IPM

The Quiet Evolution

An overview of Integrated Pest Management (IPM) and its impact on western agriculture

Foreword

This document was written with the cooperation of university, government, industry, and other specialists in the field of Integrated Pest Management. The following organizations support its content and the implementation of IPM practices.

Agricultural Council of California

Agricultural Retailers Association

American Crop Protection Association

Arizona Cotton Growers Association

Blue Anchor, Inc.

California Agricultural Production Consultants Association

California Association of Nurserymen

California Association of Wheat Growers

California Canning Peach Association

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California Dept. of Food and Agriculture

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California Winegrape Growers Association

Far West Fertilizer & Agchemical Association

Imperial County Whitefly Management Committee

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Table of Contents

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IPM Goal: High Yields, High Quality, Low Risk

The ultimate goal of IPM is to ensure production of abundant, high quality food and fiber in an environmentally and economically sound manner.

Today, sophisticated IPM systems exist for scores of crops.

Integrated Pest Management (IPM) is a practice where pest management is but one component in an overall crop production system. IPM is based on the principle of providing growers with the widest array of options to control pests, e. g., cultural, biological, chemical and genetic techniques. The ultimate goal of IPM is to ensure production of abundant, high quality food and fiber in an environmentally and economically sound manner.

The concept of IPM has roots that date back to the beginning of this century, when farmers, agricultural researchers and farm suppliers began working in tandem to control agricultural pests. Early efforts focused on cultural practices, crop rotations and plant breeding for pest resistance. Formal IPM programs were established in the western United States in the early 1960s.

Today, sophisticated IPM systems exist for scores of crops. In California, for example, hundreds of IPM research projects have been funded through the Statewide Integrated Pest Management Program, established in 1980. Additionally, the University of California has published Pest Management Guidelines for over 30 different crops. Case studies are cited as examples that demonstrate the success of some of these programs.

Many growers have adopted IPM programs on a voluntary basis. To these growers, the rewards are obvious: Improved safety, environmental protection and economic returns. If, however, policies mandate the adoption of IPM, understanding what it is and how programs will be measured becomes critical. Specifically, IPM criteria should not be formula driven, must be broad in its interpretation and must take into account differences among commodities as well as the geographies in which they are grown. To be successful, any criteria used to judge the effectiveness of a given IPM program must be practical

Cooperation needed to overcome IPM barriers

(science based), agronomically sound (allow for variation within and among crops), economically viable (cost effective) and have achievable and measurable objectives.

IPM is intended to provide growers with the widest array of environmentally sound, safe and economical pest management tools possible, including, when appropriate, synthetic tools. Because of the potential risk of crop failure from pest damage, many growers are unwilling to initiate an IPM program that doesn't allow for the use of specific chemical alternatives when pest pressures exceed manageable threshold levels. Progressive growers, researchers and farm suppliers have long recognized the value in the judicious use of synthetic inputs as part of an overall farm management program.

There are many reasons why IPM programs are designed to decrease reliance on any one pest management practice or technique, including the use of pesticides.

One objective of IPM is to minimize or eliminate pest resistance through the judicious use of pesticides in combination with other pest management techniques.

As a result, specific chemistries remain effective and available for a much longer period of time, particularly on pests that have many life cycles in a growing season. This is an important factor to growers and suppliers alike as the cost to develop and bring replacement products to market becomes increasingly expensive. Another objective of IPM is to lower a grower's overall cost of production without reducing yields by providing a wider array of pest management tools. To remain competitive in a global economy, growers must have cost effective pest management strategies available to them.

The continued development of successful, long term IPM programs is critical if America is going to meet future needs for high quality, low cost food and fiber while, at the same time, create environmental

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To remain competitive in a global economy, growers must have cost effective pest management strategies available to them.

Scientific breakthroughs aid in adoption of IPM

The continued success of IPM programs will be based on sound research and development, applied outreach of demonstrated IPM techniques, environmentally sound agronomic decisions, effective agricultural policies and positive economic outcomes.

and economic harmony within the agricultural community. Technological advances will provide the keys to sustaining successful IPM programs.

Examples of scientific and/or technological breakthroughs which enhance the ability of growers to adopt and sustain IPM programs include the advent of narrow spectrum, minimal risk pesticides, improved plant genetics and breeding techniques, and the development of transgenic plants that optimize pathogens to control pests. The continued success of IPM programs will depend on sound research and development, applied outreach of demonstrated IPM techniques, environmentally sound agronomic decisions, effective agricultural policies and positive economic outcomes for the grower.

The agricultural community works closely with various regulatory programs to enhance pest management efforts. Growers and the agribusiness community are supportive of laws and regulations that require proficiency and continuing education of applicators, dealers and those making recommendations on pesticide use.

The widespread acceptance of the national Certified Crop Advisor Program exemplifies this support. Additionally, effective regulatory programs, sound university research and applied outreach by the Cooperative Extension system all contribute to the success of IPM programs.

