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The Pesticide Marketplace

DISCOVERING AND DEVELOPING NEW PRODUCTS

The Pesticide Marketplace

Discovering and Developing New Products

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Understanding the Customer

The pesticide industry is driven by unique pest problems that cannot be resolved by nonchemical means. Customers, realizing the utility of effective pest management, create the market that drives the discovery, research, and development of modern pesticides. Customer needs differ by climate and geographic location, local pest populations, and the management practices they use. And differing needs lead to varied product preferences.

The pesticide industry clearly understands the importance of customers' needs and those of the end consumer. Take strawberries, for example. Not only must the pesticides used on them be effective and safe for the strawberry farmer to use, they also must facilitate the production of safe, tasty, affordable fruit.

Consumer demands for quality and affordability are preeminent whether the strawberries are imported or purchased from local markets. Quality and price are the two highest consumer considerations at the grocery store, and both can be traced backwards to the transporter, the distributor, and, ultimately, the grower. The bottom line is that the grower has to produce a quality crop to earn top dollar. An inferior crop has to be sold at low dollar value for utility purposes (e.g., strawberries for jams and jellies) in order to make it out of the field at all.

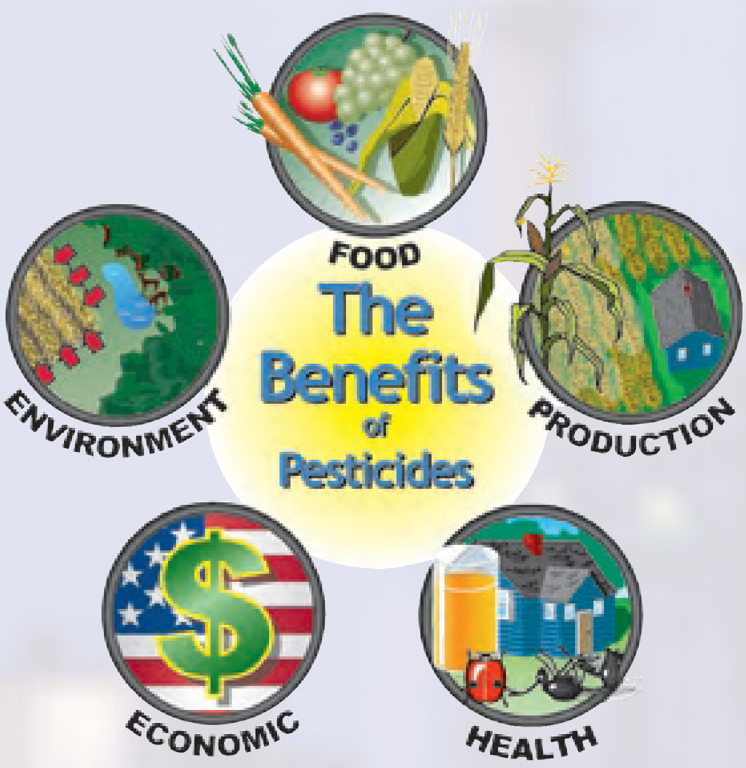
Fred Whitford

Growers use alternative pest control measures such as cultivation, site and cultivar selection, crop rotation, and balanced fertilization to minimize the impact of crop pests. In some cases, they apply fungicides to protect fruit from diseases that cause it to rot in the field, in transit or storage, or on display in the marketplace. Herbicides control weeds to allow plants enough space, light, and nutrients to grow; and they eliminate weed harborage for injurious insects and diseases. Insecticides protect plants and fruit from insects. Fungicides, herbicides, insecticides: these pesticides, individually or in combination, prevent pest damage and contribute significantly to the production of a quality product at the lowest possible cost. But because pesticides are expensive, growers' use decisions are based on maximizing the return on their pesticide investment, the same as if they were purchasing a new piece of farm equipment.

Others make similar pesticide use decisions, such as investing in a termite control program. A homeowner might compare the cost of preventive treatment to the potential cost of treatment and structural repairs if an infestation were to occur; he might also consider the impact termite damage could have on the value of his property.

Each pesticide product must offer the user a verifiable benefit. For example, if a grower sprays for insects yet realizes a disappointing economic return due to insect damage, he will have no incentive to use the product again. Users expect a calculable return on their pesticide investment just as they would on any other investment, including nonchemical alternatives.

Farmers need pesticides that meet specific needs and enable them to grow products that consumers will buy. Their profit margin depends on it. The pesticide industry has to realize and acknowledge the varying needs of its customers.



Arlene Blessing

Customer Needs Differ by Group

Homeowners: Quick and Easy

The average consumer who buys pesticides for home use is looking for products that are easy to use, fast acting, and convenient. This is why many pesticides used around the home

- come as ready-to-use products packaged with their own applicators.
- are formulated to reduce the likelihood that they will harm nontarget organisms.

Fred Whitford

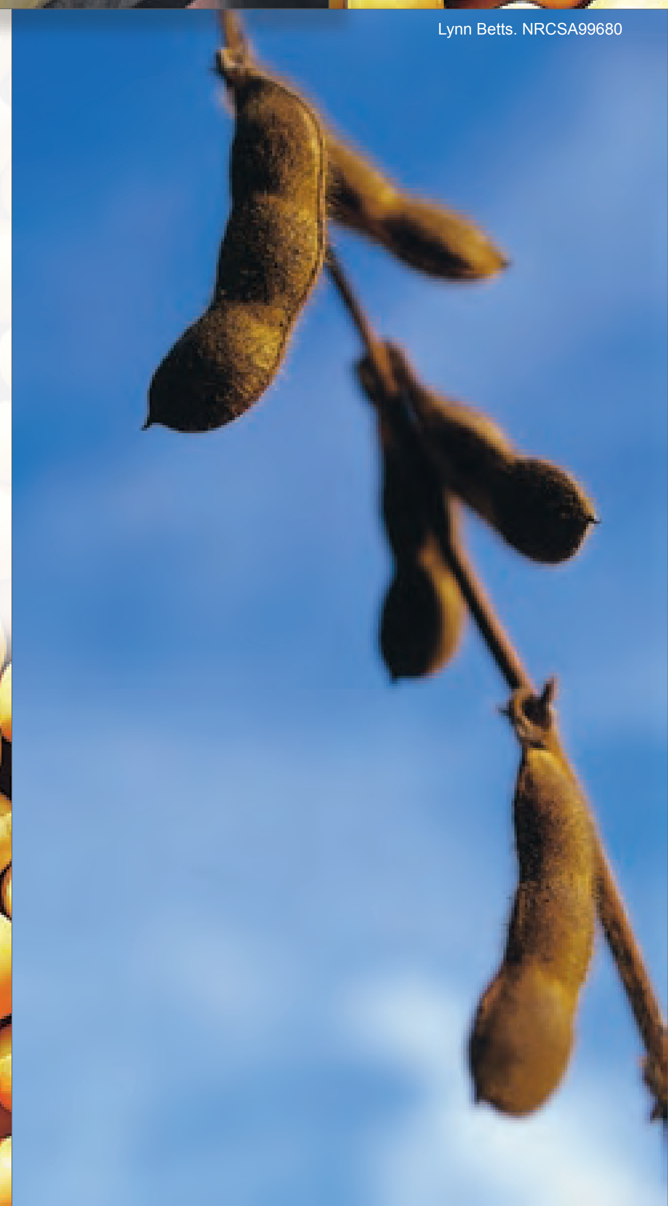
Tim McCabe. NRCSIA99280

Lynn Betts. NRCSA99679

Growers: Economical and Effective

Growers typically are better prepared than homeowners to accept complexity when it comes to selecting pesticides; often they have their own application equipment and deal in large volumes. Growers primarily ask about

- efficacy: does it control the pests in my crop?
- return: is it competitive and does it give an economic return on my investment?
- convenience: is the product easy to handle?
- safety: how safe is the product for the applicators, field workers, and consumers?



Lynn Betts. NRCSA99680

Commercial Pest Control Industry: Safety and Reliability

Safety is the primary consideration when using pesticides in and around the home and workplace. Commercial pest management professionals are looking for products that

- provide consistent performance: good control, no customer complaints.
- do not restrict their customers: no re-entry restrictions or risk to children, pets, neighbors, etc.
- can be applied safely.
- can control a broad range of pests, thus reducing the number of products needed on a service truck.

Consultants: Performance and Cost

Pesticide use decisions are more complex today than ever before, and nearly all growers consult with pest specialists before purchasing or applying pesticides. Consultants may work for distributors or companies that re-sell pesticides; they may be independent; they may be employed by large farm operations or commercial businesses. The cost of consulting with an expert is justified by increased productivity and product quality: the more high quality units produced, the lower the cost of production per unit.

Consultants depend on products they recommend to perform precisely as stated by the manufacturer. Therefore, they are careful to advise the use of pesticides that have been proven to

- perform consistently.
- improve quality and yield.
- perform well in long-term integrated pest management programs.
- increase profits.

