# Measuring IPM Adoption in South Florida Vegetable Crops

# Research Report

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## Introduction

Florida vegetable growers annually face some of the most intense insect and disease pressure in the United States. Their response to predictably heavy pest pressure, and to frequent new challenges from introduced pests and new strains of plant pathogens, has been to develop sophisticated integrated pest management (IPM) systems. These frequently include important IPM components such as regular scouting and the use of economic or damage-related thresholds, securing disease-free planting material and a range of other practices and tactics (Swisher, 1995; Funderburk and Chellemi, 1996; Bauske, et al, 1998). Still, pesticides have continued to bear the major burden in managing pests within these systems. Non-chemical control options have not become established to the extent biologically based approaches are now technically and economically feasible. The hesitance to adopt new approaches reflects concern over potentially serious economic losses, given the high value of our major fruit and vegetable crops and low market tolerance for blemishes in fresh produce like tomatoes and peppers.

Notable exceptions to this pesticide-based approach to pest management include the development of disease-resistant varieties, which have decreased losses to diseases, such as bacterial spot in peppers and *Fusarium* crown rot in tomatoes, while reducing, but not eliminating, the need for pesticide applications to avoid losses from other sources. Further, the recent commercial introduction of several insecticides that are less damaging to beneficial arthropods than conventional organophosphate and carbamate products has led some growers to adopt more sophisticated IPM systems that are proving effective and much less damaging to the environment.

Clearly, this trend is encouraging. To promote, and perhaps one day reward, the movement from conventional, chemical-intensive IPM systems programs to environmentally friendly, bio-intensive IPM, better methods are needed to highlight the key tactical transitions that a grower must move through from low level to biointensive IPM, and to quantify the linkages between progress along the IPM continuum and reliance on pesticides with their associated risks and environmental damage.

Past surveys of Florida vegetable growers' IPM practices indicate that there is a high level of basic IPM adoption; i.e., the use of scouting and thresholds to trigger pesticide applications (Bauske, et al, 1997; Swisher, 1995). While these surveys indicate some level of IPM adoption on over 75% of tomato acreage and 97% of potato acreage, they fail to provide a means of evaluating in detail the impact of these IPM programs on pesticide reliance and use, and on the total agroecosystem including soils, water, crops, pests, and non-target organisms ranging from beneficial biological control agents to local wildlife, and indeed farm workers and consumers.

The focus of this project is to develop and test a method to measure the linkages between IPM adoption, pesticide reliance and use, and pesticide risks in the context of intensive Florida vegetable production. Our work builds on the IPM measurement methodology set forth in Benbrook, et al, 1996, and incorporates preliminary results from a multiattribute toxicity ranking model under development for monitoring the impacts of Food Quality Protection Act (FQPA) implementation (C.M. Benbrook, personal communication).

The IPM measurement methodology we have applied allows a more refined measurement of the total IPM program than in previous surveys by assessing two basic components on a given field: actual IPM practices utilized, and the pesticide applications required to keep pests below damage thresholds. The more fully integrated and prevention-oriented the pest management program, the higher it will fall along the "IPM continuum". A grower whose program includes scouting and the use of thresholds, but still relies solely on pesticide applications for pest management, would be placed in the "no" or "low" level on the IPM continuum.

## Materials and Methods

The IPM measurement method used in this survey consisted of three parts: a survey of growers' pest management practices, a review of their pesticide applications for representative fields, and the construction of an IPM continuum. The intent of our IPM continuum is to gain insights into the effectiveness of different IPM systems in terms of pesticide use and risks, and to highlight the clusters of additional practices growers need to integrate into their systems in order to profitably progress along the continuum.

**IPM Survey:** To establish points for a given grower's IPM practices, a questionnaire was prepared which addressed preventive practices for insect and disease management and issues of sound crop management. Respondents were asked to provide information on the size of their farms, the crops grown, basic cultural practices, and the economics of their crop and pest management systems. Each item on the survey was weighted according to Glades Crop Care's empirical understanding of its contribution to a biologically intensive pest management program. Weights ranged from 1 to 8. For example, a grower responding positively to releasing beneficial insects could score up to 4 points, depending on the level of implementation. Similarly, he or she could score up to 2 points for monitoring insects on field margins, but would get only 1 point for calibrating spray equipment.

