently, so all herbicides were given a value of one for systemic activity. This has no effect on the relative rankings within herbicides, but it does make the consumer component of the equation for herbicides more realistic. Also, since plant surface persistence is only important for post-emergent herbicides and not pre-emergent herbicides, all post-emergent herbicides were assigned a value of three and pre-emergent herbicides assigned a value of one for this factor.

Table l. The rating system used to develop the environmental impact quotient of pesticides (EIQ) model. l = least toxic or least harmful, 5 = most toxic or harmful.

Mode of Action non-systemic- 1 all herbicides - 1 systemic - 3	**Toxicity to Fish-96 hr LC50** > 10 ppm - 1 1-10 ppm - 3 < 1 ppm - 5
Acute Dermal LD50 for Rabbits/Rats(m&/kg) >2000 - 1 200 - 2000 - 3 0 - 200 - 5	**Toxicity to Birds-8 day LC50** > 1000 ppm - 1 100-1000 ppm - 3 1-100 ppm - 5
Long-Term Health Effects little or none - 1 possible- 3 definite - 5	**Toxicity to Bees** relatively nontoxic - 1 moderately toxic - 3 highly toxic - 5
Plant Surface Residue Half-life l-2 weeks- 1 2-4 weeks- 3 > 4 weeks - 5 pre-emergent herbicides - l post-emergent herbicides - 3	**Toxicity to Beneficials** low impact- 1 moderate impact - 3 severe impact - 5
Soil Residue Half-life Tl/2 <30 days - 1 Tl/2=30-100 days - 3 Tl/2 >100 days - 5	**Groundwater and Runoff Potential** small - 1 medium - 3 large -5

In order to further organize and simplify the data, a model was developed called the environmental impact quotient of pesticides (EIQ). This model reduces the environmental impact information to a single value. To accomplish this, an equation was developed based on the three principal components of agricultural production systems: a farm worker component, a consumer component, and an ecological component. Each component in the equation is given equal weight in the final analysis, but within each component, individual factors are weighted differently. Coefficients used in the equation to give additional weight to individual factors are also based on a one to five scale. Factors carrying the most weight are multiplied by five, medium-impact factors are multiplied by three, and those factors considered to have the least impact are multiplied by one. A consistent rule throughout the model is that the impact potential of a specific pesticide on an individual environmental factor is equal to the toxicity of the chemical times the potential for exposure. Stated simply, environmental impact is equal to toxicity times exposure. For example, fish toxicity is calculated by determining the inherent toxicity of the compound to fish times the likelihood of the fish encountering the pesticide. In this manner, compounds that are toxic to fish but short-lived have lower impact values than compounds that are toxic and long-lived.

The EIQ Equation

The formula for determining the EIQ value of individual pesticides is listed below and is the average of the farm worker, consumer, and ecological components.

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

DT = dermal toxicity, C = chronic toxicity, SY = systemicity, F = fish toxicity, L = leaching potential, R = surface loss potential, D = bird toxicity, S = soil half-life, Z = bee toxicity, B = beneficial arthropod toxicity, P = plant surface half-life.

Farm worker risk is defined as the sum of applicator exposure (DT* 5) plus picker exposure (DT*P) times the long-term health effect or chronic toxicity (C). Chronic toxicity of a specific pesticide is calculated as the average of the ratings from various long-term laboratory tests conducted on small mammals. These tests are designed to determine potential reproductive effects (ability to produce offspring), teratogenic effects (deformities in unborn offspring), mutagenic effects (permanent changes in hereditary material such as genes and chromosomes), and oncogenic effects (tumor growth). Within the farmworker component, applicator exposure is determined by multiplying the dermal toxicity (DT) rating to small laboratory mammals (rabbits or rats) times a coefficient of five to account for the increased risk associated with handling concentrated pesticides. Picker exposure is equal to dermal toxicity (DT) times the rating for plant surface residue half-life potential (the time required for one-half of the chemical to break down). This residue factor takes into account the weathering of pesticides that occurs in agricultural systems and the days to harvest restrictions that may be placed on certain pesticides.

The consumer component is the sum of consumer exposure potential (C*((S+P)/2)*SY) plus the potential groundwater effects (L) . Groundwater effects are placed in the consumer component because they are more of a human health issue (drinking well contamination) than a wildlife issue. Consumer exposure is calculated as chronic toxicity (C) times the average for residue potential in soil and plant surfaces (because roots and other plant parts are eaten) times the systemic potential rating of the pesticide (the pesticide's ability to be absorbed by plants).