Distributors and Retailers: Sales and Margins

Distributors and retailers profit by selling pesticides and pest management solutions to growers, commercial applicators, and homeowners. They stock large quantities of pesticide products and carry a substantial credit risk to maintain a viable inventory. They prefer products that

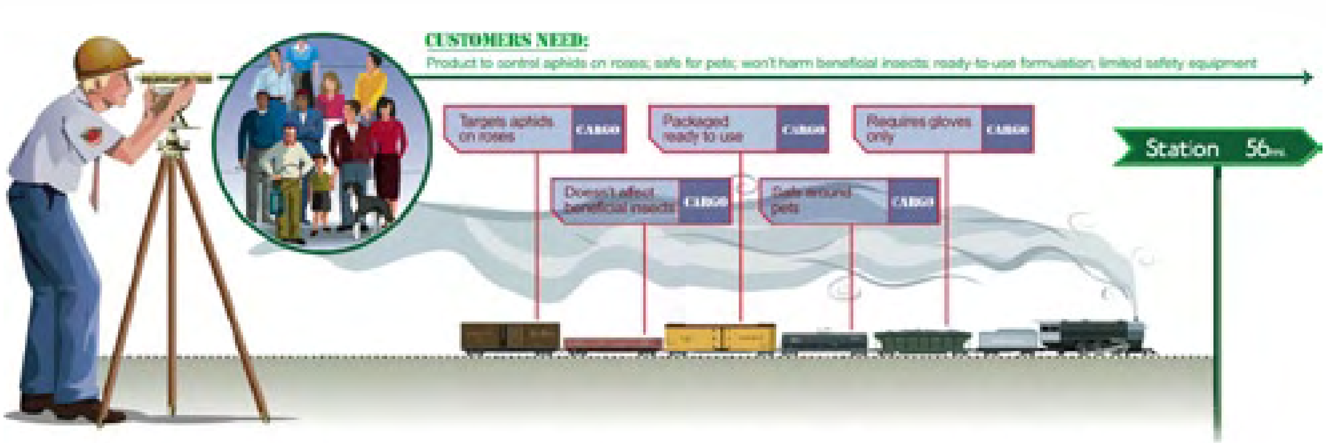
- control a broad spectrum of pests.
- are formulated for easy handling and storage.
- provide excellent value for the investment.
- sell quickly and provide a reasonable profit opportunity (low overhead/high demand).

Selecting Products to Sell

The discovery and development of new pest management solutions is an extremely demanding business. It is risky: discovery and development cycles are long and uncertain, and market changes can occur during the process. It takes eight to ten years and millions of dollars to test, develop, and register a new pesticide once a promising compound is discovered. During this lengthy cycle, customer needs and attitudes can fluctuate, new regulatory requirements can go into effect, competitive products can preempt opportunities, and market prices can change. Product development is a very risky business.

Companies engaged in discovery, research, and development must survey customer needs with sensitivity toward views on benefits and risks. The development of new or newly expanded products is based on business principles, but customer needs are the driving force behind commercial success—which, in turn, funds research for products of the future.

The process of new product development is much like planning a railroad line. For commercial success, the route must be carefully chosen and a train specifically assembled to deliver the right cargo to the right place at the right time. Once a route is committed and the track is laid, it is extremely difficult to back up and refocus. If all elements of the plan fall into place, customers will be waiting at the station when the train rolls in.



Customer needs are the driving force behind commercial success of new pesticide products

Core Markets

Each pesticide manufacturer has a business plan outlining its mission, vision, and targeted markets. Some focus on core markets—herbicides, insecticides, fungicides, rodenticides, biocides—based on the scientific and marketing strengths of the organization. Others create a niche for their unique presence, strength, or expertise. The core market for a company generally is linked to the business plan, structured around its

- relevant scientific expertise,
- ability to analyze new markets,
- dedication to new product development, and
- commitment to maintaining highly skilled technical staff to sell and support the product.

Agricultural pesticide manufacturers often expand sales to the home and garden market as well as the commercial turf, ornamental, structural pest control, and right-of-way markets. For instance, a herbicide developed for agricultural grass control also might be marketed to the homeowner for crabgrass control and to commercial applicators for accounts such as lawns and golf courses. These smaller-scale clientele cannot support the initial development of new pesticides, but manufacturers can boost profits by targeting them for sales of established products.

The estimated cost of discovery, development, and registration to bring a new pesticide active ingredient to the marketplace exceeds $180 million, not including the capital cost associated with building and operating highly specialized production facilities. Global agricultural is the only market large enough to support this kind of investment, which is why major pesticide manufacturers focus primarily on the development of agricultural chemicals.

new pesticide product...

$180,000,000

...eight to ten years

Fred Whitford

Lynn Betts. NRCSIA99104

Lynn Betts. NRCSIA99025

Certain herbicides used on roadsides and lawns were originally developed for weed control in agricultural crops such as corn and soybeans.

Consumers can choose from a large variety of pesticides in most markets, making the marketing of new products very challenging—especially as more and more products with expired U.S. patents are being produced inexpensively. New pesticides must offer unique advantages to earn a substantial piece of the market and earn the manufacturer a profit on its investment. It takes four to six years for the sales volume of a new product to reach a point where the manufacturing plant can operate at efficient capacity.

Products must be evaluated continually for ways to increase efficacy, broaden use patterns, and minimize risk.

Technical Expertise

Successful pesticide product development for new or existing markets requires researchers and marketers with technical skill and expertise. A company may recognize an opportunity but lack the personnel to accomplish its goal. For example, company managers may be aware of an opportunity to develop a fungicide for disease control in nursery stock or ornamentals (below) but not have the personnel to discover, develop, and deliver such a product. They would have to forego the opportunity or hire staff with the necessary expertise.


Fred Whitford

Improving Expertise

If a company is ill equipped to take advantage of an opportunity that comes its way, changing focus may be the solution. But change is expensive and risky. It takes considerable planning and time—sometimes years. For example, a company cannot expand into biotechnology if it lacks the necessary facilities, infrastructure, or personnel. Physical space requirements have to be met and knowledgeable staff hired to accommodate the strategic plan, and these things can take a very long time.

Purchasing Companies and Products

A company may accelerate its proficiency in a new area by purchasing another company or licensing the product portfolio and technical expertise of an established company. These options afford the buyer immediate ownership of existing products, including new technologies still being developed, and a share of the associated market.

Aligning with Other Companies

Many pesticide manufactures consider strategic alliance with competitors essential to their success. There is a growing demand for pesticide products; and, when multiple companies collaborate, the costs and risks of development decrease for each cooperating company. A wider range of products can be produced to serve a broader range of customer expectations. Agricultural pesticide manufacturers can expand their product line to include more crops or sites and more markets by aligning themselves with companies such as seed producers whose product characteristics are missing from their own portfolio.

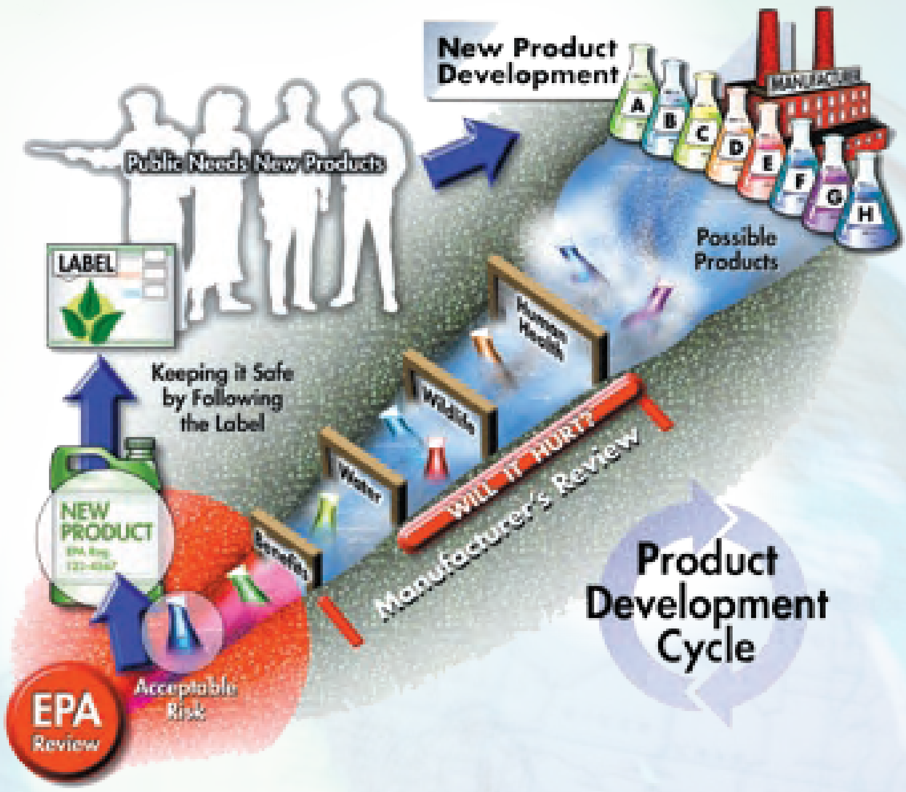
> MEDIA RELEASE
>
> **Wilmington, Delaware, USA, and Basel, Switzerland**
>
> **10 April 2006**
>
> **DuPont and Syngenta today announced in Chicago, Illinois, the formation of a joint venture and licensing agreements that will bring expanded choice to North American farmers through broader access to the companies' proprietary corn and soybean genetics and biotechnology traits....**

Financial Returns on Investments

Pesticide manufacturers must develop products that will generate a return on their investment, and it is important that the profit potential of a product be determined early in the discovery process. The overall analysis includes consideration of two important questions: Will there be sufficient demand for the product following the development process of a decade or more? Will its mammalian and environmental risk projections be low enough to facilitate registration? If all analyses are favorable, the manufacturer may risk millions of dollars and thousands of man-hours to continue developing the product.