Respondents were asked to indicate how frequently or intensively each item was practiced on the farm. The possible responses, never, seldom, sometimes, often and always, were assigned values of 0, 0.25, 0.50, 0.75, and 1, respectively. The final point value of each item was obtained by multiplying this weight by the response value. The questionnaires were divided into sections according to the focus of each item; i.e., general, disease management, and insect management. Total points were calculated for each section separately and for the entire questionnaire.

**Pesticide Use Survey:** Questionnaire respondents were asked to supply detailed information about their pesticide programs in the survey crops. In some cases, the grower's entire set of pesticide records was made available for examination. Some respondents, citing concerns for the security of these records, provided transcriptions of pesticide applications for representative fields. Fields were selected for examination from the fall and spring crops in tomatoes and peppers. Fall crop fields were planted in August and September, 1996, and spring crops in December and January, 1996. Large plantings occur during these months, and either reduced plantings or planting breaks take place in October and November. The potato crop was not divided in this manner, as plantings are usually of uniform size throughout the October to January planting season on a given farm.

For farms with more than one field, the average number of applications of each pesticide, and average rates of application, were determined for each pesticide applied. In cases where only one field's records were used, the applications were tallied for each product at its average or common use rates. Using these figures and the active ingredient (a.i.) content of each product, the amount of a.i. used for each product was determined.

**Pesticide Impact Evaluation:** Since pesticides vary greatly in their toxicity on a pound-for-pound basis, we developed a method to adjust pesticide use for the inherent toxicity of products. Acute and chronic mammalian toxicity values were obtained from the database and toxicity adjustment model used in Benbrook, et al., 1996; and C.M. Benbrook, personal communication. The active ingredients identified in the pesticide use survey were assigned relative weights reflecting their contribution to the overall mammalian toxicity and risk associated with a given respondent's crop and IPM system. The values used for these weights consisted of "Acute Toxicity Units" (inverse LD-50s) and a measure of chronic mammalian toxicity that is derived from Reference Dose and oncogenicity data in U.S. EPA documents (Benbrook, et al., 1996).

The acute mammalian toxicity factor incorporates the inverse of each chemical's LD-50 and a scaling factor. The chronic mammalian factor incorporates the following variables:

RfD = Reference Dose or other available estimate

ED = Endocrine Disrupter : if yes, ED = 3; if no, ED = 1

Q* = EPA cancer potency or best estimate available

CLASS = EPA Oncogenicity Class: if A of B/2, value = 10; if C, value = 5; if D, value = 2.

These variables were combined in the formula:

$$\text{Mam Tox Score} = [(0.01/\text{RfD}) \times (\text{ED})] + [50 \times (Q^*) \times (\text{CLASS})]$$

The mammalian toxicity score for each a.i. was multiplied by the pounds of a.i. applied per acre in each of the crops. This allowed the evaluation of the chronic human risk factors, a key step in assessing the overall risk profile associated with the pesticides applied on each farm. The weighted a.i.'s were then sorted according to their total mammalian toxicity rank among all a.i.'s. A second ranking was made within each general group of pesticide types; i.e., fungicides, insecticides, herbicides and miticides.

The original expectation of this project was to evaluate the total biological compatibility of growers' IPM programs. The mammalian toxicity adjustment factors allowed evaluation of one aspect of this compatibility. Indices for environmental toxicity and IPM compatibility are current being developed (C.M. Benbrook, personal communication). When and as such new indices become available, they will be added to our toxicity adjustment methodology to further refine the current analysis. Our results to date highlight significant tradeoffs in terms of risks as growers shift from one family of chemistry to others, and to more biologically-based products. While critical to project human health impacts, a more comprehensive toxicity adjustment methodology is essential to avoid shifting significant risks from one part of the environment to another. The capability to more comprehensively monitor trends in all major categories of pesticide risks will become increasingly important as pest management systems and pesticide use patterns evolve.

