METHODOLOGY OF AN IPM IMPACT ASSESSMENT: DEVELOPMENT AND APPLICATION OF A PROTOCOL IN MICHIGAN TART CHERRIES

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By

Mollie B. Williams

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ABSTRACT

METHODOLOGY OF AN IPM IMPACT ASSESSMENT:
DEVELOPMENT AND APPLICATION OF A PROTOCOL
IN MICHIGAN TART CHERRIES

By

Mollie B. Williams

An integrated pest management (IPM) impact assessment protocol was applied to the IPM program for tart cherries in Northwest Lower Michigan. Four pest management scenarios were developed for typical tart cherry growers in the region, the level of adoption of each of the scenarios was determined, and the profitability and environmental and human health effects from adoption of each of the scenarios was assessed. Data was collected through personal interviews with IPM specialists in tart cherries in the Northwest Lower Michigan region and using secondary data sources. Analysis of the different pest management scenarios revealed that a moderate amount of IPM adoption yielded the best profitability and environmental and human health results. The analysis highlighted the usefulness of the protocol as an IPM assessment tool and emphasized key areas where improvements in the protocol could be made, namely in improving the methods of data collection.

This paper is dedicated to my husband, Stephen, whose patience, kindness, and understanding were so essential to its completion. Thank you, Stephen, for all your support and love. To my parents, Larry and Judith, who are always teaching me new things about the world and giving me new perspectives each and every day.

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Chapter 1:

Introduction

IPM and the Need for Impact Assessment

Integrated pest management (IPM) is a pest management system promoted by many public and private organizations in the United States. The U.S. Agricultural extension system actively supports IPM projects in a variety of applications (Napit et al., 1988) and private businesses, such as Gerber Foods, also encourage IPM adoption. Proponents of IPM base their support on the assumptions that IPM practices improve farm level profitability, or that they reduce negative impacts on the environment and human health, or both.

While expert on-farm knowledge, or in some cases, just common sense, suggests that IPM practices may reduce the incidence of negative environmental and human health consequences, measurement of the outcomes from IPM adoption in much research is lacking or nonexistent. Adoption of IPM does not imply that producers will always move away from practices with the most negative environmental and human health impacts. Rather, IPM adoption implies that producers will use a variety of information sources to make decisions which are usually trade-offs between profitability and human health and environmental effects.

The effects of IPM adoption are of particular concern to the groups supporting it and to the public. IPM practices are adopted with the expectations that the practices are more biologically and environmentally sound than some alternative practices and at the same time are equally, or almost equally, as profitable and efficacious. The economic effects of a number of different IPM practices are well documented (Norton and Mullen, 1992). The environmental and human health effects of IPM adoption have been considered in some depth as well (Levitan et al., 1992). Nonetheless, few studies consider the impacts of IPM adoption on all three factors.

In 1994, Vandeman et al. published a study that measured the adoption of IPM across many commodities throughout the U.S. (1994). This study was highly criticized for two reasons. First, many groups (e.g. Benbrook et al., 1996; Steffey, 1995) argued that the definition of IPM used was too broad and that some practices used in the definition should be included in the conventional group of practices, not the IPM group. Second, while the study collected data on the practices being used and the number of producers using them, these data said nothing of the impacts of IPM adoption on the two areas of major public concern, human health and the environment, or on private profitability, a concern for growers who use IPM.

Study Objectives

The objective of this study is to test a set of IPM assessment protocols. The protocols outline the basic data requirements, and methods, for assessment of the many publicly funded IPM programs in the U.S. The data collected and quality of information provided through the use of the protocols will be used to further refine the protocols so that they may be applied as assessment tools to existing and future IPM programs.

The IPM assessment protocols were developed by a multi-disciplinary group of scientists at Michigan State University, Cornell University, Virginia Polytechnic University, and the Economic Research Service of the U.S. Department of Agriculture (ERS). They were designed to guide researchers in the IPM field as they attempt to design projects with built-in assessment features. The protocols are also important as they will make clearer to the public and to policy makers the process by which IPM adoption and the effects of its adoption on private and social profitability, human health, and environmental quality, are measured.

The goals of this project are: 1) to review IPM assessment methods currently used by researchers and outreach specialists, 2) to introduce the set of protocols to be tested, 3) to test the new protocols on an existing IPM outreach program, and 4) to provide suggestions on how the protocols can be improved.

The IPM Assessment Protocols

The assessment protocols were developed by a multi-disciplinary group of scientists from the agricultural, environmental, and human health fields. The final protocol is divided into two sections, basic and in-depth. The two sections are meant to be used independently and the choice of which to use is based largely on the resources available to the researcher performing the analysis, the stage of the program being assessed, and the pool of users to be sampled. A description of the two sections of the protocol is provided in chapter 3.

The assessment protocol was applied to the existing IPM program in tart cherries in Northwest Lower Michigan. Chapter 4 provides a detailed description of the IPM program that was assessed. Chapter 5 presents the methodology used for the economic, environmental, and human health assessment and the results of the assessment. Chapter 6 presents important conclusions from the study and suggestions on how the assessment protocol could be improved.

IPM and Michigan Tart Cherries

The assessment protocol was tested in an application to tart cherries in Northwest Lower Michigan. Tart cherries were chosen as a case study for the reasons outlined below.

Tart cherries are an important fruit crop in Michigan. In 1998, 75 percent of all tart cherry production for processing in the U.S. was from Michigan tart cherry growers (USDA, 1999). This number makes tart cherries an ideal candidate for this study since practices used by tart cherry growers in Michigan will also represent those used by the majority of the growers in the industry. Over 50% of all tart cherry acreage in Michigan is located in the Northwestern region of the lower peninsula of Michigan, specifically, in Antrim, Benzie, Grand Traverse, Leelanau, and Manistee counties (MASS, 1999). This study will focus on Northwest Lower Michigan because of the concentration of production in the region and because growers in this region use a wide range of practices that fit into all levels of IPM (Nugent and Thornton, 1999).

There were 33,500 bearing acres of tart cherries in Michigan in 1999 and 17,000 in the Northwest region (MASS, 1999). Historically, a very high percentage of tart cherry acres in Michigan receive some pesticide applications (MASS, 1998). IPM is one method promoted in Michigan to address many of the concerns about impacts from pesticide use.

A formal program to introduce tart cherry growers in Northwestern Michigan to IPM practices began in the early 1980s and continues today (Nugent and Thornton, 1999). The Michigan State University Extension Service administers nearly all of the IPM programs meant to reach tart cherry growers in Northwest Lower Michigan. Besides testing the assessment protocol and assessing the impacts of IPM adoption in tart cherries, a secondary, but important, goal for this paper is to provide some insight into the effectiveness of the IPM program in the Northwestern region in terms of adoption rates for certain practices, and the impacts of those practices, to extension specialists.

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Chapter 2:

Review of Literature on IPM Impact Assessment[1]

Introduction

Integrated pest management (IPM) has been heralded as a means to enhance agricultural profits and human living conditions while reducing pesticide risks to human health and the natural environment. During the past two decades, government programs in the United States and elsewhere have sought to encourage adoption of IPM methods. These programs have expanded recently in tandem with policies designed to reduce human exposure to pesticide risks (notably the U.S. Federal Insecticide, Fungicide and Rodenticide Act as amended in 1988 and the Food Quality Protection Act of 1996). In 1993, Vice President Al Gore pledged that the United States would achieve adoption of IPM on 75% of its agricultural land by the year 2000.

The expansion of government-supported IPM programs has been followed by a call for accountability:

- Have the programs met their goals?
- Have they in fact boosted producer incomes?
- Have they in fact reduced risks to human health and the natural environment?

This chapter catalogues prior efforts to assess the economic impacts of IPM. Although urban uses of IPM are proliferating the focus here is on agriculture. The chapter begins by

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[1]This chapter was written jointly by Dr. Scott Swinton and myself and was submitted for publication to *Agriculture, Ecosystems, and Environment* in May 1998. The content of this chapter benefitted greatly from discussion with Drs. George Norton, Susan Riha, and Lois Levitan.

defining IPM. It proceeds to examine the IPM impacts that have been measured and to evaluate the methods used for measurement. The conclusion considers criteria for designing assessment tools that are practical for government IPM projects and programs of different sizes and designs.

Defining IPM

Any successful assessment must begin from a clear definition of what is being assessed. IPM has been defined many ways since the idea was first introduced by Stern et al. (1959). Broadly speaking, the definitions of IPM may be classified as either input- or outcome-oriented. Input-oriented definitions specify IPM practices, whereas outcome-oriented definitions focus on desired results from IPM.

Input-oriented definitions

Input-oriented definitions of IPM relate to the type(s) of pest management practice used. Table 2.1 conveys several examples of input-oriented definitions. Pest management practices can be broadly classified as biological, chemical, or cultural in nature (Stern et al., 1959). Chemical pest management, of course, centers on the use of pesticides. Biological pest management practices include the use of predators, parasites and allelopathic plants to control or deter pests (National Research Council, 1996). Cultural management of pests includes such practices as tillage, timing of planting or harvest, planting density and spacing. Growers typically combine more than one approach to pest management. The advent of biotechnology has intensified the mixing of approaches, as plants are bred to incorporate natural toxins or tolerance to herbicides.

Input oriented definitions of IPM are useful for identifying IPM practitioners and measuring how much IPM they practice. Measures of numbers of farmers using at least one IPM practice have been used to estimate the aggregate level of adoption of IPM (e.g., Vandeman et al., 1994) as well as to explain what factors affect adoption. In the past decade, with sharp increases in both consumer concern about pesticides and the number of farmers practicing some form of IPM, the measurement focus has shifted from a quantitative count of "whether IPM" to a qualitative measure of "how and how much IPM." This shift is exemplified by the IPM continuum developed at World Wildlife Fund (Hoppin, 1996) to characterize IPM use on a scale from no IPM to chemical-based IPM to biointensive IPM (Benbrook et al., 1996). On this scale, higher level measures of IPM are associated with less reliance on chemical inputs and more reliance on information, cultural and biological inputs.

Input-oriented definitions of IPM have gained acceptance in many programs that either promote the adoption of IPM or else certify whether IPM practices are being followed. Massachusetts and New York have developed statewide IPM programs that provide IPM certification for many crops. Both programs rely on sets of practices related to management of insects, weeds, diseases, nematodes, record-keeping, and IPM education. A specific level of adoption is required for IPM certification. Such certifications can be used by growers for eco-labeling programs intended to communicate food production information to consumers (Vickery, 1997).

Grower associations and environmental groups have also developed guidelines for production practices that qualify as IPM. These guidelines cover much the same ground as the state IPM certification programs, although commodity grower associations, for example, will tailor the guidelines to pest management in their specific crops (e.g., cotton or potato). In some cases, the guidelines allow calculation of a total score that can be interpreted as a measure of how much IPM is being used. Such measures provide growers with a useful benchmark.

For the purpose of assessing the impact of public programs, input-oriented definitions suffer two important drawbacks. First, they tend to evolve over time with technology standards. The kind of pesticide-based economic thresholds proposed by Stern et al. in 1959 are viewed as very limited by contemporary observers such as Hoppin (1996) and Benbrook et al. (1996). A more important drawback of input-oriented definitions is that they ignore the fact that IPM is a means to one or more ends. To ignore the ends is to ignore the fundamental reasons or adopting IPM.

Outcome-oriented definitions of IPM

While input oriented definitions of IPM are useful for measuring whether and how much IPM is used, they do not address the outcomes of IPM use. Yet expected outcomes of reduced environmental risk and enhanced profits are the chief justifications of public research and outreach on IPM.

Outcome-oriented definitions of IPM relate broadly to profitability, human health, and environmental quality (Table 2.2). Although the definition of IPM used by Stern et al. in 1959 focused on input use (Table 2.1), it was designed around the concept of an economic injury level (EIL, discussed below), which is inherently an outcome-oriented measure of expected profitability. Since that time, outcome-oriented definitions have evolved in domain of applicability (from agricultural crops only to livestock to urban settings) as well as in the kinds of outcomes. Profitability has played a role since the beginning, including measures of average profitability and risk to profitability from employing some IPM practice (Stern et al., 1959; Taylor & Lacewell, 1977; Klein et al., 1990; Ward et al., 1990). Profitability impacts have been the primary outcome of concern for two reasons. First, profitability impacts are a major concern to farmers adopting IPM. Second, compared with environmental and health impacts, impacts on profitability are easier to measure.

The leading outcome-oriented measure of average (expected) profitability has been the economic injury level (EIL). The EIL measures the pest density at which management costs equal actual and potential costs from pest damage, contingent upon crop prices and a projected crop damage response function (Pedigo et al., 1986). Beyond the EIL, pest control is expected to enhance profits. While many elaborate and specialized EIL's have been developed, the basic logic behind them remains the same.

Apart from average profitability, an important subcategory of outcome-oriented definitions embrace stability of profits under IPM. Producers are concerned both with whether or not a practice is profitable, but also with the level of risk that it will not be profitable (Lazarus and Swanson, 1983; Deen et al, 1993; Swinton & King, 1994). Risk-efficient EIL's have been proposed to accommodate variability of profits under IPM (Lazarus and Swanson, 1983; Moffitt et al., 1984; Osteen et al., 1988).

During the 1990's a growing number of IPM definitions have emphasized environmental and health outcomes. Most of these are general, admitting various outcome measures of, e.g., "economic, public health, and environmental goals" (Cate and Hinkle, 1993). Others specifically allude to measurement criteria, such as reduced reliance on chemical pesticides (Kovach et al., 1992; Benbrook et al., 1997).

What Definition for Public Policy?

For public policy purposes, an acceptable definition of IPM should address pest management issues of concern to society as a whole in addition to those of growers. It should also permit measurement of degree of IPM use. And it should encourage innovation toward safer, sounder pest management practices.