Manufacturers seek as many of the following attributes as possible in a potential product. The closer they are to the ideal product, the better their chances of getting the product registered, achieving marketplace success, and realizing strong profits. New products have a reasonable opportunity for commercial success when they

- benefit the manufacturer, the distributor, the dealer, the user, and the consumer.
- offer unique benefits that current products lack.
- can be used in many different markets.
- control a broad range of pests without harming beneficial organisms or nontarget species.



- can be manufactured and formulated at low cost.
- can become registered in a timely manner.
- have lower use rates than existing products.
- do not persist in the environment.
- have low human and environmental toxicity.
- can be used safely by the pesticide applicator.
- will not leach into ground water or run off-site into surface water.
- will not accumulate in food, wildlife, or soil.

Right-to-Patent

In the United States, as in most other countries, there are patent laws to protect the owners of product and use patents. These laws protect the owners' rights for a period of 17 to 20 years, which allows time for the owners to develop and market their products and recover investment costs. Profit is the reward for taking the risk of inventing and developing new and innovative solutions; without profit, there would be no funding for continued research.

Right-to-Sell

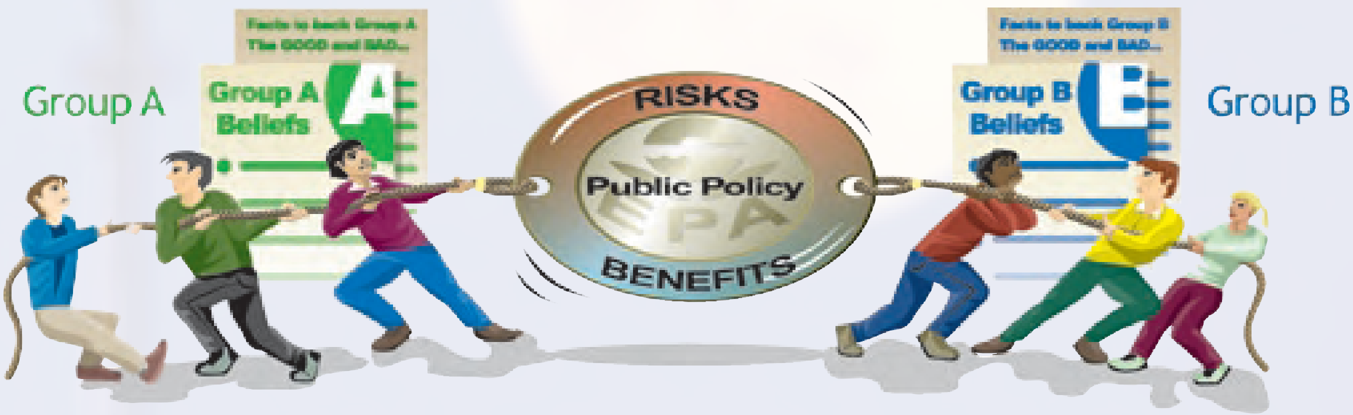
Pesticide products must be registered in each country in which a manufacturer intends to sell them, and the cost of compliance with registration standards increases each year. Regulatory agencies commonly require additional studies to satisfy concerns for human and environmental health, wildlife, product efficacy, pest resistance, etc. The duration of the regulatory evaluation process continues to expand despite an increasing level of analytical, computational, and documentational sophistication. There also is the risk that, if one country chooses not to register the product, other countries may follow suit. These uncertainties place significant pressure on manufacturers to commit only their very best product concepts to the development process.

Corporate Responsibility

Government agencies worldwide do not dictate what manufacturers may sell; they mandate only what they may not sell. Conversely, manufacturers may choose not to register a product in every country in which it meets government standards. They also may restrict registration and marketing based on a variety of legal and ethical issues.

A company's product portfolio reflects its corporate position on environmental stewardship, human safety, and global responsibility. The company's values and ethics—and to some degree its tendency to practice what it preaches—are important considerations for stakeholders. Many chemical manufacturers emphasize their compliance with Responsible Care, an initiative of the American Chemistry Council that specifies stringent operational and stewardship guidelines to protect human health and the environment.

Sophisticated investors look for companies that offer products beneficial to customers and friendly to environmental and human health; they prefer products that pass the scrutiny of environmental groups, child safety advocates, and other industry watchdogs. Product negativity such as legal battles, bad publicity, and regulatory restrictions signal a potentially bad investment. The benefits have to outweigh the risks to attract investors.



Discovering and Developing New Products

New product development is time-consuming, dynamic, and ongoing. Information on the need for new products originates with the manufacturer's field staff, pesticide-use survey information, consumer groups, university agricultural specialists, government researchers, and marketing and consulting services. Companies continually collect information to improve their understanding of what the customer wants, what their product can and cannot do, and, more importantly, how the market will look in the future.

Managers of product development must consider multiple issues:

- Is there a need for the pesticide?
- Is there an exclusive patent or otherwise defensible claim on the pesticide?
- What are its positive and negative attributes in terms of safety, health, and environmental fate?
- Is its performance proven under real use conditions?
- Are its characteristics acceptable to the Environmental Protection Agency (EPA), other governmental regulators, and global agencies?
- Will the product pass the scrutiny of nongovernmental entities (customers, consumer groups, processors, other interested parties)?
- Will the product become profitable?

New products must capture a percentage of the market and remain competitive for many years, which is why so much attention is focused on consumer and market information. Manufacturers have to decide where to focus their discovery and research efforts based on market growth projections. The correct positioning of personnel to identify tomorrow's pesticide needs—and to discover the compound to fulfill those needs—spells success for the manufacturer. It is the first step in capturing a share of the market and generating profit to reinvest in yet another product.

Expanding Product Use or Discovering New Active Ingredients

Short-Term Goals: Modifications to Existing Products

Product portfolio managers always look to expand the usefulness of existing active ingredients (pesticide compounds). The creation of new mixtures, formulations, and delivery systems to meet customers' changing needs extends the profit margin of pesticides already in production.

Sales representatives have continual direct contact with customers and often are the first to recognize changing trends and new marketing opportunities. Their reporting to research and development staff and management personnel provides the insight to develop existing active ingredients into products that keep pace with an ever-changing market.

This exchange of information is crucial because the focus during the discovery and development phase tends to be narrow; that is, the pesticide is developed for specific uses in specific markets. As more is learned about the molecule, other marketing possibilities emerge; and each additional avenue for sales adds value to the product.

Long-Term Goals: Investing in Future Pipeline Products

New products must demonstrate efficacy well beyond the performance of existing products labeled for the same or similar uses. The search for a newer, better pesticide is difficult and complex:

- What will be the driving forces of future change?
- What will the market look like in a decade?
- How will the product fit customers' future needs?
- How will economic, regulatory, environmental, and cultural practices change?

Manufacturers include a wide variety of buyers in gathering information on future pesticide markets: grain millers, baby food manufacturers, supermarkets, etc. But the end user—the farmer, the pest management professional, the homeowner—is an equally valuable source for insight into what customers' needs will be ten years into the future.

This perspective allows pesticide manufacturers to anticipate shifts in customers' expectations of the industry, such as less pesticide use, lower residues on food, less genetic modification of crops, and produce that looks appealing and stays fresh in the store.

Fred Whitford

National and international markets are important in the pesticide development process. This photograph shows bananas growing in Honduras.

Customer Information Obtained from Multiple Sources

No one group or individual can provide all of the information necessary to expand a product into new markets nor anticipate future trends in the global market. The purpose of market research is to merge and balance multiple points of view.

Manufacturer's Sales Force

Sales personnel are highly regarded for translating their customers' needs into marketable ideas for the manufacturer. The astute salesperson listens to his customers and gains valuable insight into his company's product and portfolio weaknesses. For instance, if users are telling their sales representative that a weed is becoming more difficult to control with his company's line of products, he can take that information back to his research and development scientists. The company may respond with a new product or premix, a new tank mix, a new use rate, or a change in labeling that permits the use of their current products in combination with a competitor's products.

Sales personnel also understand their competitors' products and why some users prefer them. Sales staff can offer critical insights into where and why the market is shifting (e.g., from a preemergence to a postemergence herbicide program preference).

Dealers

Customers talk with their pesticide dealers about what products are and are not working for them and about how competitive products stack up against them. The dealers relay that information to the manufacturer.

Dealers typically know whether the level of service provided by the manufacturer is sufficient to meet customers' expectations. For example, whether the manufacturer will reimburse the user if the product fails; or whether the manufacturer will send a representative to the field to handle a complaint.

University Panels

University scientists typically provide a consolidation of voices; that is, through participation in growers' meetings, field days, etc., they gather input from a wide variety of pesticide users and are able to merge customers' needs based on years of experience. Agricultural scientists offer technical perspectives from their particular areas of expertise. They can lend valuable clues to crop management needs of the future, such as pesticides and use patterns likely to prevail.

Commercial agricultural pesticide applicators and dealers learning to identify weeds (above). Growers learning about proper handling of pesticides at a Purdue University field day (left).

Market Research Providers

Market research companies conduct surveys to collect and summarize public and private information on crop production (products and practices used in specific markets). They also summarize pesticide use surveys and identify use trends; pesticide manufacturers may purchase these reports and use the data to determine which products are capturing market shares and which ones are declining. They then analyze the successful products in search of the attributes that appear critical to success.