**IPM Continuum Score Determination:** The IPM Continuum Score for each crop was determined by the method described in Benbrook, et al, 1996. Scores for preventive practices (PPP) identified in the IPM survey were totaled for each of the three portions of the survey, General, Insect Management, and Disease Management. Three continuum scores were determined using these PPP's and the weighted pesticide data from the pesticide use survey: a Total IPM Continuum Score, a Disease Management IPM Continuum Score, and an Insect Management IPM Continuum Score. These scores were calculated by dividing the PPP's by the appropriate mammalian toxicity unit values using the following formulas:

- Total IPM Continuum Score = [(General PPP + Insect Management PPP + Disease Management PPP)/(Total Mammalian Toxicity Units / Acre for all groups of a.i.'s)]

- Disease IPM Continuum Score = [(General PPP + Disease Management PPP)/(Total Mammalian Toxicity Units / Acre for fungicide a.i.'s)]

- Insect Management IPM Continuum Score = [(General PPP + Insect Management PPP)/(Total Mammalian Toxicity Units / Acre for insecticide and miticide a.i.'s)]

The IPM Continuum Scores produced from these calculations are useful from a number of standpoints. The scores themselves can be compared, vegetable grower IPM practice results can be ranked, and these rankings can in turn be compared to rankings derived from other similar surveys (Bauske, et al, 1997; Vandeman, et al, 1994).

## Results

Seventeen responses were obtained which represent nearly 9,600 acres of potatoes, tomatoes and peppers (Table 1) and a geographical area approximately 160 miles in diameter centered in the Immokalee, FL growing area. Size ranged from 35 acres of peppers at Farm P to 1,800 acres of tomatoes at Farm I. Average farm acreage by crop was 665 acres in potatoes, 757 tomatoes, and 343 peppers. These crop acres represented the major effort for most growers, with over 50% of total farm acreage devoted to the surveyed crops for 11 of the 17 respondents. Of the 30 responses sought, 12 from client and 18 from non-client users of Glades Crop Care's services, 11 client and 6 non-client responses were received.

**General IPM Practices:** The results of the growers' IPM practices survey show that south Florida vegetable growers regularly use multiple tactics to manage insect and disease pests of potatoes, tomatoes and peppers (Appendix A: Tables A1-A9). In the general IPM practices section, growers most often responded positively to five practices:

- remaining up to date regarding pest problems;
- scouting their crops regularly, whether in person or using a consultant;
- maintaining and using written scouting records;
- using best management practices to ensure crop vigor; and,
- destroying the crop and its residue according to pest threat.

Less frequently used practices were intercropping, manipulating planting schedules, and cleaning field equipment when moving from field to field. High land rents, intensive land preparation, crop maintenance schedules, and crop marketing demands are likely causes for the low level of use for these practices.

Responses to the question on sprayer calibration and maintenance indicate a low priority for this element of proper pesticide use. However, most respondents did monitor the acreage covered by each of their sprayers as a means of ensuring that the desired output was maintained.

**Disease IPM Practices:** Responses to this part of the survey generally reflected the growers' major disease control concerns for the three crops: late blight in potatoes and bacterial spot in tomatoes and peppers. Preplant or at-planting treatments were commonly used to ensure a pest-free soil planting bed. These treatments included methyl bromide/chloropicrin fumigation in the plastic-mulched tomato and pepper crops. Nematicide treatments in potatoes were used in nearly all fields, with lower use of at-planting fungicides. Frequently used practices included inspection and care for potato seed pieces and tomato and pepper transplants for disease reduction and/or exclusion. Growers expressed a high willingness to reject diseased planting material. Yet, the majority of tomato and pepper growers rejected destroying a planting if either of these diseases was found within the first three weeks after planting. Both tomato and pepper growers commonly modified hand labor practices by disinfecting workers' hands periodically during tasks such as pruning and tying to minimize disease spread.

The use of disease resistant varieties received positive responses among pepper growers, where varieties resistant to races 1, 2, and 3 of the bacterial spot pathogen, *Xanthomonas campestris* pv. *vesicatoria*, have become widely planted. An exception to this practice was Farm B, where only jalapeño peppers are grown. No bacterial spot resistant varieties of jalapeño peppers are available.

The responses of tomato growers to this question were more varied. While a variety resistant to *Fusarium* crown rot disease is available, inadequate horticultural characteristics limit its use. Two respondents had access to proprietary resistant varieties and used them in fields known to have a history of the disease.