In general, input-oriented definitions fail to meet the needs of policy makers for three reasons. First, they do not address the many consumer concerns about impacts of IPM on the environment and human health. Second, national input-oriented definitions of IPM are impractical, as regional variations between areas producing similar products make patterns and form of IPM adoption quite variable. In some areas, national guidelines might be too stringent, while in others, guidelines might be considered conventional practice. Third, input-oriented IPM definitions – like the use of input standards in general for managing environmental problems – are allocatively inefficient, in that they do not encourage producers to adopt the most cost-effective practice (Segerson, 1988).

Outcome-oriented definitions of IPM are better suited to public policy than input-oriented ones. Outcome-oriented IPM definitions directly address the issues which concern the public, and hence policy makers. Broad outcome-oriented definitions of IPM accommodate flexible, cost-effective adoption of IPM. Outcome-oriented IPM definitions also overcome the uncertainty over the relationship between IPM practices and impacts.

With these points in mind, a working definition of IPM for assessment of public programs should have three essential qualities. First, it should embody the key outcomes that justified initiation of the public program. Second, it should characterize those outcomes in a fashion that can be measured with relative ease and a minimum of subjectivity, along a continuum or in levels (Norton et al., 1996). Third, it should encourage continual improvement. A proposed working definition of IPM for public program assessment is:

> *Compared with conventional pest management practices, IPM reduces risk to human health and environmental quality without seriously compromising normal producer profitability and security against the risk of financial loss.*

This definition intentionally includes the benchmark term "conventional," recognizing that conventional practice evolves: Pest management practices that were considered IPM practices at one time will become conventional, while new IPM practices (or lately "integrated crop management" practices) will become the risk-reducing IPM alternatives.

Measurement of IPM

Successful program assessment methods build from desired outcomes a set of objectively measurable attributes. How outcomes are measured is always important, but it is especially so when key variables are not directly observable and must be measured by proxy. With this in mind, we survey prior efforts to measure impacts of IPM for the three main outcome areas identified above: profitability, human health and environmental quality. Because the large number of studies on profitability divide between those that consider profitability risk and those that focus exclusively on expected profits, we divide the profitability measures accordingly.

Profitability I: Expected profit

The largest group of IPM economic impact assessments use some measure of expected profit, that is the mean profit that could be expected in a typical year. Various measures of expected profit are used. Some studies use gross revenue minus the costs of IPM adoption ("gross margin over pest management cost"), while others include additional production costs ("gross margin over variable costs" or "gross margin over specified costs"). A very few studies go beyond the individual firm to measure IPM impacts on social welfare, a special case of aggregate profitability using producer and consumer surplus. Table 2.3 summarizes the treatment of profitability in the studies examined.

Of the 28 studies examined that measured profitability impacts, 22 measured gross margin over pest control costs, and only six used gross margin over a wider set of production costs. Of these six, three included costs arising from the health impacts of pesticide use (Antle & Pingali, 1994; Pingali et al., 1994 Crissman et al., 1998), one included averting expenditures to reduce exposure to pesticides (e.g., safety equipment; Harper and Zilberman, 1992), and two included variable production costs in addition to pest management costs (Boggess et al., 1985; Napit et al., 1988).

Three studies examined the social welfare impacts of IPM adoption using changes in producer and consumer surplus. Klein et al.(1990) addressed the impacts of an intensive program to manage cattle grubs in Alberta, Canada. Impacts on social welfare were measured in terms of the damages avoided due to the eradication program minus the costs of administering the program. Taylor and Lacewell (1977) measured changes in regional consumer and producer surplus resulting from a boll weevil eradication program for fourteen southern states. Napit et al. (1988) measured the changes in producer and consumer surplus due to the effects on net returns of adoption of specific IPM practices in numerous states.

Measurement of expected profitability affects comparability of results across studies. Proxy variables for profitability in IPM impact assessment are gross margin over variable pest management costs and gross margin over selected production costs. Potential limitations of these approaches come from 1) improper cost accounting, and 2) dynamic adjustment effects. Incomplete measurement of added labor and management costs is the leading cost accounting problem (see, e.g., Hara, 1990). Gross margins may also fail to measure fully the costs of adjustment and final equilibrium conditions when pest systems take more than two to three years to adjust to a steady state. One important dynamic profitability impact that has been omitted from many studies is the effect of pesticide management on pest development of genetic pesticide resistance (Higley et al., 1992).

Profitability II: Risk

Most information-based IPM methods pick a control measure based on *expected* pest damage. But pest damage is somewhat unpredictable, so many studies have attempted to measure the impact of IPM on the variability of farm profits. Two general approaches have been used to measuring profitability risk. One is to develop a money-based measure of risk. This can be done if the decision maker's attitude toward risk is assumed to be known, so a risk-weighted "expected utility function" can be calculated. The second, more common approach, has been to use risk efficiency criteria which pertain to large categories of decision makers with common general attitudes toward profitability risk. Efficiency criteria allow for a partial ranking of choices or outcomes given certain constraints on the preferences of the decision maker and, in some cases, the probability distributions of alternative outcomes (Barry, 1984). The three efficiency criteria applied in most of the articles examined here were first-degree stochastic dominance (FSD), which ranks technologies according to profitability across many different production conditions; second-degree stochastic dominance (SSD), which ranks technologies according to profitability and outcomes under the least profitable conditions; and mean-variance (E-V) dominance (discussed below). Coefficients of variation were also used to measure profitability risk in the studies listed in Table 2.4.

Seven of the seventeen studies listed in Table 4 used FSD and SSD (Musser et al., 1981; McGuckin, 1983; Moffitt et al., 1983; Boggess et al., 1985; Deen et al., 1993; Swinton and King, 1994) or else generalized stochastic dominance (Greene et al., 1985). Two other studies used expected utility functions to develop a money measure of utility (Liapis and Moffitt, 1983; Swinton and King, 1994).

Mean-variance dominance is the other efficiency criterion widely used in the studies reviewed (Table 4). Mean-variance dominance is defined such that, given an outcome with mean (E) and variance (V), that outcome dominates another outcome with mean (E') and variance (V') so long as $E \geq E'$ and $V \geq V'$, and at least one of these relationships holds as a strict inequality (Barry, 1984). In all, ten studies used mean-variance dominance to compare alternative outcomes under uncertainty (Musser et al., 1981; Lazarus and Swanson, 1983; Moffitt et al, 1984; Napit et al., 1988; Osteen et al., 1988; Harper and Zilberman, 1992; Antle and Pingali, 1994; Swinton and King, 1994; Yu et al., 1994; Crissman et al., 1998). As indicated in the table, some studies used more than one measurement technique.

Environmental Impacts

Environmental impacts of IPM and other pest management practices touch upon a wide range of environmental media. In assessments of environmental risk, impact measures are almost exclusively mean values, such as the concentration of an aquatic toxin in that is lethal to 50% of some aquatic species (LC50). Thus, these measures are comparable to the expected value measures of profit. By contrast, none of the IPM assessment articles reviewed employed measures of environmental impacts that use probabilistic terms, such as those discussed above under profitability risk. In general, the research into economic evaluation of environmental impacts is much more scarce and more recent than the large body of work on profitability impacts.

Environmental media measured

Many different criteria are used to assess environmental impacts and risks. These include the quality of water, air, and soil, as well as the health of non-target species of mammals, birds, fish, insects, plants and other life forms (Table 2.5). Kovach et al.'s (1992), environmental impact quotient (EIQ) for pesticides, uses eight criteria in calculating the environmental components of the indices. Higley and Wintersteen (1992) followed by Mullen et al. (1997) use five separate criteria to characterize environmental risks from insecticides and herbicides in calculating their environmentally adjusted EILs (EEILs). None of these studies include site-specific criteria, like soil types or depth to aquifer, in estimating environmental impacts or risks for pesticides. Instead, all criteria were based on previous studies that characterized specific non-target impacts or pesticide specific characteristics, like soil residue half-life and toxicity to bees.

The studies by Hoag and Hornsby (1992), Teague et al. (1995), and Crissman et al. (1998) approach environmental risk assessment similarly to the ones discussed above, but they add site-specific criteria. Hoag and Hornsby (1992) develop a trade-off frontier for pesticide costs and a groundwater hazard index (GHI). The criteria used to develop the GHI include pesticide specific criteria and site-specific criteria that might affect the likelihood of contamination of groundwater by pesticides. Teague et al. (1995) compare the EIQ with two other measures of environmental risk. The other two measures include site-specific estimates of environmental fate of pesticides, in addition to the toxicity and leachability measures in the EIQ. Crissman et al. (1998) also included site-specific information on soil types and rainfall in their measure of pesticide leaching risk.

Proxy variables for environmental impact measurement

Since direct measurement of some of the environmental impacts of IPM adoption is impossible, or prohibitively expensive, a wide range of proxy variables has been used to measure environmental impacts. The most common proxies are pounds of active pesticide ingredient (a.i.) applied or dollars spent on pesticides (Musser et al., 1981; Moffitt et al., 1983). Both measures emerge from the very dubious assumption that environmental damage correlates with quantity of pesticide used, regardless of the specific chemicals and formulation. An even rougher proxy simply to measure whether or not pesticides are used in a production, based on the implicit assumption that any pesticide use must harm the environment (Reichelderfer and Bender, 1979).

The demand for more rigorous, qualitative measures of environmental impacts triggered development of a new generation of proxy variables. The EIQ, for instance, combines eight pesticide impact variables by weighting their relative importance into a single index of environmental risk. Hoag and Hornsby (1992) and Teague et al. (1995) also use weighted indices that incorporate the kind of toxicological and leachability criteria in the EIQ with site-specific measures of likely exposure.

Human Health Impacts

Studies of health impacts from IPM adoption can be divided into two broad areas. Imputed health risk studies use controlled laboratory experiments exposing small mammals to acute doses of pesticides, extrapolating from these to likely human health risks. Epidemiological studies use survey data linking human morbidity and mortality to life styles and exposure to risks sources, such as pesticide application.

Research on the human health of pest management has mostly focused on the acute toxicity effects of pesticides and pesticide exposure. A toxicity estimate commonly found in health risk assessments is the World Health Organization's index of acute mammalian toxicity, or

LD50. The LD50 is the dose of pesticide that is lethal to half of the test population, typically composed of rats or rabbits. Most studies dealing with health impacts used LD50s as acute toxicity risk estimates (Higley and Wintersteen, 1992; Hoag and& Hornsby, 1992; Kovach et al., 1992; Penrose et al., 1994; Teague et al., 1995; Mullen et al., 1997;). We are not aware of attempts to measure the risk of nonchemical pest management practices.

Risk of pesticide exposure depends on its propensity to move in the environment (e.g., water solubility, clay particle adsorption) and the characteristics of the setting in which it is released. The EIQ is a result of three separate calculations of likely risk and exposure for consumers, farm workers, and the environment. Likewise, Harper and Zilberman (1992) divide worker health risks according to form of exposure to aerially sprayed pesticides (mixers/loaders vs. pilots vs. flaggers on the ground).

More recent epidemiological research has begun to consider the chronic effects of pesticide exposure on carcinogenicity and the human neurologic, endocrine, immune, and reproductive systems (Blair et al., 1996). Epidemiological pesticide risk assessments have focused largely on risk to farmers and pesticide applicators (Blair and White, 1985; Hoar et al., 1986; Zahm, 1997). Most recent studies have focused on cancer mortality risks via Hodgkin's disease, leukemia, multiple myeloma, non-Hodgkin's lymphoma, and cancers of the lip, stomach, prostate, skin, brain, and connective tissues (Alavanja et al., 1996). In addition to epidemiological studies of acute effects of pesticide exposure in the United States (Blair, Francis & Lynch, 1997), several recent studies have been done elsewhere. Antle and Pingali (1994) and Pingali et al. (1994) evaluated the acute health effects of pesticide use by Philippine farmers; they further estimated the value of these acute impacts on farmer productivity. In a similar set of studies, Crissman et al. (1994, 1998) evaluated the acute health impacts of pesticide use by Ecuadorean farmers and calculated profitability tradeoffs associated with higher and lower levels of pesticide use.

Proxy variables for health impact measurement

The most commonly used proxy measure for health risks from pesticide use is the mammalian LD50. All of the studies that mixed multiple criteria for assessing pest management systems use LD50s proxies for health risk (Table 2.5). Other studies include variables that characterize the risk of exposure due to pesticide characteristics or site-specific variables as components of the proxy variables of health impacts (Harper and Zilberman, 1992; Higley and Wintersteen, 1992; Hoag and Hornsby, 1992; Kovach et al., 1992; Penrose et al., 1994; Teague et al., 1995; Mullen et al., 1997). The epidemiological studies that evaluated average health risks measured health outcomes directly, but only for certain classes of mortality and morbidity associated with pesticides. Antle and Pingali (1994) and Crissman et al. (1994, 1998) also used actual medical records.

Approaches to Combining Different IPM Assessment Criteria

Difficult as it is, measuring individual impacts of IPM is not enough. IPM assessment also requires that individual measures be combined in a meaningful fashion. There are two general approaches to combining criteria: 1) building a single index, and 2) creating a trade-off frontier based on multiple criteria. Studies using each approach are listed in Table 2.6.

The index approach calls for some way of weighting different criteria. Kovach et al.'s Environmental Impact Quotient uses a subjective weighting of relative environmental risk in an additive index constructed from eight pesticide impact variables. The resulting EIQ index can be compared only with EIQ's for other pesticides. The indices reviewed by Teague et al. (1995) and Penrose et al. (1994) are comparable. Another approach to building an index is to do it in monetary units. The contingent valuation studies of Higley and Wintersteen (1992), Mullen et al. (1997), and Owens et al. (1996) each used surveys to elicit farmer willingness to pay for safer pesticides. The results were used to adjust pesticide costs to reflect health and environmental costs in addition to cash costs. The adjusted cost can be interpreted as a monetary index that combines profitability with health and environmental risk factors.