In spite of the well documented successes attributed to IPM, barriers exist that impede its development. As identified by the National Foundation for IPM, these barriers fall into the general categories of research and development (R&D), policy, and grower education.

With regard to R&D, there is a lack of funding for applied research and demonstration programs. As to policy, a burdensome regulatory process coupled with little or no consideration of IPM by government agriculture programs is pervasive. Finally, among growers, there is relative widespread confusion as to what IPM really is and what economic benefits it brings to the table.

IPM: Many Definitions, Many Interpretations

The concept of utilizing varied techniques to control pests on a crop is a practice that has been in use for almost as long as mankind has farmed. During the 1950s a group of entomologists at the University of California at Berkeley began formalizing the concept of what was to become integrated pest management, or IPM. The original intent of these entomologists was to integrate the use of pesticides and natural enemies (predators and parasites) to manage insect pests. Today, the term IPM has evolved far beyond this initial concept.

As the formalization of IPM has evolved over the last 40 years, the term became burdened with many definitions and interpretations, often leaving growers, policy makers and the general public confused as to its real meaning.

In a practical sense, IPM is a complex mixture of practices and technologies, specific to a given crop, to control pests. Ultimately though, IPM is an evolutionary process that continues to advance the way growers manage pests to the benefit of society's environmental and economic well-being.

In spite of the many definitions, there is common ground with respect to the principles, the tools and the goals of IPM.

Principles of IPM

- A systems approach to managing crops pests.
- Devises strategies to prevent economic pest damage.
- Relies on a balance of techniques to manage pests.

Tools of IPM

- Biological (protect/enhance/release natural enemies).
- Cultural practices (crop rotation, cultivation, irrigation, pest monitoring).
- Chemical (pesticides, insect growth regulators, pheromones).
- Genetic (sterile release, resistant varieties, transgenic plants).

Goals of IPM

- To ensure production of high quality food and fiber in a sustainable, environmentally sensitive and economical manner.
- To minimize the risks to human health and to the environment.

IPM is an evolutionary process that continues to advance the way growers manage pests to the benefit of society's environmental and economic well-being.

What IPM Is...

IPM has many definitions. Common to all are favorable economic and environmental outcomes.

IPM is a thinking farmer's philosophy for pest management.

IPM is "the intelligent selection and use of pest control actions that will ensure favorable economic, ecological and societal consequences." R. L. Rabb, NCSU, 1972. (Association of Applied Insect Ecologists)

IPM is a pest population management system that anticipates and prevents pests from reaching damaging levels by using all suitable techniques such as: natural enemies, cultural management, and the judicious use of pesticides. Farm and Forest INSIGHTS.

IPM is a systems approach based on science and proven crop production and resource conservation practices. It uses all suitable techniques, such as natural enemies, pest resistant plants, culture management, and pesticides in a total crop production system to anticipate and prevent pests from reaching damaging levels. Bruhn et al., Consumer Response to Information on Integrated Pest Management. Journal of Food Safety (1992) 12: 315-326.

IPM is a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health and environmental risks. National Coalition for Integrated Pest Management, January 1994.

IPM is a complex set of behavior, decision-making procedures, methods, technology and values organized to provide efficient alternative methods of pest control. J. Apple and R. Smith [eds] 1976. Integrated Pest Management. Plenum Press. New York.

IPM is a thinking farmer's philosophy for pest management. A thoughtful, comprehensive approach to the challenge of farming, it calls on many different disciplines, seeking links and relationships among them rather than seeking to establish a separate science. It is an environmentally based pest control strategy offered as part of an overall crop production system. IPM provides a diverse array of practices that can be used together to fight crop pests in an economically and environmentally efficient manner. Kenneth Farrell,Vice President, Agriculture and Natural Resources, University of California.

"Integrated pest management" means a coordinated decision-making and action process that uses the most appropriate pest control methods and strategy in an environmentally and economically sound manner to meet agency pest management objectives. From Oregon Statute, as used in ORS 634.650 to 634.670.

What IPM Is Not

It is critical to know what IPM is not to prevent unrealistic expectations of what the concept can and cannot do for agriculture.

IPM is not new
In one form or another it has been around since the advent of agriculture. Scientifically based programs specifically focused in this area, however, are only a few decades old.

IPM is not implemented overnight
The development of an IPM program may take years of research and involve participants such as university and Extension researchers, production agriculture, pest control advisors, industry scientists and, most importantly, farmers.

IPM is not organic farming
Organic farming is a philosophical approach to crop production that relies on no synthetic inputs for either pest control or plant nutrition. Organic farmers are prevented from using some of the low-risk techniques and technologies available to growers practicing IPM, simply because they are synthetic.

IPM is not a formula to eliminate or reduce pesticide use
Well developed, science-based IPM programs have consistently resulted in reduced pesticide use, as they employ a wider array of pest management techniques. IPM programs, by design, result in safer, more judicious use of pesticides.

IPM is not a rigid program of management techniques
IPM is a balance of all suitable techniques, providing the grower with options to manage pests within a given crop production system.