Potato growers had mixed responses to resistant variety use since none are available.

The link between cultural practices and disease management has been widely recognized among survey respondents. Management of water tables as a means of managing root and stem diseases received mostly positive responses. Choosing liming and fertilization as disease management tools was not quite as high, but was considered at least 50% of the time. This is important in the tomato and potato crops, where differences in pH and nitrogen sources can promote the soil-borne *Fusarium* and scab diseases.

Crop rotation and addition of mycorrhizal organisms to soil were generally not used. This is probably due to market-driven farming decisions and lack of clearly demonstrated efficacy, respectively.

**Insect IPM Practices:** Insect management practices are intensive in Florida's vegetable crop. Growers frequently used scouting for both pest and, to a lesser degree, beneficial insect species in all crops. Thresholds were cited as very important in intervention decision-making by the majority of respondents; however, thresholds are not the only application trigger. The number of responses in the "sometimes" and "often" categories reflects the programmatic applications of imidacloprid for protection against viruliferous silverleaf whiteflies, *Bemisia argentifolii,* in tomatoes and against melon thrips, *Thrips palmi*, in some pepper fields. Also, routine beet and southern armyworm pressure during the fall crop results in regular applications of *Bacillus thuringiensis* (*B.t.*) products in tomatoes and peppers, although this practice usually ends when insect pressure decreases in October.

Respondents expressed a willingness to delay insecticide applications at times if beneficial insects were present, even though thresholds had been exceeded. The use of biologically friendly pesticides, such as *B.t.*, over standard pesticides was more frequently cited in tomato and pepper crops than in potatoes. Most growers used adjuvants such as crop oils or spreader/stickers to enhance the activity of insecticides allowing a lower a.i. use rate. Rotating among classes of insecticides to delay the development of pesticide resistance was used by a majority of respondents.

Infrequently used practices included the maintenance of unsprayed refugia or the use of cover crops in non-crop areas specifically for promotion of beneficial insects. Weed control as an insect pest management tool was more frequently cited by tomato growers than potato or pepper growers. Releasing beneficial insects and the use of pheromone traps as monitoring tools were seldom used.

Scores for responses to individual questionnaire topics are summarized in Appendix A: Tables A10 - A18. Overall scores are summarized in Table 2. With few exceptions, respondents received 50% or more of the total points possible in each section of the questionnaire. All respondents scored between 50.80% and 68.75% of all possible points in all questionnaire sections. These scores place respondents in the “medium” IPM implementation category, as defined by Bauske, et al, 1997 (Table 13). In the Disease Management portion of the questionnaire, all respondents placed in the medium implementation level. In the Insect Management portion, all respondents except potato Farm F, tomato Farm O, and pepper Farms G and M placed in the medium IPM implementation level. These farms placed in the low level along the IPM continuum.

Using the criteria set forth by Vandeman, et al, 1994, – scouting and application in accord with thresholds, plus at least three other preventive practices – all growers fall into the high category when combined insect and disease management are considered (Table 13). For disease management, respondents placed in the high level, except tomato Farm E and pepper Farm B. For insect management, potato Farm H was in the high category, and the remaining respondents fell into the medium implementation level. Noticeably, potato Farm F and pepper Farm G fell into the low level.

**Pesticide Use Survey:** The results of the pesticide use survey are summarized in Table 3 (all crops) and detailed in Appendix B, Table B1 (potatoes), Tables B2 - B4 (tomatoes) and Tables B5 - B7 (peppers). In potatoes, 8 fungicides, 5 herbicides, 9 insecticides, and 1 fumigant, chloropicrin, were used, totaling 23 a.i.’s. In tomatoes, 11 fungicides, 4 herbicides, 17 insecticides and 2 fumigants, methyl bromide and chloropicrin, were used, totaling 34 a.i.’s. In peppers, 5 fungicides, 4 herbicides, 22 insecticides, 2 miticides and 2 fumigants, methyl bromide and chloropicrin, were used, totaling 35 a.i.’s. Fumigant use is summarized in Table B8. Due to the high mammalian toxicity values for methyl bromide, these were not included in any of the IPM impact calculations. This was to allow for a more consistent comparison of programs among the three surveyed crops. Chloropicrin was used in one potato field, and methyl bromide and chloropicrin were used in all pepper and tomato fields in the survey.