The multiple criteria assessment approach keeps IPM evaluation criteria separate, but identifies "efficient" trade-off frontiers such that one criterion cannot be improved without sacrificing performance on another. Levitan et al. (1995) observe that this method typically compares profitability impacts measured in monetary terms with environmental impacts measured on some other scale. For example, Hoag and Hornsby (1992) graph a groundwater hazard index (GHI) against herbicide cost. The trade-off frontier represents herbicides that have the lowest GHI for their cost; hence, lower GHI cannot be obtained without increasing herbicide cost, and vice-versa. Teague et al. (1995) and Crissman et al. (1998) also construct trade-off frontiers combining multiple IPM impact criteria. The approach is similar to Pareto optimality or the mean-variance dominance criterion described above for profitability risk.

Directions for Planning Economic Assessment of Public IPM Programs

As IPM has evolved from a cost-saving practice for farmers to a risk-reducing practice for farmers and consumers, the appropriate way to assess IPM programs has evolved as well. The desired outcomes for most IPM programs are producer profitability, environmental quality and human safety. Gross margin measures of expected profitability are generally easy to do and adequate when the pest management systems being compared undergo similar or rapid adjustments to reach new steady state equilibria.

Much more daunting is the threefold challenge of how to assess profitability risk, environmental impacts and human health impacts. Compared with expected profitability, these attributes involve more criteria to measure, greater difficulty in observing what is to be measured, and greater difficulty in forecasting dynamic adjustments.

Where profitability risk matters, as it often does, the stochastic efficiency measures have the advantage over the expected utility functions that the former apply to broad categories of decision makers. However, they require information on pest management results under various states of nature. If these data are collected from the field, they can be slow and costly to acquire; if simulated, they may be of questionable validity.

Measuring environmental and health impacts poses difficulties that are analogous, albeit greater. For most of these, IPM program assessment will have to extrapolate from minimal measurements. Multiple criteria assessments have the political advantage of requiring few value judgements, but neither do they provide clear guidance for how to make trade-offs between points on the efficient frontier or trade-offs between pairs of the many points that typically lie off the frontier. Indexes, on the other hand, offer clear rankings, but they are subject to criticism for subjectivity in how they weight different impact criteria.

The difficulty inherent in measuring and placing values on environmental, health, and profitability risk impacts suggests that when economic assessments of IPM programs aspire to go beyond simple measures of expected profitability, they will be driven by constraints on budgets and time. Minimal, prudent indicators of environmental and health impacts should be developed that can be used to extrapolate from prior studies elsewhere. In special cases of large, well-funded programs, more extensive primary assessment data collection may be merited.

This chapter has described many of the methods that have been used by researchers in the past to perform IPM impact assessments on profitability and environmental and human health factors. Chapter 3 will outline the assessment methods recommended by the basic and in-depth protocols. Many of the methods mentioned in the protocols, and the challenges one faces in using them, have been described in-depth here. This chapter should serve as a reference for those who are unfamiliar with the methods recommended in the IPM assessment protocols.

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Table 2.1 Examples of input-oriented definitions of IPM

Definition (quoted from source text)	Source
Biointensive IPM ... relies on resistant varieties and promoting plant health, crop rotation, disrupting pest reproduction, and the management of biological processes to diversify and build populations of beneficial organisms.	Benbrook et al. (1997)
Integrated pest management (IPM) programs provide individual pesticide users with techniques proven to reduce pesticide use. The keystones of IPM programs are economic injury levels (EILs), which are objective criteria for determining when to manage pests	Higley & Wintersteen (1994)
Cotton IPM systems include such components as scouting to determine when control actions should be taken, planting trap crops, and using short season varieties of cotton.	Liapis and Moffitt (1983)
Integrated pest management (IPM) is a systematic approach to crop protection using increased information to make better pest management decisions.	Rajotte et al. (1987)
Applied pest control which combines and integrates biological and chemical control. Chemical control is used as necessary and in a manner which is least disruptive to biological control.	Stern et al. (1959)

Table 2.2 Samples of outcome-oriented definitions of IPM

Definition (quoted from source text)	**Source**
Integrated Pest Management is the judicious use and integration of various pest control tactics in the context of the associated environment of the pest...to meet economic, public health, and environmental goals.	Cate and Hinkel (1993)
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.	Kovach et al. (1992)
...integrated pest management (IPM) strategies are being developed and implemented that combine biological, cultural, physical, and chemical control tactics to minimize economic, environmental, and health risks.	Mullen et al. (1997)

Table 2.3 IPM assessment articles grouped by measure of profitability

Private Profitability	Social Profitability	Profitability Risk
Gross margin minus pest control cost		
Deen et al.		
Ferguson et al.		Ferguson et al.
Greene et al.		Greene et al.
Hara		
Hoag & Hornsby		
Klein et al.	Klein et al.	
Lazarus & Swanson		Lazarus & Swanson
Liapis & Moffitt		Liapis & Moffitt
McGuckin		McGuckin
Moffitt et al. (1983)		Moffitt et al. (1983)
Moffitt et al. (1984)		Moffitt et al. (1984)
	Mullen et al.	
Musser et al.		Musser et al.
Osteen et al.		Osteen et al.
Rawat et al.		
Reichelderfer & Bender		
Swinton & King		Swinton & King
Szmedra et al.		Szmedra et al.
Taylor & Lacewell	Taylor & Lacewell	
Teague et al.		
Trumble & Morse		
Ward et al.		
Yu et al.		Yu et al.
Gross margin minus production costs		
Antle & Pingali		Antle & Pingali
Boggess et al.		Boggess et al.
Crissman et al. (1998)		Crissman et al. (1998)
Harper & Zilberman		Harper & Zilberman
Pingali et al.		

Table 2.4 IPM assessment articles grouped by measure of probabilistic risk

Method	Profitability	Environment	Health
Stochastic Dominance	Boggess et al.		
	Deen et al.		
	Greene et al.		
	McGuckin		
	Moffitt et al. (1983)		
	Musser et al.		
	Swinton & King		
Mean-Variance (E-V)	Lazarus and Swanson		
	Moffitt et al. (1984)		
	Musser et al.		
	Napit et al.		
	Osteen et al.		
	Swinton & King		
	Harper & Zilberman		Harper & Zilberman
			Crissman et al. (1994)
	Crissman et al. (1998)		Crissman et al. (1998)
	Yu et al.		
	Antle & Pingali		Antle & Pingali
			Pingali et al.
Coefficient of Variation	Ferguson et al.		
Expected utility function	Liapis & Moffitt		
	Swinton & King		

Table 2.5 Environmental impact assessment criteria

Environmental impact assessment criteria	Source
Aquatic organisms, beneficial arthropods, birds, ground water, human acute toxicity, human chronic toxicity, mammals, surface water	Higley and Wintersteen (1994); Mullen et al. (1997)
Acute human toxicity, chronic human toxicity, leachability	Hoag and Hornsby (1992)
Acute dermal LD50 for rabbits/rats, groundwater and runoff potential, long term health effects, mode of action, plant surface residue half-life, soil residue half-life, toxicity to bees, toxicity to beneficials, toxicity to birds, toxicity to fish	Kovach et al. (1992)
EIQ criteria from Kovach et al., plus leachability, percolation, acute toxicity, and human toxicity, and criteria for leachability and percolation adjusted using acute and human toxicity.	Teague et al. (1995)

Table 2.6 IPM assessment articles grouped by approach to assessing multiple criteria

	Profitability	Environment	Health
Indexes			
		Higley & Wintersteen	Higley & Wintersteen
		Kovach et al.	Kovach et al.
		Mullen et al.	Mullen et al.
	Penrose et al.	Penrose et al.	Penrose et al.
		Teague et al.	Teague et al.
Multi Criteria Dominance			
	Crissman et al. (1998)		Crissman et al. (1998)
	Hoag & Hornsby	Hoag & Hornsby	Hoag & Hornsby
	Teague et al.		Teague et al.

Chapter 3:

Methodology for Applying the Assessment Protocol to a Specific Commodity

Introduction

The IPM protocols are described in detail in this chapter. Though only the basic protocol is applied in this study, the steps in applying the in-depth protocol are also described. The different methods of impact analysis that are recommended in each of the protocols are described in detail and alternative sources for data in each of the sections are also highlighted.

The IPM Assessment Protocol

The assessment protocols were developed by a multi-disciplinary group of scientists from the agricultural, environmental, and human health fields. The group[2] met numerous times in 1997-1999 to discuss and develop the final assessment protocol, which can be found in Appendix 3.1. Central to these discussions were issues about the appropriateness of the proposed assessment methods and the time and data requirements for the methods at each levels of the assessment protocol. The final protocol is divided into two sections, basic and in-depth. The two sections are meant to be used independently and the choice of which to use is based largely on the resources available to the researcher performing the analysis, the stage of the program being assessed, and the pool of users to be sampled. A description of the two sections of the protocol is provided below.

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[2]The group of scientists included Dr. Scott Swinton, Michigan State University, Dr. George Norton, Virginia Polytechnic University, and Drs. Susan Riha and Lois Levitan, Cornell University.

The Basic IPM Assessment Protocol

The basic protocol (Appendix 3.1) is intended for use when resources for the entire IPM program are limited. Since the ultimate goal of the project is to develop protocols that may be built into research programs, and so research proposals, this protocol was developed with the most basic research or outreach program in mind. The basic protocol is a listing of the data required for the most simple economic and environmental and human health impact analyses and it provides suggestions of methods to be used for such analyses. Both protocols are divided into sections that involve identifying IPM practices and gauging their adoption, and measuring economic, human health, and environmental impacts. A discussion of each of these sections follows.

IPM Practices and Adoption

The assessment protocol was designed for use with a wide variety of commodities. The first step in applying either protocol is to define IPM specifically for the commodity being studied. This involves first listing the practices to be considered as "IPM practices", dividing practices into levels of IPM adoption, and then measuring the degree of IPM adoption among all, or a representative sampling, of producers of the commodity in a given geographic area.

Listing IPM practices is important because it forces researchers to identify practices that should possibly be excluded since they are widely adopted by producers. This feeds directly into the next step in the protocol, which is to divide IPM practices into levels of adoption. Dividing IPM practices into levels of adoption has been advocated by many in the IPM field (Norton and Mullen, 1997; Benbrook et al., 1996). As argued in chapter 2, IPM should be a continually moving target just as conventional should be a continually moving baseline for production practices. Once levels of IPM have been established and adoption information within each of these levels collected, the levels will provide researchers with a useful way to gauge the state of adoption attained through the program and will likely help to identify future funding targets by highlighting the areas that need support.

After identifying the set of IPM practices of interest and dividing the practices into levels of adoption, the next step is to gauge the level of IPM adoption among producers in the region. For the basic protocol, the use of existing datasets and/or collaboration with specialists and industry representatives is recommended. If no data is available on adoption, using expert opinion to predict the rates and final levels of adoption is acceptable. Documenting adoption is important, even at the most basic level, because it provides some indication of the extent to which an IPM program has reached its goal.

Economic Impact Assessment in the Basic Protocol

The economic impacts of interest in the basic protocol are profitability impacts at the producer level and aggregations of these impacts to the producer population of interest. In both cases, partial budgeting, combined with adoption information, is the recommended method of analysis. An additional consideration for this section is the time frame during which the effects of adoption will be studied.

After identifying the IPM practices of interest and the levels of adoption, analyses of the economic impacts of IPM adoption over a single year should focus on the changes in yields and input costs between the different levels using a partial budgeting framework. The underlying assumptions of this analysis include a static price and production environment and no risks to profitability. The aggregate economic impact analysis then combines results from the partial budgeting analysis with adoption information, either real or projected, to arrive at an estimate of total economic impact on producers in the region.

Environmental and Health Impact Assessment in the Basic Protocol

At the basic protocol level, analysis of the environmental and human health impacts of IPM adoption involves collecting information only on the pesticides used by growers. With limited time and funding, an analysis of the effects of IPM adoption on pesticide use should provide, at a minimum, a representation of the effects of different levels of adoption on the pesticides used and the manner in which they were used. In addition, this data set could be helpful in future IPM impact assessment studies.

Pesticide data to be collected include: pesticide name, pesticide function, rate of application, number of applications, month of application, method of application, form applied, and the target pest. The assumptions underlying this section of the protocol are a homogeneous, static production environment and that non-pesticide impacts (i.e. sunstroke from scouting) are negligible. If these assumptions do not hold, then use of the in-depth protocol may be justified.

Summary of Recommendations from the Basic Protocol

Use of the basic protocol inherently means that the minimal amount of data required for a basic IPM assessment should be collected. Data for this protocol most often come from secondary data sources or from expert opinion. The economic impact analysis requirements are for simple budgeting or gross margin analysis exercises, or for more than one year, an investment analysis. For the environmental and human health impact analysis, simple collection of usage data for the pesticides used is all that is required.

The In-Depth Assessment Protocol

The in-depth assessment protocol (Appendix 3.1) is intended for use with well-funded programs in which an inter-disciplinary group of scientists can be called on to perform the parts of the assessment that fall within their area of expertise. The in-depth protocol is composed of sections almost identical to those found in the basic protocol, but each section requires more in-depth analysis and possibly primary data collection through surveys or other data collection procedures. It should be noted here that the basic and in-depth protocols are not exclusive of one another. Depending on the goals of the IPM project being assessed, use of the basic protocol supplemented with the in-depth section on economic impacts, for example, is appropriate and consistent with the intent of the protocol developers.