IPM programs are not universal
Depending upon the pest complex and the geography, programs may differ dramatically for the same crop in different geographies. For example, major acreage's of lettuce are grown near Salinas and El Centro, California, two dramatically different areas -- each has its own, independent pest, climatic and production challenges.

IPM is not a rigid program of management techniques.

Actions Effecting IPM Adoption

Widespread use of IPM is possible but can be hindered by unrealistic goals

IPM will only advance with understanding of agricultural systems and the intelligent use of existing and new technology.

Positive Actions To Promote IPM

• Develop policies that will foster cooperation between regulators and growers.

• Involve the regulated community, i. e., growers, crop advisors and farm suppliers, when developing policies that promote IPM.

• Recognize that although reduced reliance on pesticides is often an outcome of IPM programs, pesticides are an important tool in many successful IPM programs. Excluding pesticides from IPM programs by definition will reduce the acceptability of IPM as an effective agronomic tool.

• Develop policies that don't impede advances in minimal risk, effective pest management technologies.

• Consider geographical, seasonal, climatic, biological and cropping differences when developing IPM programs.

• Adopt evaluation criteria that are practical (science based), realistic (allow for variation within and among crops), economically viable and have measurable and achievable objectives.

• Promote IPM research, development and demonstration programs at the university and Cooperative Extension level.

• Recognize that Integrated Pest Management (IPM) is a mature concept which improves the environmental and economic consequences of pest management through better use of information and technology

Actions That Can Impede IPM Success

• Failing to recognize that acceptance of IPM by growers is driven by economics.

• Establishing a nationwide "formula" for what constitutes adoption of IPM.

• Discounting the significant contributions that advances in technology, including the advent of narrow range, minimal risk pesticides, will continue to make to IPM.

• Viewing IPM as a mechanism to simply reduce pesticide use or equating IPM with organic farming. IPM will only advance with understanding of agricultural systems and the intelligent use of existing and new technology.

Promoting Real World IPM Policies

Policies must acknowledge the need for efficient agricultural production

The benefits of adopting IPM are quite appealing and are obvious to most growers in the western United States. In fact, most western growers practice IPM to some degree.

Differentiating between what IPM is and what it is not continues to be one of the biggest challenges to practitioners and regulators alike. If policies are to be developed that offer incentives for IPM adoption, the definition of what constitutes IPM will become critical.

Furthermore, incentives to adopt IPM practices should be just that: factors that encourage the adoption of IPM rather than predetermined mandates that attempt to impose IPM. The concept of establishing mandates, i. e., formulas for determining if a particular grower's crop plan qualifies as an "approved" IPM program is fraught with problems and should be avoided.

Throughout western agriculture, climate and soil conditions vary greatly among growing regions. Geographical variances, coupled with seasonal variations pose continually changing pest management challenges to growers producing the same crops.

Attempting to impose IPM through a formula approach could result in a grower with an "approved" IPM program in one area and the same grower being unable to adopt an "approved" program in a different area. For example, lettuce growers in the marine climate of Salinas, California would adopt very different pest management practices than would growers in the desert climate of California's Imperial Valley. Thus, a single IPM formula, too tightly prescribed, is not sensitive enough for the seasonal, climatic, biological and crop diversity in western agriculture.

The challenge for policy makers designing incentives or formulas for increased adoption of IPM is to make those policies practical, realistic, economical and achievable.

Policies founded upon these characteristics will capitalize on the existing willingness in the production community to move further along the IPM continuum, while fostering an atmosphere of trust and cooperation. Policies founded on philosophy or ideology, how-

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Policies must be achievable, economical

Policies founded on philosophy or ideology, however, will lead to logistically impractical programs, creating dissent and resistance and will result in failure.

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Necessary Elements of a Successful IPM Policy

Practical. IPM programs must be based on sound science. This process involves the coupling of solid field biology research with workable delivery systems. For IPM to succeed, a grower has to be able to apply sound scientific principles to his agronomic decisions.

Realistic. IPM programs must be broad enough to allow for variation from area to area and from time to time throughout the growing season (e.g., CA Cotton Manager). IPM policy elements must allow for enough flexibility and options to accommodate differences due to geography, temperature, climate and other variables that exist within any given commodity. Rigid, specific formulas will not provide the necessary flexibility.

Economical. The bottom line is that in order for IPM programs to be successful, they must work economically for the grower. Rigid, formula driven IPM programs will likely result in increased grower costs, i. e., exposure to economic loss, because growers may not have the flexibility to adapt to pest problems that are specific to a particular crop or region.

Achievable. IPM programs must include realistic, measurable objectives. Measurements must be based on sound science rather than philosophy. Criteria that are too narrowly focused may invite manipulation rather than interpretation needed for meaningful change.

For example, a narrowly focused measurement such as a fixed percent of pesticide use reduction, while sounding workable to the uninformed, creates nightmares for program administrators, e. g. does one measure total pounds used or total acres treated; what basis is used for comparison;

To be successful, IPM programs must work economically for the grower

is the measurement based on an individual year or on trends drawn from several years; how are the data collected and verified?