- ***Fungicides:*** In potatoes, fungicides were directed primarily against late blight disease, caused by *Phytophthora infestans*, US 8 and US 17, which was epidemic during the 1996 - 97 season. Standard University of Florida recommendations call for application of protectant fungicides, chlorothalonil and mancozeb, for this disease. Other protectants, metiram and triphenyltin hydroxide, were used less often. Two other fungicides, propamocarb and metalaxyl, were infrequently used.

Fungicide use in peppers was primarily for control of bacterial spot disease, caused by *Xanthomonas campestris* pv. *vesicatoria* (XCV). The protectant EBDC fungicide, maneb, was commonly used as a tank mix with one of several copper formulations, usually copper hydroxide or copper sulfate. Copper and maneb were used sparingly at Farm C compared to other respondent fields. This grower appears to have taken greater advantage of the varietal resistance to bacterial spot disease than the other pepper growers. However, the increasing presence of XCV Race 6, to which there currently are no resistant varieties, appears to justify the increased amounts of fungicide for control of this disease.

Farm B is noteworthy since the jalapeño varieties grown there have no resistance to bacterial spot disease. The grower maintained comparable disease control, even though his tank mixes relied more on copper hydroxide, and included maneb at a reduced rate.

Tomatoes were doubly threatened during the 1996 - 1997 season due to bacterial spot disease (XCV) and a late blight epidemic caused by strain US 17 of *P. infestans*. Chlorothalonil, maneb, and mancozeb were heavily used for late blight control. The EBDC's were usually tank mixed with either copper hydroxide or copper sulfate for XCV control. Amounts of the coppers and EBDC's were higher in the fall crop, reflecting the higher incidence of bacterial spot disease during the rainy fall season, while chlorothalonil use increased due to elevated late blight pressure during the cooler, drier spring season. The systemic fungicides were used sparingly.

- ***Herbicides:*** The highest amounts and diversity of herbicides occurred in the potato crops. A herbicide burndown is a standard potato cropping practice. The most commonly used active ingredients were paraquat dichloride and metribuzin, followed by metolachlor, diquat dibromide, and sethoxydim.

  The herbicide programs in tomatoes and peppers saw paraquat dibromide as the most commonly used herbicide, followed by metolachlor and sethoxydim in peppers and by metribuzin and sethoxydim in tomatoes. Glyphosate was used in both crops (Farms M, O, P and Q) as a preplant herbicide applied after the beds had been fumigated and mulched, but two or more weeks before the pepper or tomato crops were transplanted.

Due to a lack of mammalian toxicity data, the herbicide monocarbamide dihydrogen sulfide (MCDS) was deleted from the general pesticide review. The amounts of this herbicide applied are summarized in Table B9. The lack of mammalian toxicity data for MCDS is unfortunate, as large amounts of this herbicide are required for control of paraquat-resistant weeds, especially black nightshade, *Solanum nigrum*.

- ***Insecticides:*** Insecticide use was highest in potatoes due to the amount of the granular insecticides, aldicarb, ethoprop and phorate applied at planting or at lay by. Other insecticides commonly used were oxamyl applied at Farms H and K, and methamidophos applied at Farms F and K. Of the four potato respondents, overall insecticide use was highest at Farm H, where both ethoprop and aldicarb were applied. The oxamyl applied at this farm may have been unneeded, as it was directed at nematodes, which should have been controlled by the aldicarb. Farm H also invested greater resources in control of the armyworm complex, *Spodoptera* spp., notably *S. eridania*, the southern armyworm, as several applications of *B.t.* and methomyl were made. Respondents A and F each made one or two applications per acre for worm control.

  The most commonly used pepper and tomato insecticide was *B.t.* Amounts of this a.i. are low due to the low a.i. content of most *B.t.* formulations. The exception to this is the Mycogen product, Mattch, which is actually crystallized δ endotoxin, microencapsulated in killed bacterial cells. This product contains 1.05 lb a.i. per gallon. Regular use of this product at Farms M and O resulted in high amounts of a.i. being applied. This a.i. was considered equivalent in mammalian toxicity to the a.i. in other *B.t.* products for the purposes of this study.