If pesticide manufacturers view something in a market survey as either an opportunity or a threat, they can hire a firm to gather additional information from panels of users or experts. There are marketing consultants who specialize in designing customer questionnaires and serving as mediators in round-table or focus group discussions.

Advisory Councils

Remember that the term "customer" is broadly defined. A customer could be a farmer, a nongovernmental organization, an environmental group, a childcare advocacy group, a grain miller, a supermarket produce buyer, a fresh fruit buyer, etc. Each has a stake in pesticide products placed in the marketplace. Each has an idea of

- what product characteristics are desirable.
- what characteristics they would like to see increase or decline in the future.
- what the social and political landscape will be in ten years.
- how the regulatory environment may change in the next ten years.
- what the probability is for global acceptance of genetically improved crops.
- how sprayable pesticides will be accepted in ten years.


Fred Whitford

Marketing 101: Turning A Profit by Meeting Customers' Needs

Marketing research begins with an analysis of the different customer levels. For instance, questions are directed toward end users (e.g., apple growers, cotton farmers), dealers who sell pesticides, distribution outlets, and consultants. Those selected for intensive interviews, individually or as members of a panel, are the decision-makers (or those who influence the decision-makers) within each group of customers.

Asking the End User, What are Your Critical Needs?

Manufacturers conduct qualitative interviews and quantitative surveys with customers to determine their needs. The end user generally has the shortest time line expectations, primarily because his need for a new product is based on problems faced during the previous growing season. Often the desire is for incremental improvement: better performance, quicker response, a broader range of effectiveness, etc. Manufacturers use the information from users to direct the fine-tuning of existing products.

A grower may not be able to respond effectively if a marketer asks, What pesticide changes would benefit your production? But he certainly would know if his customers want a product he cannot produce. For instance, he may indicate that the public preference is moving from a hardy, disease-resistant apple variety to one that tastes better but is prone to disease. The market researcher would recognize the need for a product to control certain apple diseases.

Growers have concerns about weeds becoming resistant to herbicides. A test on giant ragweed from one field (above) shows the labeled herbicide rate (1x) to be inadequate for control. A test on giant ragweed from another field (right) demonstrates control at full (1x) and half (½x) rates.

Manufacturers want unbiased feedback on the performance of their products and services, on their reputation, and on their competitors' products. The process starts with the manufacturer conducting qualitative interviews with customers from around the globe. The company names the key markets on which to focus, outlines specific objectives, and recommends key questions for marketers to ask.

For instance, the manufacturer wants to develop an insecticide for the wine grape industry and market it in the United States and Europe. The manufacturer determines that 200 grower surveys are needed to assess the wine grape marketplace.

The manufacturer must develop a profile for the U.S. and European growers it wants to interview. The main criterion is that they grow vines on at least 40 acres. The market research firm then uses a database to compile names of people who do so and potentially meet other selection criteria set forth by the manufacturer. Most market research firms can access lists of end-use customers in the countries of interest.

Questions that may be asked include the following:

- Which insect, weed, and disease pests are prevalent?
- What are the most important pests?
- What level of control do you expect?
- Do you expect to make one application or multiple applications?
- What level of control do you currently achieve?
- What products do you currently use?
- How do you use our products?
- Would you rather use liquid or dry products? Water- or oil-based?
- Do you have any concerns about equipment damage caused by current formulations?
- Is there any evidence of resistant pests in your area? If so, what pest and what compound?
- What nontarget species need to be considered?
- What critical attributes do you use to select one product over another?
- What do you want the product to do and not do?
- What are the weaknesses of current products?

A disease outbreak in a vineyard can be devastating. Fungicides are needed to protect against powdery mildew on chardonel grapes (top right) as well as Phomopsis cane and leaf spot on Melody grapes (right).

Bruce Bordelon

Bruce Bordelon

- Do you anticipate changes that could alter the way you do business?
- Do you see any emerging pest problems on the horizon?
- Do you expect the basic pesticide manufacturer to help you manage your crops (e.g., by lending scouting expertise)?
- Would you pay this amount for a product with these attributes?
- How important is it to buy from a local agricultural outlet?

Data from the survey broadly define what type of pesticide is needed, how it should be formulated, what pests it must control, and the attributes necessary for peak effectiveness (e.g., knockdown capability, residual activity). For instance, the grape growers may indicate that any product they use must achieve 90 percent control of certain insects. If they also indicate that the products they already use meet this goal, the pesticide manufacturer may not recognize a need for another product. Based on this information, it might be very difficult to develop an insecticide with greater than 90 percent control.

However, if their current insecticide requires application every three days, the growers might find a product that could be applied only once—and still achieve 90 percent control—very desirable. In this example, the pesticide manufacturer could surmise that growers would pay more for a product that would last longer (require fewer applications) than products currently on the market, ultimately saving themselves time and fuel.

Asking the Distributor, Dealer, and Commercial Applicator, What Are Your Critical Needs?

Distributors, dealers, and commercial applicators have tremendous influence over the growers they serve. In particular, dealers often are the first to utilize new products, selling them to farmers along with their application services. The farmers tell others about their successes with the new product, and the word gets around. Retailers encourage their customers to use the products they carry. If they have more success selling one manufacturer's products than another's, that is where their loyalty will lay, thereby influencing the market.

Dealers and distributors think differently about pesticides than do their customers: first from a business standpoint, then from their customers' (price, efficacy, ease of use). The principal problem dealers face is lack of adequate warehouse space; often they must restrict their inventory to products from only one or two manufacturers.

Dealers and distributors also are concerned about how pesticide manufacturers market or promote their products, what profit margins the dealers will achieve, and what other incentives manufacturers offer dealers for choosing their product line over that of another company. Technical support is a good example: dealers expect manufacturers' representatives to help them resolve grower complaints and respond to use questions.

The Manufacturer's Decision: Can the Market Support the Product?

Market research information is collected, assembled, reviewed, and summarized to gain an understanding of what the future may hold, which helps determine whether there is a need strong enough to support the development of a new product.

Gauging the Size of the Potential Market

The decision to develop a new product or enter a new market depends on the size of the market and the customers' needs and desires. Obviously, manufacturers seek markets where customer needs can be met with their new products in large quantities. But only a handful of crops actually meet the criteria of critical need and necessary volume. The crops for which a pesticide might be specifically developed include the following:

- Corn and soybeans (herbicides)
- Cotton (insecticides and herbicides)
- Wheat and barley (fungicides and herbicides)
- Rice (herbicides, insecticides, and fungicides)
- Tree and vine crops (fungicides, herbicides, and insecticides)
- Potatoes (fungicides and insecticides)
- Fruit and vegetables (fungicides, insecticides, and herbicides)

Manufacturers consider several factors when gauging the size of a market:

- What is the total crop area compared to the treatable crop area? Crops can be evaluated from two general standpoints: the total acreage treated or the number of applications made during a growing season. Corn, soybeans, cotton, and wheat are each grown on a large number of acres, so the product may need to be applied only to a small portion of the total acreage to become profitable. Grape, vegetable, and tree fruit acreage often is too small to support the development of new products. However, these still may be important markets because they are high-value crops with varying multicycle pest problems that require multiple treatments during the growing season. For instance, 2.5 million acres of grapevines in France are treated for downy mildew six to eight times each growing season—about 15 million acres altogether.

- What are the acceptable thresholds for weeds, insects, and diseases? While a few insects in a corn or soybean field will not decrease crop yield or quality, even a few insects can cause detrimental effects in less tolerant crops. A single, glassy-winged sharpshooter can transmit the devastating grapevine virus known as Pierce's disease. Potato late blight can infect an unprotected potato field at almost imperceptible levels and totally destroy the crop within a matter of days. An apple grower can lose his entire crop by missing one disease outbreak.
- How much are growers currently spending on pesticides?
- Is there a global market for a new product? Manufacturers tend to look for multiple-market opportunities. For instance, if a broad spectrum insecticide is needed in one crop, are there additional major crops on which the pesticide could be used?
- What countries grow crops on which the new pesticide could be used? Product registration difficulties and competition from existing products make some markets unattractive.
- What is the profit potential of the new pesticide, assuming a reasonable market share projection?
- Are current products and active ingredients under-performing, thus creating the need for new technology?

Manufacturers can begin projecting market opportunities only after they have answers to these questions. Careful scrutiny is essential in determining whether the massive investment of time, money, and manpower to produce a new product is warranted.

New Product Development: from the Laboratory to the End User

The mission of product discovery and development is to find new pesticide products that can be used safely and effectively, with true profit potential for the manufacturer.

It costs an average of $180 million—plus the cost of a new manufacturing facility—to introduce an active ingredient to the marketplace; so marketing professionals continually seek products that can be used successfully on multiple crops in various geographic situations. Multiple formulations of a pesticide widen its use capabilities and increase the manufacturer's profit.

It takes nine years, the review of 140,000 compounds, and $180 million to discover and develop a new pesticide product.

	Percentage of Total Cost
Chemistry	22.3
Biology	23.9
Toxicological/Environmental Chemistry	23.4
Developmental Chemistry	10.8
Field Trials	13.6
Registration	6.0

Source: The Cost of New Agrochemical Product Discovery, Development, and Registration in 1995 and 2000. Phillips-McDougall. 2003.