The ecological component of the model is composed of aquatic and terrestrial effects and is the sum of the effects of the chemicals on fish (F*R), birds (D*((S+P)/2)*3), bees (Z*P*3), and beneficial arthropods(B*P*5). The environmental impact of pesticides on aquatic systems is determined by multiplying the chemical toxicity to fish rating times the surface runoff potential of the specific pesticide (the runoff potential takes into account the half-life of the chemical in surface water).

The impact of pesticides on terrestrial systems is determined by summing the toxicities of the chemicals to birds, bees, and beneficial arthropods. Because terrestrial organisms are more likely to occur in commercial agricultural settings than fish, more weight is given to the pesticidal effects on these terrestrial organisms. Impact on birds is measured by multiplying the rating of toxicity to birds by the average half-life on plant and soil surfaces times three. Impact on bees is measured by taking the pesticide toxicity ratings to bees times the half-life on plant surfaces times three. The effect on beneficial arthropods is determined by taking the pesticide toxicity rating to beneficial natural enemies times the half-life on plant surfaces times five. Because arthropod natural enemies spend almost all of their life in agroecosystem communities (while birds and bees are somewhat transient), their exposure to the pesticides, in theory, is greater. To adjust for this increased exposure, the pesticide impact on beneficial arthropods is multiplied by five. Mammalian wildlife toxicity is not included in the terrestrial component of the equation because mammalian exposure (farm worker and consumer) is already included in the equation, and these health effects are the results of tests conducted on small mammals such as rats, mice, rabbits, and dogs.

After the data on individual factors were collected, pesticides were grouped by classes (fungicides, insecticides/miticides, and herbicides), and calculations were conducted for each pesticide. When toxicological data were missing, the average for each environmental factor within a class was determined, and this average value was substituted for the missing values. Thus, missing data did not affect the relative ranking of a pesticide within a class. Table 2 lists over 120 pesticides by chemical class, fungicides, insecticides/miticides, and herbicides.

Table 2: List of Pesticides

http://www.nysipm.cornell.edu/publications/EIQ/files/EIQ_values_2012entire.pdf

http://www.nysipm.cornell.edu/publications/EIQ/files/EIQ_values_2012fung.pdf

http://www.nysipm.cornell.edu/publications/EIQ/files/EIQ_values_2012herb.pdf

http://www.nysipm.cornell.edu/publications/EIQ/files/EIQ_values_2012insect.pdf

The values of individual effects of each pesticide (applicator, picker, consumer, groundwater, aquatic, bird, bee, beneficials), the major components of the equation (farm worker, consumer, and ecological) and the average EIQ values are presented in the tables. The tables also include the factors in the evaluation process that contained missing data. Less confidence should be placed on the EIQ values of pesticides that have many data gaps and more confidence placed on EIQ values with few or no data gaps. Using the tables, comparisons of environmental toxicity of a given weight (pounds, grams, etc.) of the individual active ingredients can be made within a class of compounds. Field comparisons should not be made with these data. Other considerations, such as the percent of active ingredient in a formulated product and the dose required to provide control, need to be assessed before the desirable or least toxic pesticide choice can be made in the field.

EIQ Field Use Rating

Once an EIQ value has been established for the active ingredient of each pesticide, field use calculations can begin. To accurately compare pesticides and pest management strategies, the dose, the formulation or percent active ingredient of the product, and the frequency of application of each pesticide need to be determined. To account for different formulations of the same active ingredient and different use patterns, a simple equation called the EIQ Field Use Rating was developed. This rating is calculated by multiplying the EIQ value for the specific chemical obtained in the tables by the percent active ingredient in the formulation by the rate per acre used (usually in pints or pounds of formulated product).

EIQ Field Use Rating = EIQ x % active ingredient x Rate

With this method, comparisons of environmental impact between pesticides and different pest management programs can be made. For example, if several pesticides can be used against a particular pest, which pesticide is the least toxic choice? Table 5 shows an example comparing the environmental impact of three insecticides: carbaryl (Sevin 50WP), endosulfan (Thiodan 50WP), and azinphos-methyl (Guthion 35WP). Although carbaryl has a lower EIQ (22.6) than endosulfan (40.5) or azinphos-methyl (43.1), it may take more of it to provide equivalent control. For example, 6 lbs/acre of Sevin may provide the same level of control of a certain pest as 3 lbs/acre of Thiodan or 2.2 lbs/acre of Guthion. In this situation, Guthion would have the lowest EIQ Field Use Rating (33 .2) and would be the least toxic choice. Thiodan (60.8) would be the second choice and Sevin (67.8) would be the last.