IPM Practices and Adoption in the In-Depth Protocol

The in-depth protocol requires that IPM practices be listed and divided into levels exactly as for the basic protocol. In gauging adoption of IPM practices, the in-depth protocol requires more information be collected either through existing data or through producer surveys. The researcher should not only consider the current state of IPM adoption, but also projected adoption levels. This can be done by using expert knowledge and/or data from the survey of adoption to predict maximum adoption levels and then extrapolating from experiences within the commodity with other IPM practices or from similar research on agricultural technology adoption, to project future adoption rates. Here, also, the researcher should be careful to consider certain methodological issues, like sampling bias, that were ignored in the basic protocol.

Economic Impact Assessment in the In-Depth Protocol

The protocol recommends that researchers consider many factors assumed homogeneous, or static in the basic protocol when performing the assessment of economic impacts from IPM adoption in the in-depth protocol. Not only should researchers consider the profitability effects outlined in the budgeting analysis in the basic protocol, but also the factors that might influence these effects as well as IPM adoption. For example, in the basic protocol, prices are assumed to be constant, while for the in-depth protocol, the effect of IPM adoption on prices should be considered.

Two other methods of analysis recommended for use in the in-depth protocol are economic surplus calculation and an estimate of the risks IPM adoption poses to producer profitability. Economic surplus calculation involves estimating losses or gains to producers and consumers who might be affected by IPM adoption. For producers, the loss or gain might be in the form of higher input prices or higher prices for their output, while for consumers, the loss or gain would be reflected in product prices (Nicholson, 1989).

Simulation analysis and stochastic dominance analysis are two methods recommended for examination of the effects of IPM adoption on the economic risk faced by firms. In simulation analysis, an analytical model of a production system is developed to analyze interrelationships between the factors and processes in a production system. Simulation models can be either stochastic or dynamic, can cover many time periods, or only one, can represent many parts of a production process, or only one, and may be behavioral or mathematical (Barry, 1984). Depending on available time and resources, the type of model used, and its flexibility, can be quite variable. Stochastic dominance analysis involves the use of an efficiency criterion to order choices between outcomes depending on a preference for risk pre-specified for a particular class of decision maker (Barry, 1984).

Environmental and Human Health Impact Assessment and the In-Depth Protocol

Building on pesticide use data collected in the basic assessment protocol, the in-depth protocol focuses on the water quality and human health impacts of IPM adoption. For effects on water quality, the pesticide use data will be combined with areal data, like soil type, watershed, or zip code, to identify the influence of the production location on impacts of IPM adoption. Though no direct correlations can be made between actual impacts and pesticide use data, something can be said of the likelihood of impacts based on the use data and an estimate of environmental sensitivity which the areal data provides. An important addition to the pesticide use data in the in-depth protocol is the timing of pesticide applications. This variable, used in conjunction with the areal data and environmental sensitivity data mentioned above provides an important data set from which estimates of environmental impacts can be made.

Direct human health impacts are probably the most difficult to measure of all the impacts considered in the protocol. Data on exposure to applicators, as well as consumers, should be collected and combined with toxicity risk estimates like those from the World Health Organization (MSUE, 1999). In addition, mortality and morbidity data from registries, or from primary data collection, should be collected.

Integrating Environmental and Economic Impacts in the In-Depth Protocol

Joint economic and environmental impacts from IPM adoption are important to consider as decision makers must be concerned with effects on profitability and the environment. While these methods of analysis provide important and interesting results, they should only be included in an IPM impact assessment when the most time and resources are available.

Two basic approaches to analyzing these impacts are multi-criteria analysis and an indexing approach. Studies using the multi-criteria approach often compare the profitability and environmental outcomes of a number of different production systems and then rank the systems based on a joint comparison of the outcomes. Hoag and Hornsby compared herbicide costs with an index of groundwater hazard using a trade-off frontier as the method of multi-criteria analysis (1992). Mathematical programming is an alternative method appropriate for multi-criteria analysis (Anderson et al., 1994). Nonetheless, the weights used for environmental effects in mathematical programming techniques are often arbitrarily assigned, and so, of questionable analytical value.

Indexing approaches commonly use non-monetary approaches to develop absolute numerical ratings for pest management practices. Alternatively, they may use a money metric approach, like contingent valuation. Non-monetary index approaches have been criticized for the weighting procedures developed for components of the indices. For example, the EIQ double counts the effects of pesticides on some factors and weights effects on human pesticide applicators and beneficial arthropods identically (Kovach et al., 1992).

Money metric approaches are open to criticism as well since they often rely on proxy variables for measuring impacts or artificially constructed markets for environmental goods. For contingent valuation (CV), respondents are asked for personal valuations of some good in a hypothetical market. While results from studies using contingent valuation are often criticized for being inaccurate and unprovable, often CV is the only method available and applicable to a wide range of environmental problems (Pearce et al., 1992). Other methods that use proxy variables to estimate costs associated with environmental problems include: averting expenditures, cost-of-illness, and the cost of environmental remediation.

Summary of Recommendations from the In-Depth Protocol

The analysis of impacts from IPM adoption at the in-depth protocol level requires more time and effort. Data for this level of the protocol should come from very specific existing data for from grower or producer surveys. The economic impact analysis requires that variable components of the market for the product in question be considered. These components, like price effects, growing conditions, which were held constant in the basic protocol, should be included in the economic impact analysis. More attention to effects on social benefits and costs and risk to profitability effects must also be given in the in-depth economic impact. The environmental and human health impact analysis requires consideration of locational factors that might influence impacts on water quality, even more specific pesticide usage data, and possible direct human health effects. The integration of environmental and economic effects is a section exclusive to the in-depth protocol and requires the use of multiple criteria analysis or index approaches.

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Appendix 3.1

IPM ASSESSMENT PROTOCOLS*

The attached protocols are designed to assess the economic, environmental and health impacts of applied research and outreach programs in IPM. Their focus is on measurable impacts. These protocols therefore may not be applicable to IPM basic research programs or to assessments of IPM policy.

Primary Intended Users:
Statewide IPM program leaders / coordinators

Levels of Assessment:
Basic and In-depth (see draft protocols)
These levels are distinguished on the basis of one or more of the following criteria:
1. Stage of program development
2. Pool of users sampled
3. Resources available for assessment

Scale of Applicability:
The primary scale is assessment of regional or statewide IPM programs. However, the protocols may be useful in scaling up for broader regional and national assessments in two ways:
1. Evaluating a subset of programs could allow inferences to be made concerning the impacts of programs nationally.
2. The protocols encourage the collection of minimum, standardized data sets which will facilitate extrapolation of results across regions and commodities.

Flexibility of design vs. Uniform comparisons
Two reasonable objectives for an IPM assessment protocol are 1) adaptability to diverse IPM projects and programs, and 2) potential for making a standard comparison of performance among many different IPM projects. These two objectives are in conflict with one another, since the former calls for flexibility of design, while the latter demands uniformity. Where a compromise was needed, these protocols have favored flexibility.

Basic IPM Assessment Protocol

The basic protocol is intended for use when time, resources, and data availability preclude a more in-depth analysis.

List IPM practices to be assessed

Identify IPM practices with direct, measurable environmental, health & economic impacts

Not for inclusion: IPM practices which in themselves are measurable, but which are unlikely to have a clear, measurable impact on economic or environmental outcomes (e.g., sprayer calibration)

Measure of IPM degree

Levels of IPM practices should be defined clearly for the individual programs:

- "Conventional"
- Restricted set of IPM practices
- Enhanced set of IPM practices

IPM Adoption and Usage

1. Existing data: Use secondary source (e.g., NASS) on both adoption levels and typical usage
2. No data available (projected adoption):
   - Specify max adoption level expected (check w/ industry folk, not just scientists)
   - Specify number of years expected to max adoption
   - Use expert opinion to predict likely usage rates (including with pesticides)

Impacts - Economic

Consider time frame

Single year (IPM practice set X commodity):

- Partial budget for "average" conditions (yield potential, pest pressure)
- Assumptions: No price impacts, no risk, no dynamics, homogeneous conditions
- If adoption to occur in future, discount @ specified rate (e.g., 5%)

Multiple year: Investment analysis

- Example: Disease-resistance tree variety

In either case, combine partial budget results with adoption information or projections to get aggregate economic impact

Impacts - Environmental/Health

Pesticide use data (a.i.)

- Pesticide name, function (e.g., herbicide, fungicide), rate, times sprayed, month applied, method of application, form applied, pest

Assumptions: homogeneous environment, no dynamics, negligible non-pesticide impacts.

- Where these assumptions are violated, an in-depth assessment may be justified.

IPM ASSESSMENT PROTOCOLS
In-depth Protocol

List IPM practices and measure IPM degree: Guidelines on defining set(s) of practices at different levels of IPM [Same as Basic Protocol]

Adoption

1. Existing adoption data: Survey adoption level (e.g. of indiv. component IPM practices) to make inferences with statistical validity
    - Individual practice
    - Current & intended adoption
2. Projected adoption:
    - Extrapolate from similar technology
    - Use expert knowledge
3. Methodological issues:
    - How representative is the sample or expert?
        - What kinds of bias may be present and how should results be interpreted?
    - Reasons for non-adoption are important too (e.g., pest not a problem so no IPM vs.
        - IPM practices were flawed, ergo undesirable)

Impacts - Economic

1. What factors explain extent of IPM adoption & its profitability impacts?
    - Cross-sectional variability: Surveys
        - Prices:
            - Input cost: Can use adjusted retail prices, NASS, state budget data, Doanes
            - Output: Median from recent years (if low inflation)
        - Yield & pest pressure
        - Production conditions likely to affect pest impacts (other IPM factors)
        - Conditioning variables (farm size, location)
        - Regress pesticide use on explanatory variables, including IPM practices
        - Consider time lags before adoption is achieved
2. Do private benefits justify public expenditure?
    - Economic surplus calculation
    - Income distribution analysis
3. Is economic risk affected by the IPM practices?
    - Risk analysis w/ simulation & stochastic dominance (secondary importance)

Impacts - Environmental/Health: Focus on water & human health

- Pesticide use data set from Basic assessment protocol
- Water quality:
    - Location data (soil type, watershed, zip code) will be used to identify likely location effect on environmental impact.
        - Environmental sensitivity
    - Timing of exposure (esp. when seasonal)
    - Possible tools to include:

Environmental regions (Indiana approach)
Watershed delineations, using output from NAPRA, GLEAMS, others
Direct human health:
Applicators exposed (survey data)
Toxicity risk (WHO acute health risk data, others)
Pesticide residue on food (from date of spraying)
Mortality and morbidity data
Events and disease rates by geographic area, race, sex, and age
Population-based mortality and morbidity registries
Assumptions: No confounding by established disease risk factors.
Other relevant environmental impact(s) (depending on specific cases)

Integrating Environmental and Economic Impacts
Multiple criteria analysis (e.g., Hoag & Hornsby's groundwater hazard frontier)
Index approaches
Non-monetary (e.g., EIQ)
Money metrics (e.g., contingent valuation results, cost-of-illness, averting expenditures, cost of environmental remediation)

* These protocols were developed by George Norton, Virginia Polytechnic University; Susan Riha, Cornell University, and Scott Swinton, Michigan State University.

Chapter 4:

Key Tart Cherry Pests and Management Practices Available

This chapter will review the key pests of tart cherries in Northwest Lower Michigan and the pest management practices commonly used by growers for their control. The end of this chapter will describe pest management practices that are not directed at a specific pest, but instead, are practices used for general plant and pest management.

Key Tart Cherry Pests

Key pests are any pests that are capable of inflicting significant economic damage on a crop (Pedigo et al., 1988). While other pests of tart cherries do exist in Michigan, this study will focus only on the few key pests of tart cherries, brown rot, leaf spot, cherry fruit fly, plum curculio, and two-spotted spider mite (Table 4.1.). A general list of the pest management practices used by tart cherry growers in Michigan is given in Table 4.2. The list is general since a single tactic is often used to manage a variety of different pests. The management tactics used for each of the key pests are discussed below. Included in the discussion are the types of damage inflicted by each of the pests, management practices used to control or prevent damage from the pests, and any other practices used to collect information on the pest.

Brown Rot

Brown rot is a disease pest of tart cherries that causes lesions on the fruit while on the tree, or during shipping and storage (Jones and Sutton, 1984). The lesions leave the fruit unuseable and the disease can spread within an orchard through fruit to fruit contact. Brown rot can also damage the blossoms, and thus the development of fruit, on cherry trees. Temperature and wetting conditions greatly affect the development of brown rot during the growing season, while infected litter from the previous year can provide the inoculum needed for disease development(Jones and Sutton, 1984). The use of fungicides at appropriate intervals is the only preventative measure available for controlling brown rot. Fungicides are applied when peak infection periods occur prior to the development of the disease. The fungicides used by tart cherry growers have a residual effect which prevents development of the disease at the time of application and for many days afterward. Orchard sanitation is an important IPM practice for controlling brown rot since it physically removes the inoculum, present in infected fruit, from the orchard. Nonetheless, orchard sanitation alone does not guarantee prevention or control of the disease. Monitoring weather conditions and wetting periods can help growers identify peak periods for development of brown rot in fruit. Weather monitoring is also considered an IPM practice.

Cherry Leaf Spot

Cherry leaf spot is a fungus that primarily infects the leaves of tart cherry trees. If not controlled, cherry leaf spot can lead to premature defoliation of trees, which in turn reduces hardiness for overwintering, possibly leading to tree death. Cherry leaf spot can overwinter in leaf litter in the orchard and then infect trees in the spring when leaf wetting at optimal temperatures occurs (Jones and Sutton, 1984). Traditional management of cherry leaf spot is achieved through application of fungicides at regular intervals during the growing season (MSUE, 1998). Monitoring of temperatures and leaf wetting periods, combined with protectant sprays are key IPM practices used to avoid cherry leaf spot infection. These are IPM practices because they use information about the development of the disease to form spray decisions, whereas, the traditional pest management practice uses only the calendar to make spray decisions. Alternate row sprays are also an IPM strategy for managing cherry leaf spot, since less pesticides are used to achieve a comparable level of disease control (Nugent and Thornton, 1999).