Setting Product Goals

Methods used to discover new pesticides and related chemistries differ among manufacturers, and sometimes even within a company. For example, the methods used to discover a new insecticide may be quite different than those used to discover a novel herbicide, rodenticide, bactericide, or fungicide. Some manufacturers license chemistries from other companies. Some co-develop; some co-sell; some sell products developed by others; some exchange products or rights. But one element is common to all: input from the marketing team is essential to the discovery team's identification of product goals.

Product goals are key to finding the right product to meet projected market needs. Although general goals often are established by market research, product discovery and development scientists require more specific guidelines. Consider the following:

- A broad-spectrum fungicide is needed for control of diseases in European cereals and other high-value commodities such as fruits and vegetables.
- A broad spectrum insecticide is needed to control chewing insects in fruit and vegetable production.
- A nematicide is needed for high-value fruit and vegetable crops.

Scientists working in discovery and development consider these goals too general to use as benchmarks; they refine them into a series of technical attributes that serve as guidelines for comparison.

Product discovery is not about finding just another pesticide; it is a search to find novel solutions. Discovery is focused research aimed at finding a few active ingredients that meet very specific criteria. It is the research and discovery group that will design the tests and screen, identify, and evaluate compounds in the laboratory, greenhouse, and field trials.

Consider the following instance where a sales force has identified a need for a new insecticide for the U.S. vegetable market. Market research indicates that growers are unhappy with the inconsistency of current products. Further analysis finds that over-the-top sprays on vegetables do not control aphids feeding on the undersides of leaves. Insect control is further weakened as aphid populations build and the plants' leaves begin to curl, creating a protective environment for insects in hiding. The problem is compounded by thrips feeding on lower portions of the plants, where leaves form a dense protective cover.

Based on this information, the discovery group decides that the necessary molecule must be systemic (move within the plant) to be effective against both aphids and thrips. They can focus their search on molecular structures known to have systemic characteristics. These technical attributes not only help identify new molecules but also link marketing professionals and their customers.

Flexible Goals


Fred Whitford

Goals have to be adaptable to meet changing needs. Years of searching to find a specific molecule may be lost if a competitor releases a similar product into the marketplace. In other cases, the need for a new product may cease to exist when a pest-resistant crop variety is released, a biotechnological solution is applied, or the pest spectrum changes.

Roundup herbicide by Monsanto is a good example of how introduction of a new plant and seed technology product can influence the direction of industry research. In a relatively short time, Roundup-Ready soybeans, along with the use of Roundup as the principal herbicide, became the dominant soybean seed/herbicide system used in the Midwest. Ninety percent of soybeans planted are tolerant to this herbicide, and almost every acre planted to Roundup-Ready soybeans receives at least one application of Roundup or its generic equivalent.

Some pesticide manufacturers concluded that any new products brought to the soybean weed control market would have difficulty outperforming Roundup products at a lower cost to growers. This illustrates how a widely used, novel technology can disrupt a market and influence competitors' research. In this case, competing companies likely will reallocate soybean herbicide research dollars to insecticides, fungicides, and herbicides for use on other crops.

But the decision not to invest and compete in the soybean herbicide market can change quickly. With the extensive use of glyphosate (e.g., Roundup and a long list of generics), resistant weeds and weed population shifts may occur. This would cause companies to examine the possibility that growers would buy products that could be tank mixed with glyphosate to prevent, delay, or control development of resistant weeds. Millions of acres of soybeans are planted each year, and capturing even a small piece of the total market could prove financially rewarding. But companies reentering the soybean herbicide market will experience a significant lag time between the initial screening of new molecules and the sale of the final product.

Specify, Review, and Question

Pest management professionals looking for new products are well aware that success involves more than just controlling pests. Products need multiple positive attributes to make them successful and financially attractive. Control is just the beginning.

Successful product launch requires positive answers to the following questions throughout the discovery and development process:

- Is the product biologically active?
- Is the mode of action new, or is it based on an existing mode that is relatively benign to nontarget organisms?
- Does it have an acceptable toxicological profile?
- Can it be patented, or can we get around someone else's patent (e.g., license the technology from the company with the patent, or develop the product in a manner that will not violate the patent)?
- Will the cost of production be reasonable?
- Will it meet other countries' registration requirements?
- Will the use restrictions be acceptable to customers?
- Will it control multiple pests on multiple crops?
- Will it be efficacious and reliable?
- Will it be safe to crops?
- Can it be competitively priced?
- Will it be easy to handle?
- Will it offer significant advantages over competing products?
- What are the projected returns?

Answers to these questions allow researchers to focus valuable resources on the promotion of a potentially successful pesticide and eliminate those that fail to meet company, consumer, or regulatory expectations.

Seldom is a new molecule perfect. Trade-offs often force manufacturers to balance the positive aspects of a new product against negative attributes. For example, lowering use rates may make the product safer for the applicator, less prone to leach into ground water, or less likely to run off-site into streams. But the spectrum of pests controlled at lower rates may be very narrow, jeopardizing its market competitiveness.

Lower rates

- may not control targeted weeds.
- may make it more difficult to control insect larvae or weeds in advanced stages.
- may not prevent infection when disease pressure is high.
- may reduce the competitive nature of the molecule. For example, if a molecule is altered to be less persistent in the environment, the product may need to be applied multiple times as new flushes of weeds or insects occur, adding to the user's expense.
- may hasten the development of pest resistance. Increased selection pressure allows the more tolerant strains and populations to survive.

Trade-offs are a part of product development. For example, a company may identify a need for leaf mite control in apple orchards. The discovery team, using product goals for a new miticide, finds a molecule that shows promise under greenhouse conditions; but testing in apple orchards reveals that the molecule exhibits sustained efficacy against the mites only at high application rates. Unfortunately, the increased rates kill beneficial predatory insects and mites that would otherwise keep the pest mites under control; without beneficial insects to control their numbers, mites can become re-established in a short time. In this case, eliminating beneficial mites allows pest mites to become an even greater problem.

The product development team might recommend dropping the molecule from consideration. Or they could argue that the insecticide could be used effectively and without harm to the predatory mites if it were labeled for two sequential applications at lower rates, which would place a burden on the apple producer. Market analysis staff would have to determine if the product would be attractive to growers and competitive in the marketplace despite the cost of multiple applications.

Discovery Phase: Finding the Few Among the Many

The process by which a molecule is discovered, developed, and formulated into a pesticide product is tenuous and risky. From the examples presented, it is easy to understand the importance of seeking input from a diverse group of specialists, scientists, and analysts throughout the process. Even so, fewer than one in 140,000 molecules tested for pesticidal properties ever becomes a registered pesticide product.

It takes an average of one to two years to determine if a molecule has useful pesticidal properties. A three-year predevelopment phase follows for compounds that show sufficient promise, then a three-year development phase and a commercial launch phase. New pesticidal chemistry is identified by altering existing compounds or discovering new ones.

Tom Campbell

Evaluating the efficacy of a herbicide on selected weeds in a greenhouse study.

Innovation of Existing Chemistry

The goal of companies that choose to develop new products from existing compounds is to enhance certain critical characteristics—spectrum, residual qualities, selectivity—that will lure customers. Scientists modify compounds to improve their efficacy, spectrum of control, and chemical profile. The pyrethroid insecticides are good examples.

The first synthetic pyrethroid was based on the structure of pyrethrum derived from chrysanthemums. Useful innovations of that original molecular structure have been created to increase soil persistence and decrease toxicity to nontarget organisms.

New Discoveries

The pesticide industry must continually introduce new products to maintain long-term profitability; and these breakthrough products bring premium prices. Products developed from new chemistries (versus those adapted from existing pesticides) generally are easier to patent, provide longer-lasting value for the manufacturer, and increase customer satisfaction. Customers do not choose one product over another solely because of its novelty, but the manufacturer usually profits by providing the customer an alternative he has sought.

Compound Synthesis and Acquisition: Where Do the Molecules Come From?

Promising new chemistries can be found various ways. Manufacturers may purchase, sell, or trade molecules from other commercial laboratories, pharmaceutical companies, and universities.

Other molecules may be selected by computer on the basis of characteristics determined internally. These may be targeted materials about which a scientist has read in a journal or learned at a meeting; or they may be natural molecules accessed through agreements with universities or companies that specialize in unusual natural products.

Microbes are collected from the bottom of the sea, from coral reefs, and from soil profiles, plant extracts, and numerous other locations worldwide. Pharmaceutical companies have collected, grown, and cataloged microbial populations for more than a hundred years. Penicillin is one of the best-known products originating from microbial organisms. Pesticide chemists are interested in testing chemicals that microbes release into their environment, as they grow, which alter their surroundings (e.g., chemicals used to eliminate their competition). The pesticidal properties of chemicals released by microbes are variable, depending on type of growth media, temperature, humidity, and light regimes. Pesticides that originate from microbial organisms are important sources of new and unique products.

Designer Molecules:
Modeling of Target Sites / Building Structures in the Laboratory

The scientific knowledge necessary to build molecules with pesticidal properties can originate from proprietary research conducted by a company. This knowledge provides a basis for biochemists, chemists, and computer modelers to design molecules that have the desired efficacy, safety profiles, and physical and environmental properties.

Scientists generally understand which metabolic sites in weeds, insects, and diseases are most vulnerable; that is, where to target control. Modelers create a three-dimensional visualization of the structure of an enzyme or receptor to determine how bioactive molecules interact and inhibit the target enzyme. This visualization can be used to propose new molecules for better efficacy. Modelers sometimes can design a new molecule based entirely on a computer model of how it will interact at specific target sites.