Poorly drawn measurement criteria can have unintended consequences. Consider the example of percent of pesticide use reduction discussed above. Conceivably, growers may have been relying on a "soft" pesticide such as B.t. to control a specific pest. Such a material, though it has a very benign human and environmental profile, often must be applied more frequently or at higher rates to achieve control than a more toxic material.

A poorly drawn mandate could cause a shift in use away from the B.t. to the more toxic material simply because the latter material results in fewer pounds of active ingredient being applied. Although meeting the requirement of the mandate, such a criterion could result in an increase rather than a decrease in potential exposure to human and environmental risk.

To be successful, IPM programs must work economically for the grower. Policy makers should enlist the help of the regulated community in the promulgation of programs designed to foster greater use of IPM.

There is willingness among growers and pest consultants to use innovative production techniques as long as those techniques can demonstrate equal or greater economic benefit. Time and again growers and pest consultants have demonstrated their eagerness to work with the Cooperative Extension system and industry scientists in developing better methods of pest management.

More than ever, growers and consultants are aware that their ability to continue producing is dependent upon favorable public perception of their practices. They truly can be part of the solution.

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Role Of Government Agencies In Successful IPM Programs

An effective regulatory structure can have a positive influence on IPM use

Grower initiated pest management projects exist and have proven to be successful in many areas.

There are a number of existing laws and regulations that directly and indirectly deal with IPM on both the federal and state levels. Laws that directly impact IPM deal with pests, their management and, in some cases, methods for control. Laws and regulations that indirectly impact IPM include plant quarantine and eradication efforts, pest control/abatement districts, the pesticide registration process and the licensing and training of dealers, pest control advisors and operators.

The regulatory infrastructure, if used effectively, can have a positive influence on the implementation of IPM. The following discussion uses California's pesticide regulatory program as an example of how the regulatory infrastructure can facilitate IPM programs.

Pest Eradication. Eradication programs are established once an exotic pest is introduced into a state. Such programs are based on IPM. For example, in California the Mediterranean Fruit Fly project includes constant monitoring for the pest. Eradication efforts begin once the existence of the pest has been established in containment areas. The initial eradication effort involves releasing sterile male flies. This biological control method has proven to be highly successful. However, in those situations where using the sterile male technique fail to eradicate the pest, a pesticide alternative is used.

Grower-Regulator Partnerships. Grower initiated pest management projects exist and have proven to be successful in many areas. Some of these projects are run by the state while others are operated by growers in accordance with state requirements.

The pink bollworm in cotton is an example of a successful state-run project. Growers fund the state to establish and maintain a program to ensure that this pest does not become established in the San Joaquin Valley. The state continually monitors for the presence of the pest and mandates

Effective mix of research and regulations is needed

specific actions to growers, e. g. a plowdown date for cotton stubble to remove overwintering sites for the pest.

Through state law, growers have also established several grower-run pest management districts such as the Fillmore Citrus Protective District and the Stone and Pome Fruit Pest District Control Law. The state's role is to assure that funds are collected and that district operations comply with the law. Both programs are excellent examples of growers and government working together to modify agricultural practices over a given geography. Participation in these programs results in higher yields for growers with minimal economic and environmental costs.

Regulatory Actions. In some cases regulatory actions have been necessary to ensure that pesticides are used judiciously. For example, in 1982 fish kills in the Sacramento River caused by rice herbicide runoff led to a change in cultural practices to prevent a reoccurrence. Changing water holding requirements to reduce the flow of the herbicide from rice fields resulted in a 99.5% reduction in transport of the herbicide to the river.

This reduction was the result of a sound, science-based program. It is also an example of how reduction of significant off-site movement and risk to nontarget organisms was accomplished without eliminating the use of an effective pest management tool.

Laws and Regulations. The California Department of Pesticide Registration licenses sellers of pesticides and biological control agents, pest control applicators and pest control advisors. IPM training courses are offered to license holders as part of the continuing education process, (Note: this occurs not only in California but across the country as well, e. g., the course requirements of the national Certified Crop Advisor (CCA) program emphasizes a systems approach based on IPM principles). Furthermore, pest control advisors are legally and ethically bound to consider alternatives to pesticides

Through state law, growers have also established several grower-run pest management districts.

The challenge is to maintain a balance

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when making pest control recommendations to growers.

Summary. California is fortunate to have a combination of a strong university and Cooperative Extension system that can develop and deliver IPM programs to growers; a strong state regulatory infrastructure that has a track record of promoting and using its regulatory authority to minimize the risks associated with pesticides without hindering agricultural productivity; and a progressive agricultural community that has demonstrated its willingness to experiment with and adopt new, effective pest management practices and technologies. It is this effective mix, plus the challenge of dealing with 250 different commodities, that makes California a leader in IPM practices.

These examples demonstrate that policy makers, regulators and the regulated community can work cooperatively to effectively address a number serious pest management challenges. It is in this spirit of cooperation that unacceptable risks must be identified and dealt with.