Sterol inhibitors are a class of fungicides commonly used for protecting against cherry leaf spot infection. However, because they are extremely effective and widely used, many experts have become concerned that overuse will hasten the development of resistance to these fungicides(MSUE, 1998; Nugent and Thornton, 1999).

Cherry Fruit Fly

Cherry fruit fly is one of the most important insect pests of Michigan tart cherries since the U.S. Food and Drug Administration has mandated a zero tolerance policy for cherry fruit fly maggots in processed tart cherries (Nugent and Thornton, 1999). This means entire loads of tart cherries can be rejected upon discovery of a single cherry fruit fly maggot. The life-cycle of the cherry fruit fly coincides almost perfectly with the primary development season of tart cherry fruit (June through early August). Damage or injury to fruit occurs through adult feeding and through oviposition and the subsequent feeding of maggots (Howitt, 1993). Conventional management of cherry fruit flies is achieved through regular sprays made throughout the insects life cycle (MSUE, 1998). Population monitoring and the application of insecticides are the primary IPM practices used for controlling damage from cherry fruit flies. Sticky traps bated with ammonium acetate or ammonium hydroxide are used to monitor population numbers (MSUE, 1998). Information collected from the sticky traps, and other sources, can then be used to make spray decisions, affecting both the timing of the spray and the decision of whether to spray at all. Sprays made using information collected on the pest is the primary IPM method for cherry fruit fly.

Plum Curculio

Plum curculio is another important pest in tart cherries and in other fruits in Michigan. Damage or injury to fruit caused by plum curculio occurs in one of the following ways: oviposition and feeding injury to the fruit in the early spring, further internal injury to the fruit from burrowing activity of the larvae, and premature dropping of the fruit as a result of larval feeding. Among the pests of tart cherries, plum curculio is one of the most damaging. In addition, plum curculio maggots are nearly indistinguishable from maggots of the cherry fruit fly, so, the zero tolerance policy for maggots in processed cherries, though targeted at cherry fruit fly, applies de facto to plum curculio maggots. Conventional management of plum curculio is the use of calendar spraying and some pest experts recommend full rate sprays to best control the pest (Howitt, 1993). IPM practices associated with the direct management of plum curculio are monitoring of, and information collection about, population levels. The "Plum Curculio Model", developed at MSU, uses growing degree day information to predict peak periods for the emergence and onset of plum curculio as a pest (Laubach, 1995). This model is widely used by growers in Northwestern Michigan (Thornton, 1999). Other information collection practices include the use of traps to assess pest population numbers, examination of developing fruit for evidence of feeding or oviposition injury, and the collection of weather monitoring information to determine the likelihood of significant pest outbreaks (Howitt, 1993).

Two-Spotted Spider Mite

Two-spotted spider mites damage cherry trees by sucking chlorophyll from the leaves. The mites do not directly damage the fruit of trees nor do they affect fruit harvest during the year. Rather, severe mite feeding decreases tree vigor and can reduce yields by decreasing the number of buds set by cherry trees. Here again, the most effective IPM control method for this pest is the collection of pest population information through population and weather monitoring accompanied by the application of miticides once critical population levels are reached (Howitt, 1993).

Other IPM Practices

Many of the practices listed in Table 4.2 were not described above as management methods for the key pests of tart cherries. For example, mowing or chopping to control weeds, spray equipment decisions, sprayer calibration, and pruning are all listed as IPM practices but were not mentioned in the discussion of key tart cherry pests above. These methods are not used in the direct management of pests, but rather, are practices associated with responsible pest, and resource, management. For example, selecting pesticides that have the least impact possible on beneficial mite populations is not involved directly with the control of pests, but does indicate that a grower recognizes the potential benefits from protecting beneficial mites.

Significance of the Pest Management Practices

All of the pest management practices mentioned in the preceding discussions were used to develop the levels of IPM required for applying the basic protocol presented in Chapter 5. These are practices commonly used by tart cherry growers in Northwest Lower Michigan

(Nugent and Thornton, 1999) in the control of the key tart cherry pests and in the management of tart cherry orchards.

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Table 4.1 Key Insect and Disease Pests of Michigan Tart Cherries

Common Name	Scientific Name
Brown rot	*Monolinia fructicola*
Leaf spot	*Blumeriella jaapii*
Cherry fruit fly	*Rhagoletis cingulata*
Plum curculio	*Conotachelus nenuphar*
Two-spotted spider mite	*Tetranychus noticae*

Source: Howitt (1993)

Table 4.2 Pest Management Practices used to Establish Levels of IPM Adoption

Category of Practice	Pest Management Practices	Expected Effect(s) of IPM Practice
Pest Control Tactics		
	Pesticide application	Control of pests through use of pesticides [in the most effective manner possible]
	Less than full cover sprays of pesticides	Control comparable to full cover pesticide application with lower expense; less chemical exposure for human applicator and environment
	Mowing/chopping to control weeds	Reduced stress on trees during growing season; replace herbicide application; better yields
Monitoring and Information Collection		
	Calendar sprays	Regular "calendar-based"spraying uses no pest population information
	Scouting	Better* information about pest population levels, possible outbreaks, and the need for sprays
	MSUE Code-A-Phone and internet resources	Better information about pest population levels, possible outbreaks, and the need for sprays
	MSUE CAT Alerts	Better information about pest population levels, possible outbreaks, and the need for sprays
	Weather Monitoring	Better information about pest population levels, possible outbreaks, and the need for sprays
	Bait-lure traps to monitor cherry fruit flies	Better information about pest population levels, possible outbreaks, and the need for sprays
	Plum curculio model to predict emergence and critical populations	Better information about pest emergence, possible outbreaks, and the need for sprays

Other Good Management Practices		
	Protection of beneficials through timing of sprays or pesticide selection	Decreased need for pesticides; less exposure to pesticides for human applicator and environment
	Spray equipment decisions	Better coverage using less spray material; less exposure to pesticides for human applicator and environment; better yields

* "Better", as used in this table, implies and improvement over conventional pest management practices.

Chapter 5:

Applying the Basic Protocol to Michigan Tart Cherries

Introduction

This chapter will describe the steps taken to apply the basic protocol to tart cherries in Northwest Lower Michigan. It should serve as a template for analysts who might apply the protocol in the future. While tart cherries are used as an example, the basic steps in applying the protocol should be similar regardless of the commodity.

IPM and Adoption Levels

The key pests of tart cherries and the management practices used to control them were reviewed in chapter 4. Following the basic protocol, the next step is to divide these pest management practices into levels of IPM. Table 5.1 lists many of the same practices as Table 4.2, but divides practices into levels of IPM adoption. Each column represents increasingly advanced levels of IPM adoption. The column called Conventional includes practices that are widely used by all tart cherry growers in Michigan. The levels of IPM adoption are important because, unlike many technologies that have been the objects of adoption research, IPM is composed of a bundle of practices. Practices in the Conventional and Basic IPM columns represent practices that were introduced near the beginning of the IPM program for tart cherries or practices that require less managerial or capital investment to adopt. Practices in the Intermediate and Advanced columns are practices that were introduced recently or that require more time, knowledge, and resources to adopt (Nugent and Thornton, 1999). The levels of IPM adoption were developed in a series of meetings with IPM specialists from the Michigan State

University Extension Service (Nugent and Thornton, 1999; Nugent et al., 1999). The different bundles of practices represent the expert's groupings of practices based on the levels of IPM adoption. These are those practices that would likely be used by growers at each level of IPM adoption. Using these bundles allows for estimates of the number of growers likely to be at each level of IPM adoption.

Adoption rates among tart cherry growers in Northwest Lower Michigan of the different levels of IPM were established by interviewing the same IPM specialists from the Extension Service. Since adoption rates are variable within groups of practices, the experts identified single practices within the groups that are the best indicators of a given level of IPM. The practices and their levels of adoption are given in Table 5.2. In Table 5.2, the column titled "Adoption level and year" includes estimates of the level of adoption of the indicator practice (a proxy for the bundles of practices mentioned above) at the inception of the IPM program in 1980, the level of adoption in 1999, an estimate of the maximum or minimum expected adoption, and where possible, when the maximum level of adoption might be reached. Estimates of when 100 percent adoption will take place do not exist since this level of adoption is not expected for any of the IPM adoption levels (Nugent and Thornton, 1999). The column titled "% of acres in Northwest Lower Michigan represented at each level in 1999 (base = 17,000 acres)" lists the number of acres in Northwest Lower Michigan managed using the bundles of practices for each of the IPM adoption levels. These numbers were also estimates from the IPM specialists from the Michigan State University Extension Service (Nugent et al., 1999).

Economic Impact Analysis

The purpose of this section of the protocol is to compare the farm level profitability of different levels of IPM adoption. The data on pesticide usage rates by level of adoption in this analysis were collected during the same interviews with IPM specialists mentioned above. Data were collected on pesticide usage rates among growers in the different levels of IPM adoption.

A cost analysis is used to compare costs for the different levels of IPM adoption. The experts indicated that they expected no yield differences between groups of growers, so comparisons of the three IPM scenarios and conventional pest management will be based solely on costs. Tables 5.3 through 5.6 are analyses of the costs of pesticide application and information collection for each of the levels of IPM adoption. A general explanation of the labels and data in the columns and rows of each of these tables follows.

The table titles indicate that the analysis was conducted for 10 acres of tart cherries grown in Northwest Lower Michigan in 1999. Ten acres was chosen as the reference size for two reasons. First, the average size of a tart cherry orchard in Northwestern Michigan is nearly 50 acres, so a 10 acre block is not unreasonable (MASS, 2000). Second, most growers manage their orchards on a block by block basis, so, management practices are likely to be consistent across all acres or trees in a given block. Northwest Lower Michigan is the primary tart cherry producing region in Michigan. 1999 was chosen as the production year of reference so that the experts interviewed would have a time frame for their answers and because it was the most recent growing season.

The first column of the tables indicates two things. First, the table is for pesticide use and information collection and second, which level of IPM the table represents. For example, Table 5.3 is for conventional pest management (PM). The first column also indicates the different time periods at which pesticide applications are made throughout the growing season. Plant growth stages are commonly used for this delineation (MSUE, 1998), however, the number of weeks before and after petal fall (WAPF) provides a more accurate representation of the time periods when pesticide applications actually take place (Thornton and Nugent, 1999). The second column indicates the pest being targeted at the particular time period. The third column indicates what sort of pesticide was applied at each time period. For Table 5.3, the words in parentheses after the type of pesticide application indicate whether the application made was to every row (full) or to alternate rows only (alt). Herbicides are always applied to every row.

Columns under the "Labor" section all deal with labor costs associated with applying pesticides or collecting information on the pest population. "Labor Hours" indicates the number of hours each of the activities requires for a 10 acre block, "Wage Rate" is the hourly rate paid to the worker performing the task, "Cost per 10 acres" is the product of the two preceding columns, and "Freq." is the number of times during the given time period an application was made or information was collected. Data on labor hours and the wage rate were taken from Kelsey et al. (1997) and from Nugent and Thornton (1999).

Columns under the "Machinery" section address the machinery used and the cost per unit of use. The "Equipment" column details the types of tractors and sprayers used by growers, "Hours of Use" indicates the number of hours each of the implements was used to make the application. "Unit cost" is the per hour cost of using the implements and includes costs associated with operation of the machinery, like fuel, lubrication, repair costs, salvage value, and so on (Kelsey et al., 1997). The machinery "Cost per 10 Acres" is just the unit costs multiplied by the amount of time required to cover 10 acres, including turn around time and loading. Data for these columns was taken from Kelsey et al. (1997) and Swinton et al. (1997).

The two "Materials" columns indicate the type of pesticides used and their cost per 10 acres. The pest management specialists provided information on the types of pesticides used at each time period. The costs for insecticides and fungicides are from an annually published list of pesticides and their costs per acre for tart cherries and other fruits (Thornton, 1999). Herbicide costs are from a dealer list of retail herbicide costs for 1999 (Mason County Elevator, 1999).

The columns in the "Total Variable Costs" section represent the variable costs at each time period for 10 acres of tart cherries in Northwest Lower Michigan receiving the type of treatment indicated. The second column, "% of growers using practice", are percentage estimates from extension experts of the number of growers at each level of IPM adoption who made the indicated pesticide application in 1999. This column is included because not all growers in a given scenario apply a given pest management practice at the same time. But, the "% of growers using the practice" should not be confused with the adoption level percentages in Table 5.2 that refer to entire pest management strategies rather than to individual tasks. In instances where two numbers exist, the top number is for the percentage of growers who applied the first pesticide listed under the "Item" column in the "Materials" section and the second percentage is for the second pesticide in the column. The "Use-adjusted VC" column is the product of the variable cost number and the percentage use estimate. This adjusts total variable costs for each management practice by the estimated number of growers using the practice at a given tart cherry growth stage.

A summary of the total costs that vary for each of the pest management scenarios reveals that the bundle of practices in intermediate IPM provide the lowest cost pest management (Table 5.7). Intermediate IPM is the lowest cost pest management alternative because pesticide usage at this level is less than for any of the other three levels. This result will be discussed further in the results section of this chapter.