Conversely, by predicting which molecular structures may interact with target sites known for becoming resistance mechanisms, modelers can help companies avoid the development of molecules prone to rapid development of pest resistance.

Especially significant among other properties of candidate molecules that may be altered with computer techniques are those that can improve environmental or human safety. Environmental chemists can move functional groups within the molecule in an effort to fine-tune its environmental characteristics. For example, a chemist may be able to change molecular properties so that a pesticide which previously leached from the soil becomes more tightly bound in the soil.

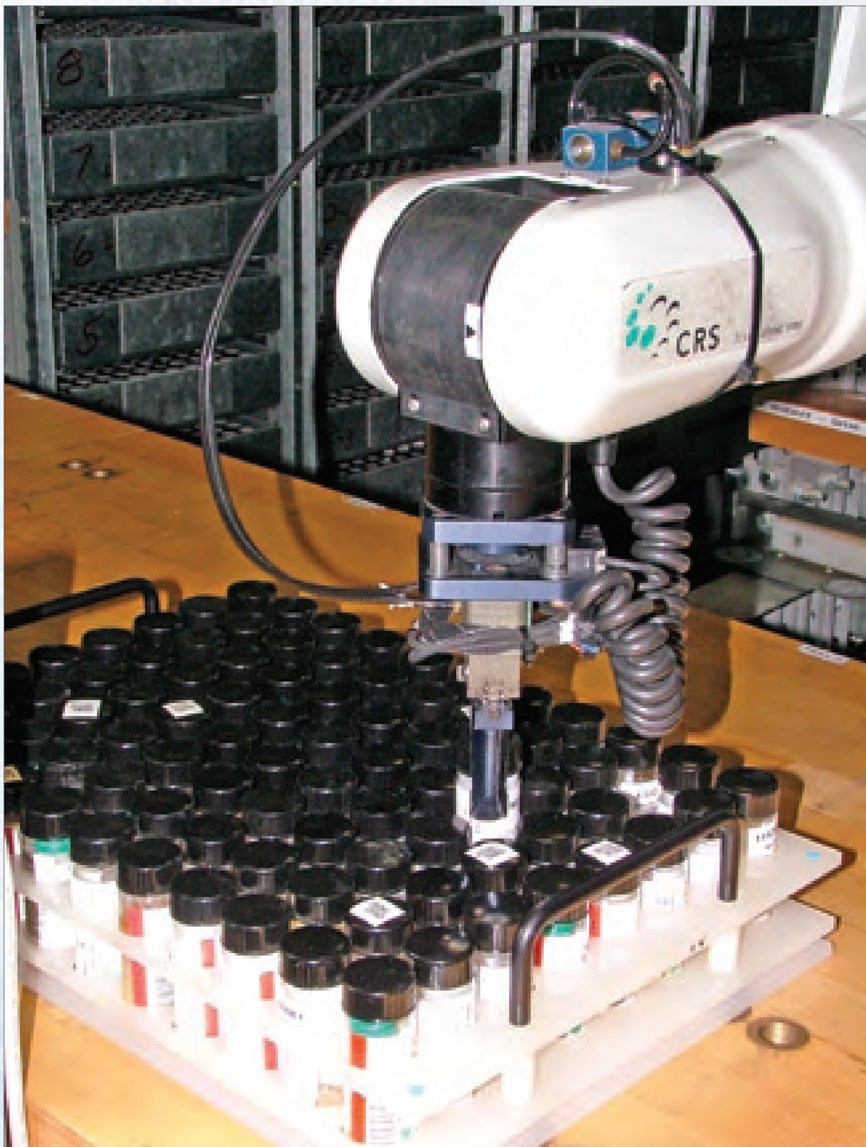
Genomics promises to speed the process by which new modes of action are discovered. By unraveling the genetic code of plants, insects, and diseases, chemists may discover specific sites sensitive to interruption by novel pesticides.

Computer Screening:
Does the Molecule Meet the Company's Selection Criteria?

The process examines hundreds of thousands, perhaps millions, of molecules in the search for a dozen or so promising candidates. Because the discovery process is so costly, scientists must eliminate questionable molecules as early as possible and focus their attention and resources on marketable compounds. Very few ever become viable products.

Computers are effective, efficient tools for sorting, selecting, and discarding millions of molecules offered for sale by vendors. Companies can purchase electronic lists of molecules (virtual compounds) and their structures. The computer programs generate information on molecular weights, functional groups, and other chemical attributes for each molecule, based on its structure.

The molecules on the electronic list are evaluated against a series of selection criteria (established by the company) based on product goals, technical attributes, and the company's experience. This virtual screening is quicker and less expensive than biological screening.



Robots select the correct sample from the millions in storage.

The selection criteria are known as filters or screens; they eliminate molecules that do not meet desired specifications. For instance, one screen might reject molecules that contain heavy metals; another filter might select for physical properties required for mobility in plants. In this manner, molecules are screened for specific structures, functional groups, and physical properties; molecules that do not meet the criteria are rejected.

The computer sorts through thousands of molecules and assigns a selection score to each, based on the filters it passes. Ultimately, the computer classifies a few into a small subset that is reviewed by synthetic chemists, biochemists, modelers, and market analysts; this is the final quality control procedure before selecting molecules to order from the vendor.

Evaluation of the chemical library is a very generic sweep of potential pesticides. Many of the molecules eliminated from consideration have pesticidal properties, yet it would be too costly and time consuming to test each one for biological activity. Pesticide manufacturers are not interested in finding just another pesticide; they are searching for *the* pesticide that meets or exceeds the needs of their customers.

Detection of Biological Activity: Does the Molecule Show Any Activity?

Biological activity is determined for molecules that pass the screens. Most molecules do not demonstrate biological activity at reasonable doses and are eliminated quickly. Methods and criteria used to screen these molecules vary, but most companies use “high throughput screens.”

High throughput screens are highly automated tests that use typical analytical methods to measure activity. The activity may take the form of chemical reactions such as color changes and new products.

Other methods to test the activity of a compound involve the use of an insect, weed, or disease organism. The procedure might be as simple as placing an insect larva in a well (small container) with food containing the molecule. A technician monitors and records the larva’s responses to the insecticide; scientists may examine the test for several days to see if the larva is affected.

High throughput screens often are yes-no filters that provide qualitative results. Assuming thousands of molecules are entered into a high throughput screening, fewer than 100 show activity suggesting they are worthy of further research.

Bar-coded samples handled by robots make high throughput screening possible.

Bill Johnson

Detection of Biological Activity: Does the Molecule Have Activity on Whole Organisms?

Molecules that pass the computer and high throughput screens have desirable chemical characteristics and a level of biological activity warranting further investigation. Since weak molecules sometimes can be modified to become more active, chemists test them against “indicator” insects, weeds, diseases, or other organisms known to be sensitive to low levels of biologically active pesticides. The common theme among indicator organisms is that they must be cheap to produce uniformly in large numbers, and they must be easy to rear in the laboratory. Fewer than 10 out of 100 molecules advance for further evaluation.

Evaluating whole organism activity often requires scientists to examine the effect of each dose individually on every organism.

Bill Johnson

Screening for Herbicides

Lemna is an aquatic plant used by many companies for assessing bioactivity; it is very sensitive to exogenous chemicals. Another plant used in genetic research is *Arabidopsis thalania,* a well-known relative of mustard and oilseed rape. Other plants used as sentinel species include common weeds such as foxtail, velvetleaf, lambsquarter, and waterhemp.

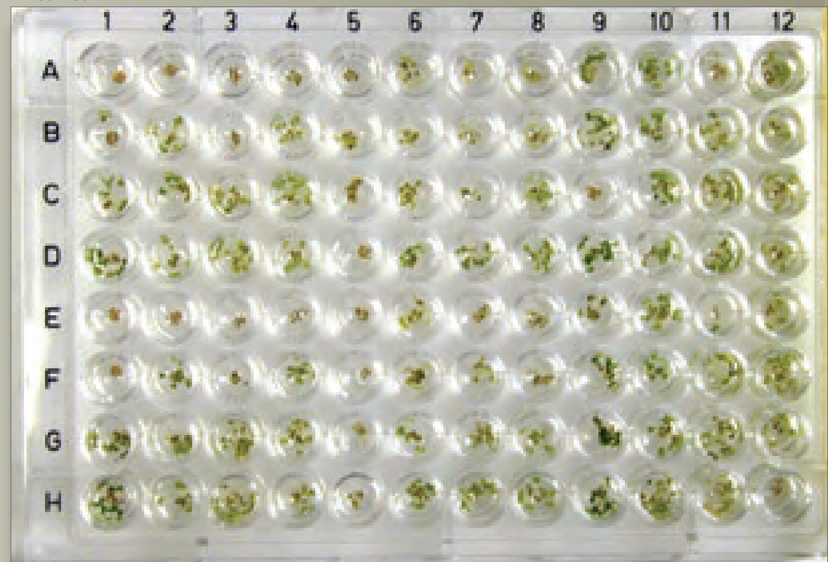
Screening for Fungicides

Two or three fungal pathogens normally are used. These could include plant pathogens such as blight and leaf spot.

Screening for Insecticides

Since many important crop insect pests are Lepidopterous insects, caterpillars such as the beet armyworm and the tobacco budworm are used as indicator pests. Discovery groups also have been known to use house flies, fruit flies, and mosquito larvae.