It must also be recognized that risks come in many forms; environmental, human and economic. The challenge of policy makers is to be sensitive to maintain a balance when establishing programs aimed at achieving efficient, cost effective pest management in production agriculture.

Role Of Universities In Successful IPM Programs

Results of research efforts and case studies

California

In 1980 the University of California (UC) initiated formal operation of the Statewide Integrated Pest Management Project. The project was borne out of the realization that in spite of the benefits that synthetic pesticides bring to agriculture, such as improved productivity and more reliable production, they also have limitations, in the form of pesticide resistance and human and environmental concerns. These programs encourage growers to reduce their reliance on pesticides and consider a wider array of pest management options than they previously had. By the end of 1990, a total of 222 IPM projects in 35 crops were funded. (*California. Agriculture,* 1990, Vol. 44, No. 5).

Today the University of California publishes Pest Management Guidelines for crop pests in over 30 commodities -- a list which will no doubt expand as pest management research continues. The Guidelines, written by UC researchers, extension specialists and farm advisors, provide growers with the University's official guidelines for monitoring techniques, pesticide use and alternatives to pesticides in over 30 agricultural crops. They contain information on pest identification and damage, damage thresholds, timing, biological and cultural control methods and pesticide recommendations.

There is also a series of Integrated Pest Management Manuals. The manuals are comprehensive, well illustrated books describing pests and IPM programs. These manuals combine the expertise of many University of California researchers and extension specialists and provide an orderly, science based system for diagnosing, recording, evaluating and treating pest problems in a variety of crops. The manuals are written for professional pest control advisors and others directly involved in managing crops pests.

In addition to the above publications, the University of California and the Cooperative Extension Service hold an extensive series of grower meetings through-

These programs encourage growers to reduce their reliance on pesticides and consider a wider array of pest management options.

Pest Management Guidelines have been developed for crops representing over 6.7 million acres

Working in partnership with innovative farmers and farm suppliers, STEEP researchers set out to design and implement sustainable systems to control soil erosion.

out the year, providing growers with the latest developments in pest management. A vast array of crops and pests are discussed at these meetings.

The 30+ commodities for which Pest Management Guidelines have been developed represent over 6.7 million acres (1992 CA ag stats) -- or over 70% of the state's irrigated acreage. The guidelines do not attempt to quantify the percentage of crop acres under IPM but, due to the substantial county outreach and influence of the Cooperative Extension, one can be confident that a great number of growers have implemented IPM programs.

The Northwest

Researchers from Washington State University (WSU) were early IPM innovators. Approximately 18 years ago, researchers at WSU, the University of Idaho, and Oregon State University, established the Solutions to Environmental and Economic Problems (STEEP) Research Program. STEEP is funded by the USDA and is a multidisciplinary, integrated approach to solving on-farm agronomic problems in the Pacific Northwest dryland wheat growing region. Working in partnership with innovative farmers and farm suppliers, STEEP researchers set out to design and implement

IPM guidelines have been published for the following crops by the University of California

Fruits & Nuts		Vegetables	Field Crops
Almonds	Olives	Carrots	Alfalfa Hay
Apples	Peaches	Cole Crops (2)	Barley
Apricots	Pears	Cucurbits	Cotton
Cherries	Pecans	Garlic	Dry Beans
Citrus (1)	Pistachios	Lettuce	Oats
Figs	Plums	Onions	Rice
Grapes	Prunes	Peppers	Sugar beets
Kiwis	Strawberries	Potatoes	Wheat
Nectarines	Walnuts	Tomatoes	

(1) Oranges, grapefruit, lemons, tangerines, tangelos, mandarins, tangors
(2) Brussels sprouts, broccoli, cauliflower, cabbage

Interdisciplinary teams take an integrated approach to problem solving

sustainable systems to control soil erosion.

However, they quickly learned that when the soil tillage system was altered, soil-borne pests and disease organisms were altered as well. This realization increased the scope of the entire program, and STEEP researchers formed interdisciplinary teams allowing them to take an integrated approach to problem solving.

In 1985, STEEP initiated an integrated pest management research study in wheat, which looked at three different tillage methods and three levels of chemical weed control. The researchers evaluated the effectiveness of these treatments for weed control, economics of the system and affects on weed seed banks in the soil.

At the same time, plant pathologists evaluated diseases and monitored shifts in soil microbial population dynamics. This unique project allowed researchers to determine the economic threshold for weeds, something which had not been accomplished before, and as a result, farmers have adopted conservation tillage practices in a profitable manner. Additionally, Dr. R. James Cook, head of the USDA Root Disease and Biological Research Control Research Unit in Pullman, Washington was selected as a member of the National Academy of Science in large part because of his pioneering efforts in developing an integrated approach to the management of soil borne plant pathogens of Pacific Northwest Wheat.

STEEP research, with its emphasis on "hands on" research in the field, and linking partnerships among farmers, agronomists, and farm suppliers, has been a significant success story in stewardship of the land in the dryland wheat producing region of the Pacific Northwest. University researchers and Cooperative Extension personnel have worked shoulder to shoulder with growers to conserve the land and manage weed, insect and soil borne pests.