  Insecticide use in tomatoes and peppers varied from the fall and spring, reflecting differential pest pressures. *B.t.* use was higher in the fall, as was the use of chlorpyrifos and methomyl due to higher armyworm pressure between August and October, compared to the remainder of the season. The leafminer controls, avermectin and cyromazine, were mostly used in the spring tomato crop when this pest is of more concern. In peppers, both methomyl and oxamyl are used to manage pepper weevils, which increase gradually through the season and can become crop-threatening in the spring crop.

  Imidacloprid was used in both fall and spring peppers and tomatoes to control silverleaf whiteflies in tomatoes and melon thrips in peppers. The high level of whitefly control obtained from imidacloprid has greatly reduced the amounts of other insecticides applied to tomatoes since its 1994 registration. Loss of this insecticide to resistance would almost certainly result in dramatic changes in the a.i. profile of the Florida tomato crop.

  Encouraging signs of the adoption of alternative management tools can be found in the tomato and pepper crops. Nuclear polyhedrosis virus was used on one respondent's farm for control of the beet armyworm, *S. exigua,* while azadarachtin and the oil extract from the neem seed were used on several farms for control of worms and weevils. Sulfur has largely replaced dicofol as the miticide of choice in peppers for control of the broadmite, *Polyphagotarsonemus latus*.

**Pesticide Impact Evaluation:** Active ingredients for all crops are ranked according to the magnitude of the mammalian toxicity adjustment factor in Table 3. The mammalian toxicity values for the a.i.'s applied to individual crops are contained in Tables B10 (potatoes), B11 - B13 (tomatoes), B14 - B16 (peppers), and B17 (fumigants for all crops).

The range in raw mammalian toxicity adjustment values covers five orders of magnitude, with a low value of 0.074 for glyphosate and a high value of 2400 for triphenyltin hydroxide. The value two hundred was selected as a cap for the mammalian toxicity value since a few of the values were so high that legitimate IPM tactics were disguised. The importance of these vast differences is clearly shown in the weighted application tables for each crop. From Tables 4 - 6, it can be seen that a few of the a.i.'s account for a significant portion of the overall mammalian toxicity profile, compared to the majority of the chemicals involved. The highest contribution is from methyl bromide. Even though this a.i. has a moderate mammalian toxicity adjustment factor, the high application rates for soil fumigants result in disproportionately high mammalian toxicity unit values per acre. Seasonal trends in the mammalian toxicity profiles for the remaining a.i.'s reflect the differences in overall pesticide use.

Mammalian toxicity unit values for each crop are further summarized on an average per-acre basis across all respondents' farms according to their contribution to the overall mammalian toxicity profile (Tables 4 - 6) and according to their ranking within each general group of pesticides (Tables 7 - 9). These tables show that a small number of a.i.'s significantly increase the mammalian toxicity units per acre. These include mancozeb, ethoprop, aldicarb and metiram in potatoes, mancozeb and maneb in tomatoes, and maneb, methomyl, chlorpyrifos and dicofol in peppers. These eight a.i.'s contribute over 80% of the mammalian toxicity units in the crops included in this survey.

While these results point out important considerations relative to the pesticide use environment in south Florida vegetable crops, it is critical that the following be kept in mind:

The only factor considered in the current discussion of risk factors is mammalian toxicity. While this is a significant component, it is only a part of the total impact pesticides have on the agroecosystem. Mammalian toxicity considerations are most relevant to farm workers and pesticide applicators.

Should other weighting factors be applied, the profiles of risk factors could be completely different. The score of synthetic pyrethroids, for example, will rise appreciably when ecological and biointensive IPM impacts are factored into the toxicity adjustment model. These and other a.i.'s with high non-target organism toxicity, but relatively low or moderate mammalian toxicity values, would have increased their importance in a profile emphasizing ecological impacts.

**IPM Continuum Score Determination:** Scoring growers according to their placement on the IPM continuum is detailed in Tables 10 - 12 for potatoes, tomatoes and peppers, respectively. Separate scores were determined for spring, fall, and whole season crops in tomatoes and peppers. These scores were further broken down into disease management, insect management, and total IPM scores. To aid in interpreting the results, all scores were scaled by a factor of 100. In addition to the scores presented in the tables, these results are also presented graphically in Figures 1 - 7.