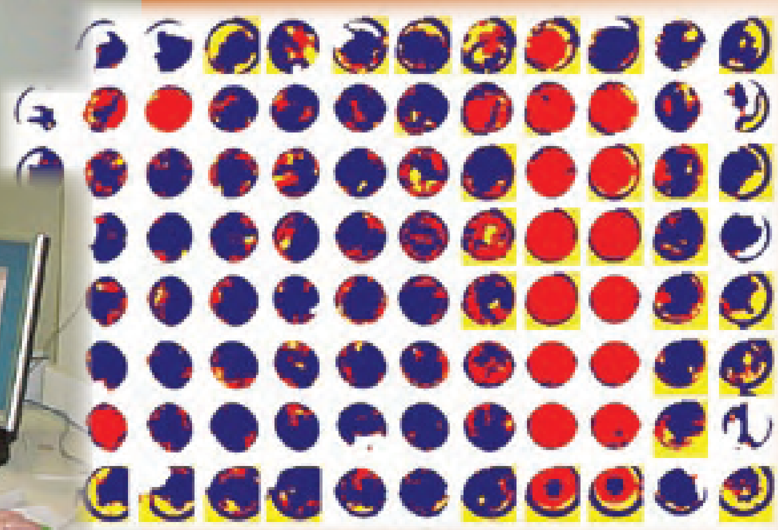
Bill Johnson



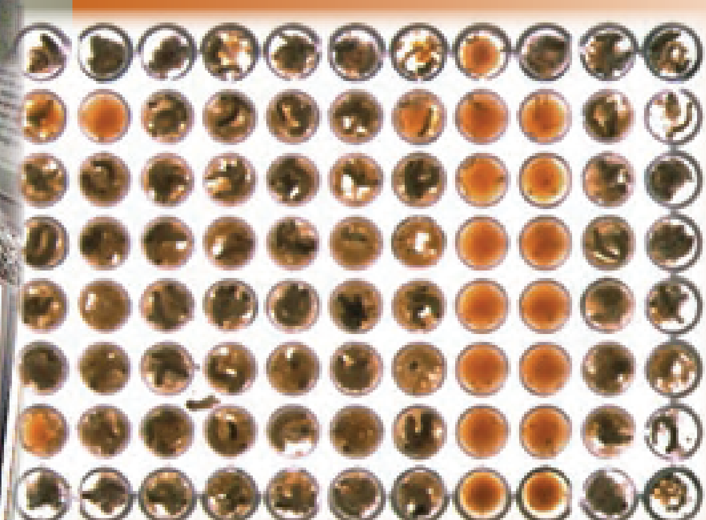
Plant cells cultured in tiny wells are useful for high throughput herbicide screening. Less green indicates herbicide effectiveness; that is, the herbicide is preventing the plant cells from growing. More green signals ineffectiveness of the test product.

Flies often are used as early stage screening tools in insecticide discovery.

Automated systems, such as this one that detects insect movement (three left-hand photos), are critical to early screening programs.



The digital image of a high throughput insect bioassay (above) is processed into the color classified image (below), for detection of insect response to the treated diet. This allows rapid detection of the "hits" in the assay.



Developing Analogs: Can the Molecule Be Improved?

The manufacturer is interested in the commercial potential of the few molecules that pass the early phases of testing. A team of scientists reviews each compound to determine if it is unique enough to warrant continued investigation. Molecules that pass this review are tested further; chemists look for ways to alter each molecular structure to improve efficacy or reduce environmental impact.

If the biologically active molecule has a mode of action for which the chemists can design a three-dimensional structure, the better the modifications would fit the target site. Chemists can use three-dimensional structures of the target site to screen new targets on the computer to make sure the desired synthetic changes will not decrease binding to the target site.

For example, a biologist might determine that a molecule affects only a certain mildew species in the fungal screens, but a broader spectrum of activity is needed. The team then might ask questions such as, We have limited spectrum, so what is limiting its activity on other fungi? It could be that the molecule is not mobile; that is, it does not move to untreated portions of the plant. Another possibility is that the pest metabolizes the molecule rapidly after application. Key questions seek to determine how the molecule might be modified to make it more effective.

Molecules may demonstrate unfavorable environmental impact, be phytotoxic to the plant, and/or have toxic characteristics. Chemists may be able to develop analogs (different forms of the same molecule) with decreased toxicity to humans, the host plant, wildlife, and the environment; or they may ask the vendor if there are specific analogs available for purchase. A dozen chemists may be assigned to develop as many as 500 analogs of a single molecule.

Computer modeling of potentially effective analogs (right) accelerates discovery.

Chemists begin by looking for structures similar to the successful candidate compounds. They can alter the chemical characteristics of a compound by making slight changes in the structure through modification of its constituent elements. Generally, the more adaptable the molecular structure, the more opportunities there are to find the right combination. The discovery team eventually focuses on the most promising analog, bringing along three to six secondary analogs as backups. The secondary analogs sometimes are substituted for the lead analog once factors such as cost, performance, and product registration criteria are considered.

Initial Greenhouse Screening: Will the Molecule Control Key Market Pests?

The screening process moves to the greenhouse for detailed testing of a few molecules in a simulated real-world situation. Generally, only one to five molecules remain of the thousands initially evaluated; but sometimes greenhouse screening may involve higher numbers, especially for analog comparison.

Greenhouse comparison of the biological performance of analogs is a necessary but costly process.

A single chemist may spend weeks or months synthesizing enough of the compound in the laboratory for testing in the greenhouse. The discovery team then begins to test the molecule against organisms that correspond to some of the pests identified in the product marketing goals. If the goal is to control weeds in wheat, perhaps a dozen key weeds normally found in wheat are used as indicators of real market value.

Many molecules fail to advance beyond this point, for a wide variety of reasons:

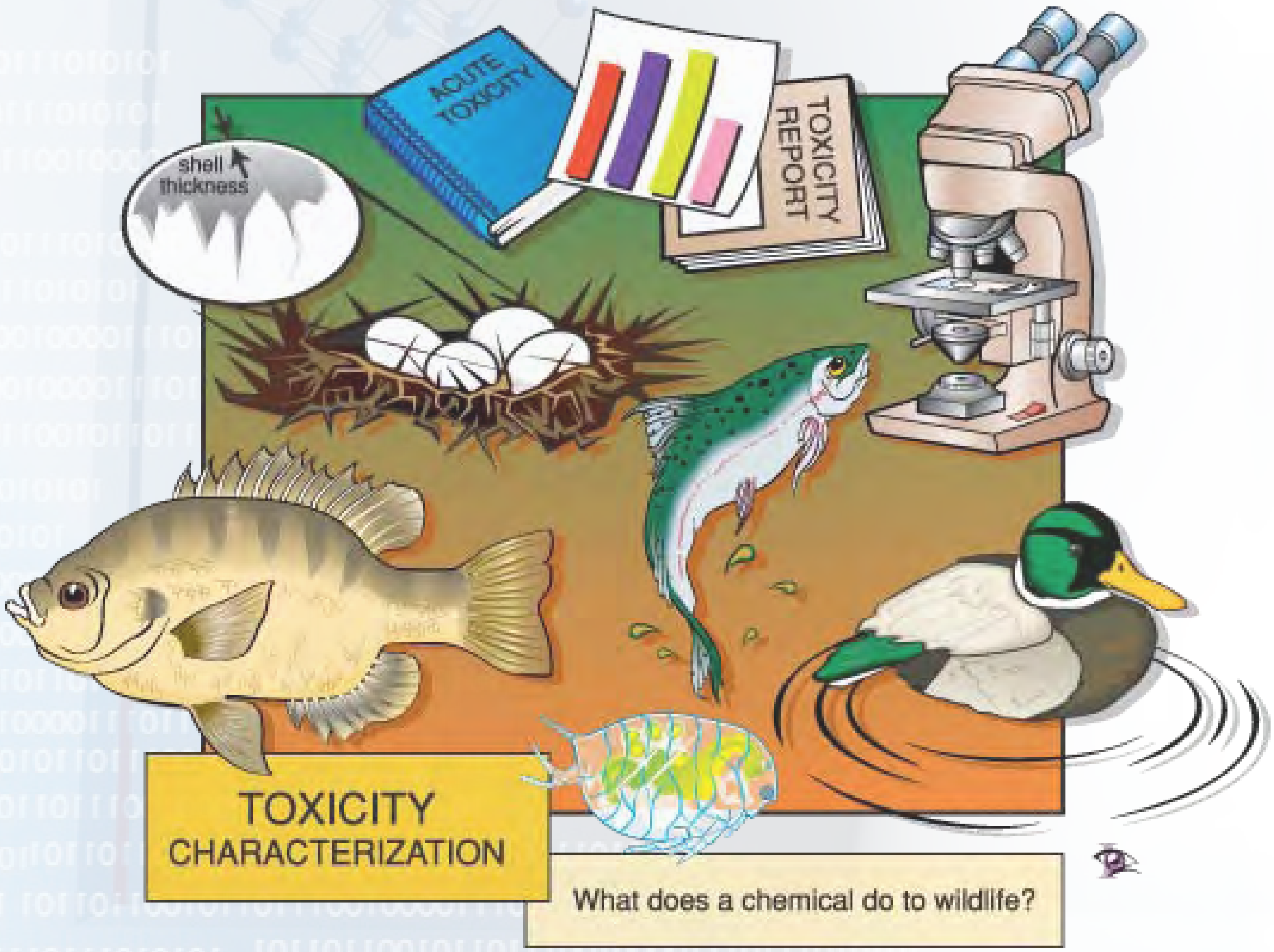
- Activity observed during initial screening is not present in greenhouse studies.
- Control is limited to a very narrow range of pests or a poor pest spectrum.
- Phytotoxicity occurs in the crop species.
- Control rates are too high; the product would not be economically viable.
- Low water solubility or other undesirable chemical characteristics make the product difficult for applicators to use.