By applying the EIQ Field Use Rating, comparisons can be made between different pest management strategies or programs. To compare different pest management programs, EIQ Field Use Ratings and number of applications throughout the season are determined for each pesticide. and these values are then summed to determine the total seasonal environmental impact of the particular strategy. Table 6 compares the theoretical environmental impact of several different pest management approaches that have been used in research projects to grow 'Red Delicious' apples in New York. In this example, a traditional pest management approach to growing 'Red Delicious' apples that does not rely heavily on pest monitoring methods would result in a total theoretical environmental impact of 938 due to pesticides. An IPM approach that incorporates pest monitoring methods, biological control, and least toxic pesticides would have an environmental impact of only 167. The organic pest management approach, which uses only naturally occurring pesticides, would have a theoretical environmental impact of 1,799 according to the model. The environmental impact of the latter approach is so much larger than the other strategies primarily due to the larger quantities of sulfur required and more frequent applications needed to provide the same level of control of apple scab in this variety. By using the EIQ model, it becomes possible for IPM practitioners to rapidly estimate the environmental impact of different pesticides and pest management programs before they are applied, resulting in more environmentally sensitive pest management programs being implemented.

Table 3. An example showing the EIQ field use rating of three different insecticides to determine which pesticide should be the least toxic choice.

Material	EIQ	ai	Rate	EIQ field use rating
Sevin 50WP (carbaryl)	22.6	0.50	6.0	67.8
Thiodan 50WP (endosulfan)	40.5	0.50	3.0	60.8
Guthion 35WP (azinphos-methyl)	43.1	0.35	2.2	33.2

Table 4. Theoretical environmental impact of different pest management strategies used to grow 'Red Delicious' apples in New York. Traditional Pest Management Strategy

Traditional Pest Management Strategy					
Material	**EIQ**	**ai**	**Dose**	**Applications**	**Total**
Rubigan EC	27.3	0.12	0.6	4	8
Captan 50WP	28.6	0.50	3.0	6	257
Lorsban 50WP	52.8	0.50	3.0	2	158
Thiodan 50WP	40.5	0.50	3.0	2	61
Guthion 35WP	43.1	0.35	2.2	2	66
Cygon 4E	74.0	0.43	2.0	3	191
Omite 6EC	42.7	0.68	2.0	2	116
Kelthane 35WP	29.9	0.35	4.5	1	47
Sevin 50WP	22.6	0.50	1.0	3	34
Total Environmental Impact					938
Integrated Pest Management (IPM) Strategy					
Material	**EIQ**	**ai**	**Dose**	**Applications**	**Total**
Nova 40WP	41.2	0.40	0.3	4	20
Captan 50WP	28.6	0.50	3.0	1	43
Dipel 2X	13.5	0.06	1.5	3	4
Sevin 50WP	22.6	0.50	3.0	1	34
Guthion 35WP	43.1	0.35	2.2	2	66
Total Environmental Impact					167
Organic Pest Management Strategy					
Material	**EIQ**	**ai**	**Dose**	**Applications**	**Total**
Sulfur	45.5	0.90	6	7	1720
Rotenone/pyrethrin	25.5	0.04	12	6	73
Ryania	55.3	0.001	58	2	6
Total Environmental Impact					1720

Conclusion

The Environmental Impact Quotient has been used to organize the extensive toxicological data available on some common fruit and vegetable pesticides into a usable form for field use. It addresses a majority of the environmental concerns that are encountered in agricultural systems including farm worker, consumer, and wildlife, health, and safety. By using the EIQ Field Use Rating, IPM practitioners and growers can incorporate environmental effects along with efficacy and cost into the pesticide decision-making process. IPM programs can also use the EIQ model as another method to measure the environmental impact of different pest management and pesticide programs. As newer biorational pesticides are marketed with lower EIQ values and more emphasis is placed on biologically based IPM practices, the EIQ field use ratings will continue to decrease. Eventually these ratings may approach zero, resulting in an environmentally neutral or benign agricultural production system.

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The EIQ Calculator:

http://nysipm.cornell.edu/EIQCalc/input.php?cat=3

The MGCSA acknowledges with great appreciation the information shared upon the Cornell University Integrated Pest Management Program website. www.nysipm.cornell.edu/publications/EIQ/conclusions.asp