Concerns about the potential for bias in this survey resulting from over-representation by Glades Crop Care clientele were addressed by soliciting responses from non-clients as well as users of Glades Crop Care's services. The results of the IPM program analysis and the IPM continuum scores indicate no clear differences between these two groups of growers. This is to be expected as growers faced similar problems and had similar tools at their disposal to deal with them.

The results of the IPM continuum determination for potato growers show a low value of 3.2 for Farm H and a high score of 5.2 for Farm A. The intensive insect management program at Farm H resulted in this farm having both the lowest overall and the lowest insect management scores. The use of metiram and triphenyltin hydroxide, which were applied at least once at Farms F and H, but were not used at Farms A or K, influenced the disease management scores.

Significant in the tomato and pepper crops was that most growers scored considerably higher in insect management than in disease or overall pest management. This should be expected, as the major mammalian toxicity contributors were the EBDC fungicides, mancozeb and maneb.

This difference was less striking in peppers than in tomatoes. Growers who relied on the "softer" program of *B.t.* and sulfur scored better than those who relied on methomyl, chlorpyrifos and dicofol for control of the fall pepper pest complex.

The near elimination of copper-based fungicides from the spray program at Farm E provided this grower with the highest disease management score of the tomato growers. This farm also had an extremely high insect management score, as well as the highest total continuum score. Scores for all growers were negatively affected where high amounts of EBDC's, methomyl and/or chlorpyrifos were used. This reflects the importance of these a.i.'s in contributing to the mammalian toxicity profile for these crops (Tables 4 - 9.)

In order to put this method of scoring IPM adoption into perspective, the continuum grades were entered into Table 13. This table also includes grades based on criteria used in two other IPM surveys (Bauske, et al, 1998; Vandeman, et al, 1994). Considering the overall grades alone, all survey respondents' IPM programs show a moderate or high level of IPM implementation according to these criteria, respectively. The method of measuring IPM adoption used in the current survey provides a significantly more detailed picture, especially with regard to mammalian toxicity.

## Discussion

The primary objective of this study was to apply a measurement method (Benbrook, et al, 1996) to pest management programs used by south Florida vegetable growers. This method involved quantifying non-pesticidal management practices and a weighted analysis of actual pesticide applications associated with these practices. This provided a powerful tool for analyzing the impact of the complete integrated pest management system on individual farms in terms of their potential human health impacts.

The original intent was to produce a ranking of IPM programs according to the human health and environmental impacts. However, since suitable ecological adjustment factors for the active ingredients for the surveyed crops were not available, the analysis was limited to the available indices of human toxicity. Therefore, the derived analysis and IPM continuum scores reflect human safety concerns rather than full ecological impacts.

Future analyses of pest management programs using this technique should ideally incorporate a broader range of weighting factors for pesticides. In performing the current analysis, the adjustment factors used (C. M. Benbrook, personal communication) were chosen over the EIQ values formulated by J. Kovach, et al, 1992, because of their ready availability and completeness. These adjustment factors had the additional feature of being directly calculated from toxicity data, rather than reflecting a classification according to ranges of toxicity values.

In addition to ranking individual growers on a continuum and linking IPM adoption to pesticide use, the analytical technique described here should have several other uses for field personnel, policy makers, those administering IPM labeling programs, and regulators.

Cost and benefit analysis of program components will be expedited by examination of the impact of these components of the overall IPM continuum score. For the potato growers in this survey, the decision to use phorate for soil insect control instead of aldicarb or ethoprop might be prompted by its lower mammalian toxicity, given equivalent performance of the three pesticides. Such analyses would best be conducted as an ongoing part of designing IPM programs for individual growers.

Analyzing the effects of climatic and cultural developments on IPM programs can be expedited by this technique's detailed analysis of pesticide applications. By their very nature, these analyses would involve multi-year data collections. In the current study, the effects of the late blight epidemics in potatoes and tomatoes can be clearly detected in the increased amounts of EBDC and chlorothalonil fungicides applied to the spring crops.