The progress made with STEEP illustrates the benefits achieved through IPM when agricultural researchers and farmers work as partners. Such a cooperative partnership has far greater potential for success than programs driven by inflexible government mandates poorly suited to local conditions.

Such a cooperative partnership has far greater potential for success than would programs driven by inflexible government mandates poorly suited to local conditions.

Technology: Key To Safer, More Effective Pest Management

New technology is key to managing crop pests in the future

The net result has been a significant increase in yields while reducing the grower's overall cost per acre.

To those familiar with the history and evolution of high-yield agriculture in this country, there is no question that technology is the foundation upon which this success is built. High-yield agriculture has provided the United States with the cheapest, most abundant food supply in the world. We also have the most diverse supply of food available, thanks to the hundreds of minor crops grown domestically -- most of them in the western states.

Technology has provided improved efficiency across many fronts. Crop varieties have been improved through successful plant breeding and genetic engineering to resist pests, improve quality, taste and nutrition and even to accommodate mechanical harvesting. The net result has been a significant increase in yields while reducing the grower's overall cost per acre. Plant growth regulators have been developed to improve morphological characteristics of plants resulting in better yields and crop quality. In the area of pest control, pesticides that protect crops from a wide variety of pests continue to evolve, minimizing risk to human health and to the environment.

Technology has not come without risks. Some early pesticide compounds were found to have potentially high risk to man and to the environment, thus requiring regulation to assure their safe use.

All aspects of agriculture have responded to the demand for minimal risk pesticides. Regulators have tightened restrictions on the registration and reregistration of pesticides. The land grant universities and Cooperative Extension system have developed programs to improve production with less reliance on pesticides.

Farmers have become more conscious about environmental matters and have improved farming techniques -- particularly with respect to soil erosion. As a result, pesticide manufacturers have also

Technology advances add to array of grower tools

responded by investing billions of dollars into research and by developing and marketing newer, more pest-specific and environmentally benign products. These new products provide exceptional activity in very small amounts by targeting specific biological pathways of the pest they intend to control. This advancement translates to reduced risk to man and the environment.

The above developments have set the standards for new synthetic pesticides: Minuscule rates of application, improved targeting of a given pest's "Achilles' heal," and less impact on non-target organisms and the environment. There is a virtual revolution in pesticide research and development occurring today that will deliver even better pest management options to growers. The challenge facing regulators is to recognize and reward minimal risk pesticides with quicker movement from registration to commercial use.

Among naturally occurring pesticides, significant improvements will likely come with the aid of genetic modification. *Bacillus thuringiensis* (B.t.) has been used commercially for decades with varying degrees of success. Improvements in the effectiveness of B.t. have been accomplished via transconjugation (the "fusing" of two strains to improve toxicity and spectrum). Testing is currently underway to increase the size of the B.t. toxic protein crystal and further increase its toxicity to target insects. In addition, naturally occurring organisms, known as *baculoviruses,* are being genetically manipulated to increase their speed of kill which will make them commercially viable.

Research into the basic biology of crop pests and a greater understanding of the pest-crop relationship is ongoing. Only through a basic understanding of the biological mechanisms associated with pests and their hosts will

Recent developments have set the standards for new synthetic pesticides: Minuscule rates of application, improved targeting of a given pest's "Achilles' heal," and less impact on non-target organisms and the environment.

More understanding of biological mechanisms is needed to continue advancement to safer, more effective pest management

Government policies should foster the development of technologies that will continue to advance more effective pest management options to growers.

IPM continue its advancement to safer, more effective pest management.

A good example in effectively utilizing such information is with pheromones. These insect communication chemicals can be used at minuscule levels to monitor insect populations, trap pest insects, or more recently, to disrupt their behavior to prevent mating.

Genetically modified plants may play a significant role in the future of pest management by providing a new, unique means of insect management. Transgenic plants containing the gene for the B.t. protein toxin are able to control certain types of insects. Successful field trials have already been conducted with transgenic cotton and potatoes. Research is also going on to modify plants to better resist specific disease organisms. Genetic modification of plants is not a silver bullet, rather another tool with which to manage crop pests.

The advances made with synthetic pesticides, natural organisms and genetically modified plants are adding to the array of tools needed to manage crop pests in the future. These tools target specific biological pathways in a pest and are otherwise benign to the environment as well as to humans. Such technology is a significant part of the future of IPM and can be combined with all of the other proven methods in use today. Government policies should foster the development of technologies that will continue to advance more effective pest management options to growers.

Case Studies of Successful IPM Programs

California Cotton Manager

Computer technology has the ability to play a significant role in crop production and pest management decision making. Cotton production in the San Joaquin Valley was chosen as the first crop to computerize due to the extensive knowledge base on the crop and the willingness of university researchers, Cooperative Extension and industry to work together.

A second generation system, called California Cotton Manager (CCM), is now in place. CCM is a grower-friendly computer system that utilizes a hand-held computer that provides the grower with real-time/real-world information on his crop.