Aggregate Cost Savings for Tart Cherry Growers

Aggregate effects on pest management cost savings can be calculated from estimates of pest management costs at the firm level (Table 5.7) and percent adoption rates for each of the pest management levels (Table 5.2). Aggregate cost savings are calculated by multiplying the number of acres in Northwestern Michigan and in the entire state by the dollars saved from conventional pest management, the most expensive pest management option (see Table 5.8). All cost savings estimates in Table 5.8 were divided by ten since farm-level cost savings estimates were calculated using a base of ten acres. Percent adoption estimates from Table 5.2 were for tart cherry growers in Northwestern Michigan only. State-wide estimates were also calculated, since pest management practices for tart cherries between Northwest Lower Michigan are not expected to vary substantially from those in the entire state. For the purposes of the impact assessment, it is preferable to obtain separate adoption estimates whenever adoption rates vary in a region.

The estimates in Table 5.8 indicate that for Northwest Lower Michigan and the entire state, intermediate IPM provided the greatest cost saving in 1999. Intermediate IPM provides $449.08 per acre in cost savings over conventional PM. In Northwest Lower Michigan, 7,790 acres were managed using intermediate IPM in 1999 resulting in $350,000 of costs saved over conventional PM for the region. For Michigan as a whole, intermediate IPM saved tart cherry growers $708,000 over conventional PM practices. Basic IPM provided the next greatest level of cost savings followed by advanced IPM. The values for conventional PM were not included since costs savings for IPM levels were calculated using these estimates. The main factors driving these results were the cost of the pesticides applied at each level of pest management and the number of acres receiving each type of pest management practice. The cost variable was influenced by whether the grower used a conventional type sprayer or an air curtain sprayer and the number of applications the grower made during the growing season. The number of acres was a result of the expert's estimates of the level of adoption for each of the pest management levels. A comparison of the cost savings in 1999 versus cost savings in 1980 is not justified since less than two percent of growers were not using any of the practices in the three higher levels of IPM and annual adoption rates between 1980 and 1999 are not available.

Environmental and Human Health Impact Analysis

The purpose of this section of the basic protocol is to report baseline pesticide usage data that, while not producing estimates of the direct effects of pesticide use on the environment and human health, does provide a data set from which further analysis could be done. In addition, this section provides estimates of firm-level pesticide usage that do not exist from other sources. This usage data is also combined with publicly available information on the potential for the pesticides used to cause negative environmental and human health effects. An important assumption made in this study is that growers at each level of pest management use the same pesticides. Since several alternative pesticides exist to control the target pests of tart cherries, and expert opinion was the sole source of data on pesticide usage, the most internally consistent method for estimating pesticide use was to hold the types of pesticides constant and vary the numbers of applications and application rates.

Pesticide use data, including the pesticide name, its function, number of applications, form of the pesticide applied, the target pest, and the percent of growers applying the pesticides at each growth stage are reported for each level of pest management in Tables 5.3-5.6.

Numerous estimates of the environmental and human health effects of pesticides exist. Because the estimates used in this study are the ones in the 1999 Fruit Spraying Calendar (MSUE, 1998), they are readily available to growers when making spray decisions. Data for each of the pesticides include estimates of oral toxicity, dermal toxicity, leaching potential, and run-off potential. The LD_{50} oral and dermal toxicity estimates represent the amount of pesticide, in milligrams per kilogram of body weight, required to kill one-half of the test population. The test population for the oral measure is rats and for the dermal measure, rabbits. (MSUE, 1998). The numbers used were collected from Material Safety Data Sheets which accompany all pesticides or from the Farm Chemical Handbook (MSUE, 1998). They serve as proxies for human health risks in this study.

The leaching and run-off potential estimates are from a database of pesticide properties published by the Natural Resources Conservation Service (NRCS). The numbers are general ratings for the pesticide used and are intended for use with soil ratings for water quality, also from the NRCS (MSUE, 1998). The ratings range from 1 to 3, where a rating of 1 indicates high potential for run-off or leaching and 3 indicates low potential (see Table 5.9).

Since all growers are using the same pesticides, and applying them at different rates, very little may be said about the different environmental and human health effects of the pest management levels. The four risk measures mentioned above do not provide dose-response information about the pesticides. In general, very little information exists on the effects of different levels of pesticide use (full versus alternate row spraying, for example). The number of pesticide applications made by growers at the different pest management levels does vary. However, even with this observation, many factors, like weather conditions and the type of sprayer used to apply the pesticide, can influence the potential these applications have to cause damage to the environment or negative human health effects.

Another method of estimating the environmental and human health effects of pesticide use is to combine ratings of the effects of pesticides on different factors or "endpoints" of concern. The Environmental Impact Quotient (EIQ) developed by Kovach et al. (1992) combines information on the effects of a pesticide on pesticide applicators, pickers of the product, consumers, groundwater, aquatic species, birds, bees, and beneficial organisms into a single number. An EIQ field use rating accounts for the rate at which the chemical was applied, the percent of active ingredient present in the amount applied, and the EIQ. The field use rating is recommended for use when comparing different pest management strategies (Kovach et al., 1992).

EIQ field use ratings have been developed for the different pest management scenarios and are listed in Tables 5.10-5.13. The EIQ field use rating (Kovach et al., 1992) was calculated as :

EIQ field use rating = EIQ * % active ingredient(a.i.) * rate applied (ounces per acre).

Percent active ingredient information was collected from labels for the pesticides listed (CDMS, 2000) while information on the rates used was collected from the list of pesticides applied to tart cherries compiled annually by Gary Thornton, District IPM Fruit Agent (Thornton, 1999). Rate information for herbicides was taken from the 1999 Spray Calendar (MSUE, 1998). The "Rate" column reflects that many producers use alternate row spraying when applying fungicides and insecticides. In the advanced IPM scenario, growers use alternate row spraying but make spray applications with an air curtain sprayer. The sprayer gives coverage comparable to spraying every row, but also applies fungicides and insecticides at about three-quarters the full rate, versus alternate row spraying, in which chemical is applied at one-half the full rate (Nugent and Thornton, 1999).

Since in this study actual use data is not available, the EIQ field use ratings are adjusted to reflect estimates of the number of applications made of each pesticide and the percent of growers in each pest management scenario making applications of the pesticides listed (see columns "# of applications" and "Use adjustment percentage" in Tables 5.10-5.13). These numbers are used to calculate an adjusted EIQ field use rating ("Use-adjusted EIQ rating" in Tables 5.10-5.13) which provides a more accurate ordering of the environmental or human health effects from the pest management scenarios than the EIQ field use rating. The ranking that results from the "Use-adjusted field use rating" ranks intermediate IPM as the best group of pest management practices in term of environmental and human health effects. Basic IPM, advanced IPM, and conventional PM have, respectively, more potential for causing negative environmental or human health effects than intermediate IPM.

An aggregate estimate of the environmental and human health effects of IPM adoption for Michigan can be found in Table 5.14. In Table 5.14, percent reductions in the use-adjusted EIQ field use rating are calculated for each of the pest management scenarios. These numbers provide an estimate of the amount each scenario reduces the potential for negative environmental and human health effects from conventional PM. Conventional PM is used for comparison since it resulted in the greatest potential for negative effects. Estimates of the percent of tart cherry acreage in Michigan managed using each scenario are also listed in Table 5.14. Intermediate IPM provides a 30 percent reduction in the use-adjusted EIQ field use rating on 47 percent of the tart cherry acres in Michigan. A weighted average of the percent change from conventional PM in the use-adjusted EIQ field use rating and the percent of acreage in Michigan managed under each scenario shows that the aggregate reduction in the EIQ estimate is 28 percent.

Limitations of the Environmental and Human Health Risk Measures

Numerous problems exist with the EIQ and the oral and dermal toxicity ratings used above, and to calculate the EIQ. Neither LD_{50} ratings nor the similar lethal concentration (LC_{50}) ratings provides any information about the low-level dose-response effects of a given pesticide. Instead, these ratings provide an estimate of the point at which the dose becomes lethal to 50 percent of the test population, only one point of many on the dose-response curve. The rate at which responses to a pesticide change relative to the dose (slope of the dose-response curve) is very important since some chemicals with very high LD_{50}s may cause severe adverse, though not lethal, effects at low doses (Kamrin, 1997). It is faulty, then, to use these estimates to compare the overall toxicity of different pesticides since each has its own individual dose-response curve. Another common problem is that published EIQ ratings sometimes do not exist for the pesticides used. In this study, EIQ estimates for the sterol inhibitor "Elite" (a.i. tebuconazole) do not exist. So, estimates for two other fungicides in the same class as Elite (sterol inhibitors) were combined and averaged and the resulting number was used as the EIQ estimate for Elite.

Another problem with the EIQ is the weighting of the effects on the factors considered. In the EIQ, the effects of a pesticide on each of the factors mentioned above was determined through a weighting scheme that attempts to account for the toxicity of the pesticide and the risk of environmental exposure. For example, the rating for fish is developed using an estimate of the pesticide's toxicity to fish and the potential for the pesticide to be lost through surface runoff (Kovach et al., 1992). One of the problems with this weighting system is that, while trying to account for the possibility of exposure to a pesticide, the relative importance of each of the factors is not consistent with commonly held values about the importance of effects on different species. For example, the weight given to beneficial arthropods and to pesticide applicators is the same. While this may account for the potential for exposure for each of these species, it does not accurately reflect widely held ethical values about the worth of human life.

Notwithstanding their limitations, the methods used here for ranking potential environmental and human health risks (or ones very similar), are all we have available at the basic protocol level. More complicated methods for developing these estimates would require more time and resources than the eventual users of the basic protocol are expected to have at their disposal. So, the limitations of the methods are recognized as is the fact that some consideration of the risks and benefits of different pest management choices is better than no consideration at all. At the in-depth level, the protocol suggests more complicated and costly ranking procedures.

Discussion of Results

Results of the firm level profitability analysis, aggregate profitability analysis, and the environmental and human health analysis are presented in Table 5.15 and are described in detail below with emphasis on why differences in the results from the different pest management scenarios exist.

At the firm level and the aggregate level, intermediate IPM resulted in average annual variable costs per acre at least $112.20 less than the next best alternative scenario. In addition, using the EIQ field use rating calculation, adjusted for estimates of the percent of growers making the spray application at the time indicated, intermediate IPM also has the lowest negative impact on environmental and human health factors (use adjusted EIQ = 2,944.1). Statewide, intermediate IPM has the lowest potential for causing negative environmental and human health effects on the greatest number of acres and overall, the IPM scenarios reduce the potential for negative environmental and human health consequences by 28 percent over conventional PM.

At the firm level, intermediate IPM is the lowest cost alternative for pest management because at this level, the fewesst growers make sprays at each growth stage using alternate row spraying with a conventional sprayer. In the advanced IPM scenario, even fewer growers make spray applications, but, using an air curtain sprayer they applied more pesticide per acre (see Tables 5.3-5.6 and Tables 5.10-5.13 for rate data). At the intermediate IPM level, the cost of collecting pest management information was greater than for basic IPM or conventional PM, but these were outweighed by lower pesticide costs.

The aggregate number reflects that intermediate IPM is the low cost pest management practice and is also widely adopted by growers in Northwestern Michigan. Intermediate IPM is used to manage pests on an estimated 47 percent of the acreage in Northwestern Michigan (Table 5.2). This number, combined with high cost savings, results in the largest aggregate amount of cost savings for the Northwestern region, and the state.

Intermediate IPM is the pest management scenario with the least pesticide-related impacts on the environment and human health(Table 5.14). Using the EIQ field use rating, and adjusting it for the percent of growers making a spray application at each growth stage and the number of applications made at a given rate, intermediate IPM is the scenario with the lowest numerical ranking. Here again, the remaining pest management scenarios are ordered as in the other categories as: basic IPM, advanced IPM, and conventional PM. Growers using intermediate IPM were ranked as the best because they made fewer applications of the pesticides used than did growers in the basic IPM or conventional PM scenarios. Intermediate IPM adopters were assumed to use a conventional sprayer to make spray applications, often by alternate rows, versus growers in the advanced category who used an air curtain sprayer in every other row. Statewide, intermediate IPM provides the greatest percent reduction in the use-adjusted EIQ field-use rating on the largest number of acres (Table 5.14).

Chapter 6 will discuss these results in more detail, focusing on why the pest management scenarios were ordered as they were, how the protocol design may have influenced the outcome of this project, and how the protocol can be improved for use in the future.