Evaluating the impact of other inputs to the IPM system, such as changes in program design, scouting techniques, new pesticides, and interactions with the biotic components of an IPM system will all depend on analysis of multi-year data. Some indications of trends can be found in the current survey. For example, IPM continuum grades were consistently low for Farms O and M compared to other growers of the same crops. IPM was not used in these crops. Scouting was performed by the respondent at irregular intervals with only historical trends in pest distribution to guide these efforts. Farm O tomatoes were treated with higher amounts of chlorothalonil and EBDC fungicides than other tomato crops, while *B.t.*, despite its benign nature, was apparently used in greater amounts than needed on other farms. Similarly, the amounts of maneb used and the insecticides employed at Farm M also indicate a spray program that may have been applied without consideration for actual crop needs. The situation in these two crops indicate that introducing competent IPM advice into the system would probably result in reduced fungicide use and better targeting of insecticide applications, as indicated by the records for other growers.

The impact of new pesticides on the risk profiles associated with vegetable production can be measured effectively with this survey tool. As an illustration, Tables 14 and 15 show how the replacement program for the conventional maneb and copper fungicides in pepper production would affect the mammalian toxicity profile and the IPM continuum scores for a pepper grower. The hypothetical replacements include Actigard, a novel plant defense stimulant under development by Novartis, and AgriPHAGE, a viral biological control agent under development by Agri-Phi of Logan, Utah. To further illustrate the potential changes in IPM scores, a second hypothetical scenario is given in Table 16, where in addition to the changes in the fungicide program, chlorpyrifos and diazinon are taken out of the program. In their place, Spodex (NPV virus) and *Steinernema carpocapsae* (entomopathogenic nematodes) are used to control beet armyworms, *Spodoptera exigua*, and mole crickets, *Scapteriscus* spp., respectively.

The reduction in the mammalian toxicity profile is dramatic in each of these hypothetical scenarios, with a corresponding increase in the IPM continuum grades. Such a numerical representation of program changes, coupled with successful pest control results, would certainly bolster the grower who adopted such novel control tactics.

Providing positive reinforcement for growers who are making efforts to produce high-quality crops using more environmentally benign pest management systems is a major potential benefit of the survey technique described here. Through the interactive process of reviewing practices in the questionnaire portion and providing supportive analysis of pesticide programs, growers should receive clear indications of aspects of their programs that are achieving the combined results of sound IPM and economic profitability.

A benefit that will accrue to persons off the farm is the identification of alternative pest management tools that growers need or are willing to use. For example, the responses to the question of using disease-resistant varieties indicate that if they were available, growers would use them. Fully integrating these varieties into an IPM program, on the other hand, will involve some degree of learning and education as to the proper amounts of fungicides to apply to avoid losses to secondary disease pests. For example, the list of registered fungicides for use in peppers is **severely limited**. Although growers can reduce their applications of maneb and coppers when bacterial spot resistant varieties are grown, a need for protection against other diseases, such as anthracnose and gray mold, still exists. Growers faced with this quandary are prone to continue with programmatic use of maneb and coppers, thus partially defeating the utility of the disease-resistant varieties.

Similarly, the use of mycorrhizal organisms or solarization to combat soil-borne pests is still in its infancy, despite many years of research into their use. The results of this survey indicate that a few growers have begun experimenting with the use of these techniques. Other recently developed tools which are finding use in Florida vegetables include the NPV virus for control of beet armyworms and the use of pheromone mating disruption for control of tomato pinworms, *Kiefferia lycopersicella*. During the interview phase of this survey, growers expressed concerns about reliable supplies of innovative products and lack of a proven track record against tough pests, while recognizing the needs for such alternative tools primarily as a means of managing pesticide resistance development.

To conclude, the IPM evaluation method used in this survey appears to be suitable for use in Florida's vegetable production systems. The greatest benefit of the resulting program scores will come about as historical trends are illuminated through multi-year surveys, and as changes are documented in the IPM systems typically found along the IPM continuum. Our early observations confirm that this methodology, if refined and extended to more comprehensively encompass other risks concerns, will lead to a sound basis for projecting the pesticide risk reduction benefits following progress in the development and adoption of biologically based IPM systems.

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