Specifically, CCM provides the grower with pesticide calibration information to assure correct rates and spray gallonages of materials; plant mapping (crop development) output to assure correct application of plant growth regulators; information on replanting; irrigation information for optimum use of water; proper timing for optimum defoliation of the crop in preparation for harvest; and nematode damage ratings to determine if the following year's crop will require a preplant pesticide treatment.

CCM appears to be gaining rapid acceptance among cotton growers due to its ease of use and the fact that it provides practical decision-making information for an array of crop management categories. The program is easy to use and provides real-time information -- there is no going back to the lab or office to enter and evaluate information. It is an excellent example of the evolution and harmonization of computers and biology to aid the grower in making appropriate, well-timed pest management decisions.

California Tomato Fruitworm Control Program

Prior to efforts of researchers at the University of California, the tomato fruitworm was the most destructive pest of processing tomatoes in the Sacramento Valley. In 1981, University researchers initiated a program to develop an efficient, economical means of predicting the need for pesticide applications to processing tomatoes for fruitworm control. By 1984, after three years of research, an egg sampling method was developed.

Results from demonstration fields showed reduced pesticide applications and a net positive benefit of $7.10 per acre. By 1986, survey results of growers showed that 57% had adopted the program

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and an additional 31% did some modification of the program to fit their use. These growers realized increased yields and improved quality while reducing their overall costs for pesticide inputs.

This program continues to be a success today, due to the combined efforts of growers, crop advisors, researchers and extension advisors. It is an example where a single IPM technique, years in development, has had a major impact on pest control in a crop.

Navel Orange Worm Control Program in Almonds

Almonds provide a good example of how improved knowledge of the basic biology of an insect pest, combined with multiple control techniques, can lead to a successful, self-sustaining IPM program.

Historically, almonds have been susceptible to navel orange worm (NOW), San Jose scale and mites. With the advent of the first effective materials to control NOW, pesticide use on almonds increased in the mid to late 1970s. Unfortunately, ill-timed applications of these materials killed natural predators of the San Jose Scale and mites, resulting in increased pesticide use. This situation led to a substantial research effort that focused on the development and practical application of orchard sanitation; detailed biological information on the life cycle of the NOW to better time pesticide applications; and an understanding of the natural enemy complex that controls mites in almond orchards.

By the mid-1980s, pesticide use on almonds had been reduced +40% in both the poundage used and in the number of acres treated, resulting in a direct savings to growers of more than $4 million per year.

The result of this research was the implementation of a sustainable IPM program for almonds. Today, this IPM program employs techniques, including but not limited to, tree pruning for improved spray coverage, sanitation (removal of NOW mummies from trees), timed pesticide sprays based on life cycle patterns and manageable pest thresholds, an early harvest of nuts and quick removal of nuts from the orchard floor after harvest.

By the mid-1980s, pesticide use on almonds had been reduced 40+% in both the poundage used and in the number of acres treated, resulting in a direct savings to growers of more than $4 million per year. Crop damage was also decreased accordingly, increasing grower revenues by an additional $8 million annually. The above results were achieved through research on the basic biology of insect pests and applying that information in a manner that led to the development of an array of practical IPM techniques.

Washington Alfalfa Seed Production

In Washington, lygus bug and pea aphids are two major insect pests in alfalfa seed production. Washington State University has developed an IPM program to combat these two pests which consists of combining biological and chemical control practices. The success of the entire program is dependent on scouting with the use of sweep nets to monitor pest and predator population dynamics. Also essential to the program is an early application of a broad spectrum insecticide to control the initial infestation of lygus bugs. Early insecticide applications allow predator populations to get established.

When pea aphid populations reach the economic threshold, i.e., the level at which point the economic damage to a crop exceeds the cost to manage the pest, growers use a selective insecticide which targets only the aphid pest but does not harm beneficial insects.

The beneficial insects, e. g., damsel bugs and bigeyed bugs, then transfer their feeding to the lygus bugs. Growers try to avoid using broader spectrum insecticides for control once into the growing season. As a result, natural predators (a biological control technique) become the primary control mechanism for lygus bugs in this management scenario.

This IPM program has been successful to the extent that approximately 80% of the alfalfa seed fields in Washington do not require chemical controls for lygus bug after the season has started. This combination of monitoring insect populations, allowing natural predators to provide much of the pest control and judicious and selective use of insecticides is an example of a true integrated pest management program.

Hessian Fly Control In Pacific Northwest Wheat

The Hessian fly is a pest of wheat that can be very destructive. Damage prevention measures must be taken far in advance of the situation as there is little chance of controlling the pest once an infestation has started. The type of preventive action taken depends on the severity of the pest pressure in a given field.

In recent years, management of the Hessian fly in Pacific Northwest winter wheat has become more difficult. New conservation tillage practices, employed to reduce soil erosion, preclude the use of the most effective management technique (deep plowing), leaving more infested plant residue on top of the soil surface after wheat harvest. Hessian flies emerge from this plant residue and reinfest the fall-planted crop in the spring. Deep tillage, while reducing fly populations, increases the potential for soil erosion and the chance that a grower will be out of compliance with USDA conservation tillage criteria.