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Table 5.1 Levels of IPM Adoption defined for Michigan Tart Cherries

Levels of IPM Adoption			
Conventional	***Basic IPM***	***Intermediate IPM***	***Advanced IPM***
Primary source of info is chemical dealer/or farm supply dealer			
Strategy to apply pesticides based on calendar approach			
Use of full cover sprays	Uses less than full cover sprays (50%)	Uses less than full cover sprays (50%)	Uses less than full cover sprays (50%)
	Use of plum curculio model	Use of plum curculio model	Use of plum curculio model
	3 hours per week spent monitoring pest populations/collecting relevant IPM info	6 hours per week spent monitoring pest populations/collecting relevant IPM info	More than 8 hours per week spent monitoring pest populations/ collecting relevant IPM info
		Weekly scouting during the growing season (by someone other than chemical dealer/farm supplier) for cherry fruit fly	Weekly scouting during the growing season (by someone other than chemical dealer/farm supplier)
		Use of mowing/chopping to control weeds	Use of mowing/chopping to control weeds
		Pruning/hedging for pest management	Pruning/hedging for pest management
		Use of alternate row spraying	Use of alternate row spraying
		Sprayer calibration (2 of 3 steps)	Sprayer calibration (all three steps)
			Use of border sprays for insect management
			Protection of beneficials
			Use of pheremone bait/lure traps for pest management or monitoring

			Use of air curtain sprayer or tower sprayer or conventional sprayer with electric eye sensor

Table 5.2 Rates of Adoption for IPM Indicator Practices

IPM Level and Pratice	Adoption level and year	% of acres in Northwest lower Michigan represented at each level in 1999 (base = 17,000 acres)
Conventional PM - Use of calendar spraying	1980 - 35% 1999 - 2% Minimum = 2%	2% (~340 acres)
Basic IPM - Use of plum curculio model	1993 - 1% 1999-80% Maximum = 95%	41% (~6,790 acres)
Intermediate IPM - Weekly scouting for cherry fruit fly	1980 - <1% 1999-60% Maximum = 90%	47% (~7,790 acres)
Advanced IPM - Use of air curtain sprayer	1980 - 0% 1999 - 15% Maximum = 30% in twenty years	10% (~1,700 acres)

Source: Nugent and Thornton, 1999
MASS, 1999

Table 5.3 Cost Analysis for Conventional Pest Management

			Labor				Machinery				Materials		Total Variable Costs		
Cost analysis for 10 acres of tart cherries grown in Northwestern MI, 1999	**Target Pest**	**Practice**	**Labor Hours**	**Wage Rate**	**Cost per 10 acre**	**Freq.**	**Equipment**	**Hours of Use**	**Unit Cost**	**Cost per 10 Acres**	**Item**	**Cost per 10 Acres**	**Total VC for Conventional PM**	**% of growers using practice**	**Use-Adjusted VC (vc*%use)**
Pesticide Use															
1 Week to Petal Fall	Brown Rot	Fungicide App (full)	2	12.04	24.08	1	Tractor(80 hp) PTO Sprayer	2 2	13.05 14.48	55.06	Elite 45 DF	174.20	253.34	40%	101.34
Petal Fall	Brown Rot, Leaf Spot	Fungicide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	13.05 14.48	27.53	Bravo 720	142.10	181.67	100%	181.67
1 Week After Petal Fall	Brown Rot, Leaf Spot, Green Fruitworm	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	13.05 14.48	27.53	Bravo 720 Gution 50 WSP	142.10	247.02	100% 80%	233.95
2 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	13.05 14.48	27.53	Elite 45 DF Gution 50 WSP	87.10	192.02	100% 100%	192.02
3 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	13.05 14.48	27.53	Elite 45 DF Gution 50 WSP	87.10	192.02	100% 100%	192.02
4 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	13.05 14.48	27.53	Elite 45 DF Gution 50 WSP	87.10	192.02	100% 100%	192.02
5 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	13.05 14.48	27.53	Elite 45 DF Gution 50 WSP	87.10	192.02	100% 100%	192.02
6 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	13.05 14.48	27.53	Elite 45 DF Gution 50 WSP	87.10	192.02	100% 100%	192.02
7 Weeks After Petal Fall	Leaf Spot, Brown Rot, Cherry Fruit Fly	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	13.05 14.48	27.53	Elite 45 DF Imidan 70 WP	87.10 6	193.37	100% 30%	146.68
Post Harvest	Leaf Spot	Fungicide App (full)	2	12.04	24.08	1	Tractor(80 hp) PTO Sprayer	2 2	13.05 14.48	55.06	Bravo 720	280.42	359.56	85%	305.63
May Herbicide App		Herbicide(full)	4	12.04	48.16	4	Tractor (60 hp) Weed Sprayer	4 4	13.05 9.29	89.36	Princep 4L + Roundup Ultra (2 qt + 1 qt)	38.20 9	266.85	95%	253.51
August Herbicide		Herbicide(full)	4	12.04	48.16	4	Tractor (60 hp) Weed Sprayer	4 4	13.05 9.29	89.36	Gramoxone Extra (1 qt)	73.50	211.02	95%	200.47
Information/Monitoring															
Conventional PM															
Primary source of info is chemical dealer/or farm supply dealer															
Scouting 3 times per growing season by farm employee or self			0.33	$12.04	$3.97	3							11.91	100%	11.91
Total Variable Costs													$2,684.84		$2,395.25

Sources: CDMS, 2000; Kelsey et al., 1997; Nugent et al., 1999; Nugent and Thornton, 1999, Swinton et al., 1997; Thornton, 1999

Table 5.4 Cost Analysis for Basic IPM

			Labor				Machinery				Materials		Total Variable Costs		
Cost analysis for 10 acres of tart cherries grown in Northwestern MI, 1999	Target Pest	Practice	Labor Hours	Wage Rate	Cost per 10 acre	Freq.	Equipment	Hours of Use	Unit Cost	Cost per 10 Acres	Item	Cost per 10 Acres	Total VC for Basic IPM	% of growers using practice	Use Adjusted VC (vc*%use)
Pesticide Use															
1 Week to Petal Fall	Brown Rot	Fungicide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF	174.2	210.82	50%	105.41
Petal Fall	Brown Rot, Leaf Spot	Fungicide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Bravo 720 Guthion 50 WSP	142.10 65.35	244.07	85% 15%	167.21
1 Week After Petal Fall	Brown Rot, Leaf Spot	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Bravo 720 Guthion 50 WSP	142.10 65.35	244.07	75% 40%	205.61
2 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF Guthion 50 WSP	87.10 65.35	189.07	90% 90%	173.82
3 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF Guthion 50 WSP	87.10 65.35	189.07	60% 25%	105.22
4 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF	174.2	210.82	60%	126.49
5 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF Guthion 50 WSP	87.10 65.35	189.07	60% 50%	121.56
6 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF Guthion 50 WSP	87.10 65.35	189.07	95% 80%	171.64
7 Weeks After Petal Fall	Leaf Spot, Brown Rot, Cherry Fruit Fly	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF Imidan 70 WP	87.10 66.70	190.42	95% 30%	139.38
Post Harvest	Leaf Spot	Fungicide App (full)	2	12.04	24.08	1	Tractor(80 hp) PTO Sprayer	2 2	11.65 12.93	49.16	Bravo 720	280.42	353.66	87.5%	309.45
May Herbicide App		Herbicide(full)	4	12.04	48.16	4	Tractor (60 hp) Weed Sprayer	4 4	11.65 8.29	79.76	Princep 4L + Roundup Ultra (2 qt + 1 qt)	38.20 91.13	257.25	95%	244.39
August Herbicide App		Herbicide(full)	4	12.04	48.16	4	Tractor (60 hp) Weed Sprayer	4 4	11.65 8.29	79.76	Gramoxone Extra (1 qt)	73.5	201.42	65%	130.92
Information/Monitoring															
Use of Plum Curculio Model			0.167	12.04	0.40	5							2.01	100%	2.01
Scouting 3 times per growing season by farm employee or self			0.33	12.04	3.97	3							11.91	100%	11.91
3 hours per week spent monitoring pest populations/collecting relevant IPM info			3	$12.04	$7.22	6							43.34	100%	43.34
Total Variable Costs													$2,726.07		$2,058.36

Sources: CDMS, 2000; Kelsey et al., 1997; Nugent et al., 1999; Nugent and Thornton, 1999, Swinton et al., 1997; Thornton, 1999

Table 5.5 Cost Analysis for Intermediate IPM

			Labor				Machinery				Materials		Total Variable Costs		
Cost analysis for 10 acres of tart cherries grown in Northwestern MI, 1999	**Target Pest**	**Practice**	**Labor Hours**	**Wage Rate**	**Cost per 10 acre**	**Freq.**	**Equipment**	**Hours of Use**	**Unit Cost**	**Cost per 10 Acres**	**Item**	**Cost per 10 Acres**	**Total VC for Intermediate IPM**	**% of growers using practice**	**Use Adjusted VC (vc*%use)**
Pesticide Use															
1 Week Before Petal Fall	Brown Rot	Fungicide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF	174.2	210.82	25%	52.71
Petal Fall	Brown Rot, Leaf Spot	Fungicide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Bravo 720 Guthion	142.10 65.35	244.07	85% 10%	163.94
1 Week After Petal Fall	Brown Rot, Leaf Spot	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Bravo 720 Guthion	142.10 65.35	244.07	75% 15%	153.00
2 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF Guthion	87.10 65.35	189.07	90% 90%	173.82
3 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF Guthion	87.10 65.35	189.07	40% 15%	81.26
4 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF	174.2	210.82	40%	84.33
5 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF Guthion	87.10 65.35	189.07	40% 15%	81.26
6 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF Guthion	87.10 65.35	189.07	95% 80%	171.64
7 Weeks After Petal Fall	Leaf Spot, Brown Rot, Cherry Fruit Fly	Fungicide & Insecticide App (alt)	1	12.04	12.04	1	Tractor(80 hp) PTO Sprayer	1 1	11.65 12.93	24.58	Elite 45 DF Imidan 70 WP	87.10 66.70	190.42	95% 35%	142.71
Post Harvest	Leaf Spot	Fungicide App (full)	2	12.04	24.08	1	Tractor(80 hp) PTO Sprayer	2 2	11.65 12.93	49.16	Bravo 720	280.42	353.66	100%	353.66
May Herbicide App		Herbicide(full)	4	12.04	48.16	4	Tractor (60 hp) Weed Sprayer	4 4	11.65 8.29	79.76	Princep 4L + Roundup Ultra (2 qt + 1 qt)	38.20 91.13	257.25	95%	244.39
August Herbicide App		Herbicide(full)	4	12.04	48.16	4	Tractor (60 hp) Weed Sprayer	4 4	11.65 8.29	79.76	Gramoxone Extra (1 qt)	73.5	201.42	65%	130.92
Information/Monitoring															
Use of Plum Curculio Model			0.167	$12.04	$0.40	5							2.01	100%	2.01
Weekly scouting during the growing season (by someone other than chemical dealer/farm supplier) for cherry fruit fly			0.33	$12.04	$3.97	6							23.82	100%	23.82
6 hours per week spent monitoring pest populations/collecting relevant IPM info			6	$12.04	$14.45	6							86.69	100%	86.69
Total Variable Costs													$2,781.33		$1,946.16

Sources: CDMS, 2000; Kelsey et al., 1997; Nugent et al., 1999; Nugent and Thornton, 1999, Swinton et al., 1997; Thornton, 1999

Table 5.6 Cost Analysis for Advanced IPM

			Labor				Machinery				Materials		Total Variable Costs		
Cost analysis for 10 acres of tart cherries grown in Northwestern MI, 1999	**Target Pest**	**Practice**	**Labor Hours**	**Wage Rate**	**Cost per 10 acre**	**Freq.**	**Equipment**	**Hours of Use**	**Unit Cost**	**Cost per 10 Acres**	**Item**	**Cost per 10 Acres**	**Total VC for Advanced IPM**	**% of growers using practice**	**Use Adjusted VC (vc*%use)**
Pesticide Use															
1 Week to Petal Fall	Brown Rot	Fungicide App (alt)	0.8	12.04	9.63	1	Tractor(80 hp) Curtec Sprayer	0.8	11.65 15.91	22.05	Elite 45DF	130.65	162.33	10%	16.23
Petal Fall	Brown Rot, Leaf Spot	Fungicide App (alt)	0.8	12.04	9.63	1	Tractor(80 hp) Curtec Sprayer	0.8	11.65 15.91	22.05	Bravo 720 Guthion 50 WSP	213.15 91.49	336.32	85% 5%	217.43
1 Week After Petal Fall	Brown Rot, Leaf Spot	Fungicide & Insecticide App (alt)	0.8	12.04	9.63	1	Tractor(80 hp) Curtec Sprayer	0.8	11.65 15.91	22.05	Bravo 720 Guthion 50 WSP	213.15 91.49	336.32	75% 15%	205.27
2 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	0.8	12.04	9.63	1	Tractor(80 hp) Curtec Sprayer	0.8	11.65 15.91	22.05	Elite 45DF Guthion 50 WSP	130.65 91.49	253.82	90% 90%	231.61
3 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	0.8	12.04	9.63	1	Tractor(80 hp) Curtec Sprayer	0.8	11.65 15.91	22.05	Elite 45DF Guthion 50 WSP	130.65 91.49	253.82	40% 15%	97.66
4 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide App (alt)	0.8	12.04	9.63	1	Tractor(80 hp) Curtec Sprayer	0.8	11.65 15.91	22.05	Elite 45DF	130.65	162.33	40%	64.93
5 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	0.8	12.04	9.63	1	Tractor(80 hp) Curtec Sprayer	0.8	11.65 15.91	22.05	Elite 45DF Guthion 50 WSP	130.65 91.49	253.82	40% 15%	97.66
6 Weeks After Petal Fall	Leaf Spot, Plum Curculio	Fungicide & Insecticide App (alt)	0.8	12.04	9.63	1	Tractor(80 hp) Curtec Sprayer	0.8	11.65 15.91	22.05	Elite 45DF Guthion 50 WSP	130.65 91.49	253.82	95% 80%	228.99
7 Weeks After Petal Fall	Leaf Spot, Brown Rot, Cherry Fruit Fly	Fungicide & Insecticide App (alt)	0.8	12.04	9.63	1	Tractor(80 hp) Curtec Sprayer	0.8	11.65 15.91	22.05	Elite 45DF Imidan 70WP	130.65 93.38	255.71	95% 35%	188.48
Post Harvest	Leaf Spot	Fungicide App (full)	0.8	12.04	9.63	1	Tractor(80 hp) Curtec Sprayer	0.8	11.65 15.91	49.16	Bravo 720	213.15	271.94	100%	271.94
May Herbicide App		Herbicide(full)	4	12.04	48.16	4	Tractor (60 hp) Weed Sprayer	4 4	11.65 8.29	79.76	Princep 4L + Roundup Ultra (2 qt + 1 qt)	38.20 91.13	257.25	95%	244.39
August Herbicide App		Herbicide(full)	4	12.04	48.16	4	Tractor (60 hp) Weed Sprayer	4 4	11.65 8.29	79.76	Gramoxone Extra (1 qt)	73.5	201.42	65%	130.92
Information/Monitoring															
Use of Plum Curculio Model			0.167	12.04	0.40	5							2.01	100%	2.01
Weekly scouting during the growing season (by someone other than chemical dealer/farm supplier)			0.33	12.04	3.97	6							23.82	100%	23.82
More than 8 hours per week spent monitoring pest populations/collecting relevant IPM info			8	$12.04	$19.26	6							115.58	100%	115.58
Total Variable Costs													$3,140.32		$2,136.93

Sources: CDMS, 2000; Kelsey et al., 1997; Nugent et al., 1999; Nugent and Thornton, 1999, Swinton et al., 1997; Thornton, 1999

Table 5.7 Summary of annual pest management costs for 10 acres of Michigan tart cherries under four pest management scenarios

Pest management scenario	Variable costs	Use adjusted variable costs
Conventional pest management	$2684.84	$2395.24
Basic IPM	2726.07	2058.36
Intermediate IPM	2781.33	1946.16
Advanced IPM	3160.57	2155.67

Table 5.8 Aggregate annual cost savings from pest management alternatives for Northwest Lower Michigan and the State

Pest management level	**Cost savings per acre over conventional PM**	**Tart cherry acres in Northwest lower Michigan**	**Cost Savings for Northwest lower Michigan**	**Tart cherry acres in Michigan**	**Cost Savings for the state**
Conventional PM	$0	340	N/A	670	N/A
Basic IPM	336.88	6,790	$229,000	13,735	$463,000
Intermediate IPM	449.08	7,790	350,000	15,745	708,000
Advanced IPM	239.57	1,700	41,000	3,350	80,000
Total	N/A	16,620	$620,000	33,500	$1,284,500

Table 5.9 Toxicity and runoff and leaching potentials for the pesticides used by growers in the study

Commercial Pesticide Name (common)	Oral LD50 mg/kg	Dermal LD50 mg/kg	Runoff Potential (1=high 3=low)	Leaching Potential (1=high 3=low)
Elite 45 DF (tebuconazole)	4,000	>5,000	-	-
Bravo 720 (chlorothalonil)	>10,000	10,000	1	3
Imidan 70 WP (phosmet)	113-681	1,560-4,640	2	3
Guthion 50 WSP (azinphos-methyl)	4	150-200	2	3
Princep 4L (simazine)	>5,000	>3,100	2	1
Roundup Ultra (glyphosate)	>5,000	>5,000	1	3
Gramoxone Extra (paraquat)	20-150	236-325	1	3

Source: MSUE, 1998

Table 5.10 EIQ field use rating for conventional pest management in Michigan tart cherries[3]

EIQ field use rating = EIQ * % active ingredient(a.i.) * rate applied (oz. per acre)
Use-adjusted EIQ rating = EIQ field use rating * # of applications * Use adjustment percentage

Pesticide applied	EIQ	% a.i.	Rate per acre	EIQ field use rating	# of applicat-ions	Use adjustment percentage	Use- adjusted EIQ rating
Bravo 720*	46	54	16	397.4	1	85	337.8
Bravo 720	46	54	8	198.7	2	100	397.4
Elite 45 DF*	34.3	45	6	92.6	1	40	37.04
Elite 45 DF	34.3	45	3	46.3	6	100	277.8
Guthion 50 WSP	43.1	50	12	258.6	6	96.67	1,499.9
Gramoxone Extra*	70	37	32	828.8	1	95	787.4
Imidan 70 WP	23.9	70	18.4	307.8	1	30	92.3
Princep 4L*	15.7	41.9	64	421.0	1	95	400.0
Roundup Ultra*	32.4	41	32	425.1	1	95	403.8
				Total = 2,976.3			Adj. total = 4,233.4

*Indicates a full rate application
Source: Kovach et al.(1992)
CDMS (2000)

[3]EIQ estimates for Elite 45 DF (tebuconazole) were not available. The EIQ rating used in this series of tables is an average of the EIQ rating for two fungicides, Rubigan (fenarimol) and Nova (myclobutanil), in the same chemical class as Elite 45 DF.

Table 5.11 EIQ field use rating for basic IPM in Michigan tart cherries

EIQ field use rating = EIQ * % active ingredient(a.i.) * rate applied (oz. per acre)
Use-adjusted EIQ rating = EIQ field use rating * # of applications * Use adjustment percentage

Pesticide applied	EIQ	% a.i.	Rate per acre	EIQ field use rating	# of applicat-ions	Use adjustment percentage	Use- adjusted EIQ rating
Bravo 720*	46	54	16	397.4	1	87.5	347.7
Bravo 720	46	54	8	198.7	2	75	298.1
Elite 45 DF	34.3	45	3	46.3	7	72.9	236.3
Guthion 50 WSP	43.1	50	12	258.6	6	50	775.8
Gramoxone Extra*	70	37	32	828.8	1	65	539.0
Imidan 70 WP	23.9	70	18.4	307.8	1	30	92.3
Princep 4L*	15.7	41.9	64	421.0	1	95	400.0
Roundup Ultra*	32.4	41	32	425.1	1	95	403.8
				Total = 2,883.7			Adj. total = 3,093

*Indicates a full rate application
Source: Kovach et al.(1992)
CDMS (2000)

Table 5.12 EIQ field use rating for intermediate IPM in Michigan tart cherries

EIQ field use rating = EIQ * % active ingredient(a.i.) * rate applied (oz. per acre)
Use-adjusted EIQ rating = EIQ field use rating * # of applications * Use adjustment percentage

Pesticide applied	EIQ	% a.i.	Rate per acre	EIQ field use rating	# of applicat-ions	Use adjustment percentage	Use- adjusted EIQ rating
Bravo 720*	46	54	16	397.4	1	100	397.4
Bravo 720	46	54	8	198.7	2	80	317.9
Elite 45 DF	34.3	45	3	46.3	7	60.7	196.7
Guthion 50 WSP	43.1	50	12	258.6	6	37.5	581.9
Gramoxone Extra*	70	37	32	828.8	1	65	538.7
Imidan 70 WP	23.9	70	18.4	307.8	1	35	107.7
Princep 4L*	15.7	41.9	64	421.0	1	95	400.0
Roundup Ultra*	32.4	41	32	425.1	1	95	403.8
				Total = 2,883.7			Adj. total = 2,944.1

*Indicates a full rate application
Source: Kovach et al.(1992)
CDMS (2000)

Table 5.13 EIQ field use rating for advanced IPM in Michigan tart cherries

EIQ field use rating = EIQ * % active ingredient (a.i.) * rate applied (oz. per acre)
Use-adjusted EIQ rating = EIQ field use rating * # of applications * Use adjustment percentage

Pesticide applied	EIQ	% a.i.	Rate per acre	EIQ field use rating	# of applicat-ions	Use adjustment percentage	Use- adjusted EIQ rating
Bravo 720*	46	54	16	397.4	1	100	397.4
Bravo 720	46	54	10.7	265.8	2	80	425.3
Elite 45 DF	34.3	45	4	61.7	7	58.6	253.1
Guthion 50 WSP	43.1	50	16	344.8	6	36.7	759.2
Gramoxone Extra*	70	37	32	828.8	1	65	538.7
Imidan 70 WP	23.9	70	24.5	410.0	1	35	143.5
Princep 4L*	15.7	41.9	64	421.0	1	95	400.0
Roundup Ultra*	32.4	41	32	425.1	1	95	403.8
				Total = 3,154.6			Adj. total = 3,321

*Indicates a full rate application
Source: Kovach et al.(1992)
CDMS (2000)

Table 5.14 Aggregate annual EIQ field use rating results for Michigan tart cherry pest management scenarios

Pest management level	Use-adjusted EIQ field use rating	% change from Conventional PM in use-adjusted EIQ field use rating	% of acreage in Michigan managed under scenario
Conventional PM	4,233.4	0%	2%
Basic IPM	3,093	-27%	41%
Intermediate IPM	2,944.1	-30%	47%
Advanced IPM	3,321	-22%	10%
Aggregate EIQ change	-----	-28%	-----

Table 5.15 Summary of profitability and environmental and human health effects for IPM in Michigan tart cherries

Pest Management Scenario	Use-adjusted variable costs	Aggregate cost savings in Northwestern Michigan	Use-adjusted EIQ rating	% Change from Conventional PM
Conventional PM	$2,395.24	$0	4,233.4	0%
Basic IPM	$2,058.36	$229,000.00	3,093	-27%
Intermediate IPM	$1,946.16	$350,000.00	2,944.1	-30%
Advanced IPM	$2,155.67	$41,000.00	3,321	-22%
Aggregate IPM impact	-----	$620,000.00	-----	-28%

Chapter 6:

Conclusions and Reflections on the Assessment Protocol

The purpose of this chapter is to discuss why the pest management scenarios were ordered as they were, how the requirements of the basic assessment protocol may have influenced the outcome of the IPM impact assessment, and how the basic assessment protocol can be improved for use by IPM and extension specialists in the future.

Explanation of the Orderings

A surprising result from this study is the ranking of the advanced IPM scenario in all of the categories in table 5.15. The IPM practices in the advanced IPM category are adopted by only the most progressive growers, and so, one would expect this category to have the lowest cost for pest management with the fewest negative environmental and human health impacts. The practice used to gauge adoption in this category is ownership of an air curtain sprayer. While an early study predicted that use of the air curtain sprayer would reduce pesticide use by about 40 percent compared with conventional sprayers (Swinton et al., 1997), it now appears that growers using the air curtain sprayer apply about 75 percent as much pesticide as growers using a conventional sprayer and spraying every row (Nugent and Thornton, 1999). This fact alone means that growers with air curtain sprayers will have higher pesticide costs than growers who spray every other row with a conventional sprayer. Another characteristic of the air curtain sprayer is that it can cover more area per hour than conventional sprayers (Swinton et al., 1997). What this means in practice is that growers using the sprayer can wait longer to decide whether a spray is needed than growers using conventional sprayers (Nugent and Thornton, 1999). Growers with the air curtain sprayer will make fewer sprays over the growing season than growers using a conventional sprayer. Nugent and Thornton (1999) accounted for this in their estimates of the percentage of growers making pesticide applications at each growth stage.

The Basic Assessment Protocol: Data Influences and Future Recommendations

There are several aspects of the basic assessment protocol which may have influenced the orderings of the pest management scenarios. Included in these are heavy reliance on expert opinion and perceptions of a rapidly changing IPM technology. The latter could be a special challenge to the user of the assessment protocol.

The basic assessment protocol recommends that secondary data sources and expert opinion be used for IPM impact assessment. For this study, expert opinion was used extensively to collect data on the IPM practices being used and their levels of adoption among tart cherry growers in Northwest Lower Michigan. The experts interviewed are, by far, the most knowledgeable IPM extension specialists who deal primarily with tart cherries. Nonetheless, it is possible that the opinions of these experts about IPM practices and adoption differ from actual practices.

In future applications of the assessment protocol, expert opinion is appropriate for collecting data that does not exist elsewhere. However, users of the assessment protocol should be encouraged to collect data from a variety of experts, including actual growers, IPM consultants, crop scouts, and extension specialists. This study would have benefitted from input from a variety of IPM specialists.

Another factor that may have influenced the rankings of the IPM practices in this study is the nature of the air curtain sprayer technology. Ownership of an air curtain sprayer was considered the indicator practice for those growers in the advanced IPM category. The air curtain sprayer is a relatively new type of sprayer used by only a few growers, some of whom may still be adjusting their pest management practices to the new technology. It is possible that the pesticide usage estimates the experts reported in this study are appropriate only for growers with little knowledge about the use and benefits of the air curtain technology. Specifically, the growers on whom the experts based their opinions may have been failing to adjust their spray rates downward to accommodate the air curtain sprayer (Nugent, 2000). In future IPM assessments, it is crucial that users of the protocol collect detailed information about IPM practices that are new to the experts interviewed.

To summarize the future recommendations for users of the basic assessment protocol, it is important to understand the basis for these recommendations. The basic assessment protocol was designed to outline data needs and methods for assessing an IPM project. To determine whether the protocol was successful at outlining these data needs and methods, the following questions should be answered:

1) Did the data requirements allow for complete and accurate data collection?

2) Were the methods of analysis suggested by the protocol useable by the intended audience?

3) Was the time requirement for data collection and analysis appropriate?

Whether the data requirements and analytical methods suggested in the protocol allowed for complete and accurate data collection was largely answered in the discussion of expert opinion and new IPM technologies above. More effort should be made by users of the protocol in the future to collect information from a variety of sources instead of relying on only two IPM experts. This is especially relevant since the intended users of the protocol will likely be able to complete much of the data collection from their own experience. Extension agents or IPM specialists who use the basic assessment protocol in the future should take care to interview as many other IPM specialists and growers/farmers as possible when they are unsure of the answer to questions about an IPM practice.

The methods of analysis suggested in the protocol are useable by the protocol's intended users. For the profitability analysis, a cost analysis like the one performed in this study could easily be implemented by an extension specialist. A concern here, though, is the availability of information on specific IPM, and other, production practices. For tart cherries, a number of current publications were available for use in the cost analysis. Had IPM in another commodity been examined, like strawberries, such data would not have been so easy to find. A similar situation existed in the environmental and human health impact analysis where certain estimates were available for some chemicals, but not all. This should be a consideration for those agencies who might require IPM program assessment at some future date. The data requirements and methods recommended in the basic assessment protocol are appropriate for those commodities where the needed data exist. The discontinuation of funding for an IPM project because the administrator fails to complete an assessment that is built around the use of non-existent data should not be a result of this protocol. Special consideration for data limitations should be built into the assessment protocol for future applications.

Finally, the time and effort required to implement this protocol would have been appropriate had this researcher been an IPM specialist working with tart cherries. My lack of experience in the IPM and tart cherry fields required that a much greater amount of time and effort be put forth. My experience with the protocol is important, though, since it highlights the time required to correctly apply the protocol when one is not familiar with the topic. This, too, should be a consideration for those who might require the use of the protocol at some future date.

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