This situation led to the development of a Hessian fly management program. As a first step, growers are encouraged to plant winter wheat earlier in the fall and at higher than normal seeding rates to make up for lost plants due to Hessian fly damage. If infestations are high enough in wheat stubble from the previous crop, the use of granular soil insecticides (placed in the seed furrow) are recommended at planting to protect the fall crop.

The above is an example where an effective pest management technique (deep plowing) is in direct conflict with good soil conservation practices. Thus, the

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need for additional options to control pests in a changing environment has led to the establishment of a successful IPM program.

Apple Mite Control Program (Pacific Northwest)

In the Pacific Northwest, a truly integrated approach to management of spider mites in apples is practiced. In 1961 an investigation of the entire mite complex of apples was initiated. Researchers discovered that the western predatory mite preyed upon the more common plant damaging mites and was resistant to certain insecticides that were used to control codling moth and several non-mite tree fruit pests.

In 1965 several growers decided not to spray for control of plant damaging mites, but to allow the western predatory mite to control them. They did so with great success.

Over the next few years, IPM programs based on biological control of mites and chemical control of codling moth and other key pests were widely implemented in apple orchards throughout the Northwest. As a result, the total cost for mite control in apples declined from a statewide average of $60 per acre in 1967 to $20-30 per acre in 1985. The success of the Pacific Northwest apple mite control program influenced research and grower practices in nearby areas where the western predatory mite was present.

In British Columbia, California, Utah, and Colorado, integrated mite management is now widely practiced. Pesticide resistant western predatory mites from Northwest orchards have been successfully introduced into southern California, and as far away as Australia, New Zealand, and the Republic of Georgia.

This is an example of the integration of biological and chemical control to achieve a level of pest management that could not be achieved with pesticides alone.

California Cooperative Pink Bollworm Project

The California Cooperative Pink Bollworm Project is an excellent example of a regional IPM program. It requires the cooperation of growers (Cotton Growers Association, Cotton Pest Control Board), as well as both state (Department of Food and Agriculture, County Agricultural Commissioners) and federal agencies (USDA). The result of its 30 year existence is the effective management of the Pink Bollworm (PBW), *Pectinophera gossypiella,* one of the world's worst cotton pests.

The program consists of monitoring the 1 million acres of cotton in the San Joaquin Valley with pheromone traps to detect incipient PBW infestations. If detected, sterile male PBWs are released so that eggs of mated females will not be fertile. Pheromones may also be use as mating disruption devices, preventing male moths from locating females. Growers also maintain a 90-day host-free period -- in the form of a mandatory plowdown-- to minimize or prevent the overwintering of any PBWs that may have escaped earlier control measures.

This program has yielded tremendous financial and environmental benefits at remarkably little cost. Millions of pounds of pesticides and their associated costs have been saved. Control of PBW has been accomplished with an annual grower assessment of $2 per bale of cotton, or an average of just $5 per acre.

Predator Snail Controls Pest Snail In Citrus

Citrus growers in the San Joaquin Valley are utilizing the decollate snail, *Rumina decollata*, to control the more damaging *Helix aspera* or brown garden snail population.

Brown garden snails use orange groves as a food source and can cause extensive damage in orchards by feeding on both the fruit and young leaves. Brown garden snails can also feed on young tree bark and cause severe damage in citrus nurseries. A common practice for control of the brown garden snail has been poison applications.

Over the last decade, farmers are beginning to use an IPM approach to deal with the brown snail. Decollate snails are now introduced into commercial groves where they feed on the brown snails. This practice can reduce the destructive snail populations to insignificant levels in 4 to 10 years. Decollate snails also thrive in citrus groves where low-volume irrigation systems create a moist environment.

In tests on an eight acre commercial grove, decollate snails were released at the rate of 12 snails per tree. It was three years before an effective population developed; however, this original nursery block provided snails for more than 150 acres over the next three years.

In addition to using decollate snails, skirt pruning and trunk banding are helpful in an IPM approach to controlling the brown garden snail.

Summary

These samplings of case studies range from relatively simple to more complex. They demonstrate that: IPM is a pest control strategy that is an integral part of overall crop production in the Western United States; IPM programs can differ dramatically from crop to crop; reliance on pesticides, while reduced, remains a vital component of each of these IPM programs; and the heart of any IPM program is the principles, tools and goals discussed in the beginning of this document.

Finally, it must be remembered that as knowledge and technology evolve, so will IPM programs: They are dynamic, not static entities.

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Note: The tomato, almond and cotton case studies were cited in California Agriculture, 1990, Vol. 44, no. 5. The Pacific Northwest apple mite control program for apples was cited in Anthropod Biological Control Agents and Pesticides by B. A. Croft, 1990, page 723 (J. Wiley & Sons). The alfalfa seed production case was obtained via personal correspondence from Dan Mayer, Ph.D., Extension Specialist, WSU, Prosser Research Station.

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