Usually, only one or two molecules justify more detailed greenhouse studies.

Many factors are considered when evaluating analogs to select for advancement.

Exploratory Tests Describe the Molecule's Nontarget Toxicity

During this segment of the evaluation process, the molecule is examined for its acute toxicity to laboratory animals, its potential to leach or run off into surface water, and its ecotoxicological profile for wildlife. Manufacturers use these probe studies to provide a conservative estimate of the benefit/risk profile of a molecule or a series of chemistries.



These exploratory tests are conducted only to identify and describe, in general terms, the toxicological parameters and environmental characteristics of the molecule. Candidate compounds are administered to test animals (e.g., rats and mice), and the dosage is calculated to determine the range of toxicity. Environmental chemists also might conduct environmental fate studies to estimate the persistence of the molecule in soil and water, its fate in the treated plant, and its soil adsorption properties.

These exploratory tests are early indicators that the molecules advanced to the greenhouse will or will not need to be altered to reduce potential adverse effects to humans, wildlife, and water.

Advanced Greenhouse Screening: How Does the Molecule Handle the Real World?

The desired outcome of more advanced greenhouse studies is to describe product performance in a simulated real-world setting. These studies identify effective rates and the spectrum of pests controlled at those rates. The rate that provides control of target weeds in early greenhouse tests often becomes a benchmark by which the discovery team calibrates three or more rates at higher and lower levels. An intermediate rate may be 1/10 of the benchmark dose, while the lowest dose may be 1/100 of the benchmark. Variations in the treatment rate allow researchers to see how pests respond to changing rates at different life stages and under different environmental conditions.

Weed response to increasing herbicide rates.

Bill Johnson

Large scale greenhouse tests...

Application methods also change as the molecule moves to the more advanced greenhouse studies. Instead of applying the molecules through a syringe or hand sprayer, a track sprayer is used to apply them in “field normal” dilute solution. Greenhouse researchers might test the activity of potential insecticides against different insect growth stages, or they might determine how well potential herbicide compounds control weeds at different growth stages. These studies help researchers identify effective application rates, timing, and the most sensitive pest and crop stages.

Insects are observed feeding on leaves treated with insecticide.

...simulate real world applications.

Initial Field Testing: Does the Product Respond Under Field Conditions?

Ultimately, only one or two molecules of the hundreds of thousands initially screened for pesticidal properties warrant field testing. The true test of these few surviving molecules, now called product candidates, is how well they perform under field conditions. The volume of active ingredient necessary to conduct field trials and additional toxicological and ecotoxicological studies at this point in testing increases from milligrams (ounces) to kilograms (pounds). Since there is no manufacturing plant for these new compounds, the production of quantities to support field trials usually is accomplished on a pilot scale by the company. It can be very time consuming and expensive.

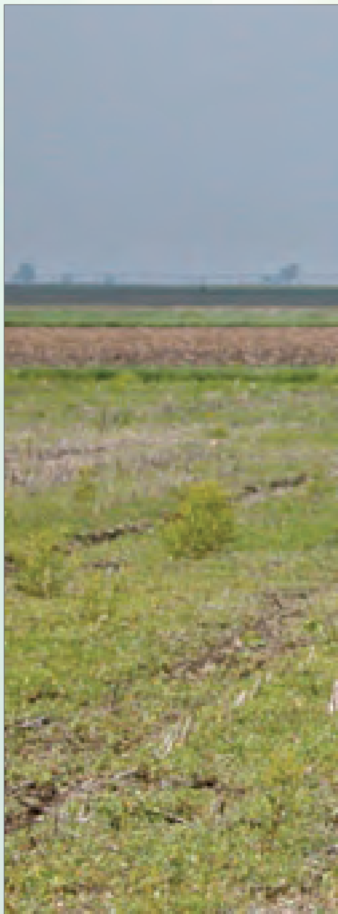
Acute and long-term environmental and toxicological studies, including application and user exposure studies, are conducted at this time. Field evaluation of a molecule is similar to the tiered testing approach used to screen compounds in the laboratory and greenhouse. Products proceed through initial, first-year field testing on limited weed, insect, and disease pests to more complex studies involving more pest species, different soil types, and wider geographic distribution.

Companies use various approaches and protocols to conduct field tests. They may have numerous field research facilities, strategically located around the world, where they test the compounds under different soil and weather conditions and on pests native to the geographic area. Companies also use academic institutions and private research facilities for this screening.

Small Plots Artificially Infested with the Pests

The protocols for the first field tests and the final greenhouse tests are nearly identical. The principal question addressed by field trials is whether the results are similar to greenhouse results. Researchers are specifically interested in whether environmental stress interaction with pests, crops, and molecules will produce undesirable effects such as increased crop injury or reduced pesticide efficacy or persistence.

Due to limited quantities of the sample, initial field trials are conducted on relatively small plots (e.g., 5 x 25 feet) and replicated two to four times. Field scientists are reluctant to rely on naturally occurring pests to infest the plots, due to this limitation, and often artificially infest the plots with insects, weeds, and diseases produced off-site. Irrigation and the use of untreated buffer rows and trap crops improve the probability of successful trials.



Indicator crops often are planted in plots known to be pest-free to prevent interference from nontarget pests. For example, it would do little good to start a trial for control of late-season aphids on corn if the crop were likely to be destroyed or seriously damaged by cutworms, first. After the plot area has been infested artificially with the desired pest and the pest has been given time to become established, backpack sprayers are used to apply the experimental compound at predetermined times and rates. For a disease, the crop may be inoculated with the pathogen before or after pesticide application, depending on how the product is expected to be used (preventive or curative). For weed evaluation, the soil may be sterilized to kill seeds in the soil. Field researchers then plant rows of specific weeds (e.g., foxtails) and crops in one direction, and the test compound is sprayed perpendicular to the plantings.

Compounds usually are first exposed to the outdoor environment during microplot (small scale) field tests (right). A hand-held sprayer is used to apply a herbicide to a small plot (below).

Bill Johnson

Intensive data collection begins after the treatments have been applied, with focus on spectrum of control, rates necessary for effective control, and crop injury. Depending on the targeted pests, field researchers can evaluate

- the percentage of pests controlled.
- which pests are controlled.
- the length of the residual effect (if any).
- how quickly the pests are controlled.
- crop injury from the treatment.
- how the molecule compares to existing company and competitive products.
- the percentage of crop plant damage from insect feeding and/or disease formation.
- how performance is influenced by soil characteristics and environmental conditions.

Intensive data collection efforts during the field research phase are necessary to ensure that the future product meets user expectations and regulatory requirements.

These data may be collected visually or by counting and measuring. Plots are observed on a regular basis over a period of days, weeks, or months, depending on the type of pesticide being evaluated and the object of the trial.

In some cases, treated plant parts are removed from the field and infested in the lab. These field/lab bioassays often are used to test early stage insecticides. Generally, these tests are conducted on a crop destruction basis; yields can be taken but not used or sold.

Data Analysis: What Will the Product Do and Not Do?

The research team reviews the strengths and weaknesses of the product following the field test cycle, taking considerable time to statistically analyze the tremendous amount of data collected. At conclusion, the development team will have determined

- which crops and pests the pesticide will be used on, worldwide.
- whether crop safety and selectivity are issues.
- how pests respond to various product use rates.
- whether product performance is reliable.
- how field performance of the molecule compares to that of competitive products and whether it satisfies the company's internal standards.

Pesticides are tested in various tillage systems to see if performance fluctuates.

Bill Johnson

Predevelopment Stage: Making the Commitment to Move Forward

Discovery phase research, which typically takes four years, is followed by the predevelopment stage. At this point, the company must decide whether to continue research on the few viable experimental compounds that remain. It requires millions of dollars to commit a compound to multi-year toxicological and environmental studies essential to registration by EPA and foreign governments.

The product efficacy in fields is fairly well determined by this point in the testing process. What remains to be determined is whether the molecule shows enough potential to generate profits for the company.

Experts from numerous departments within the company are asked to work collectively to build a business case. Financial predictions for the molecule are based on the following questions:

- What will the customer pay for the product?
- What kind of short- and long-term market share can we expect from the product?
- How much sales revenue will the product generate?
- What will be our expenses, including promotion, advertisement, and demonstrations?
- What will be the dose rates by country, crop, and pest?
- What quantity of active ingredient will be needed?
- Are there unique manufacturing problems associated with the product?
- What will be the cost per unit to manufacture the product?
- How much will the manufacturing plant cost to build and maintain?
- What will it cost to develop the molecule globally?

Biological data from the laboratory, greenhouse, and field are summarized by technical managers as a set of technical assumptions that will drive market predictions. A number of people representing discovery, marketing, manufacturing, regulation, and safety participate.

Technical assumptions are given for each crop on which a herbicide is expected to be used. For example, technical assumptions for a herbicide candidate might be as follows:

- The compound will control weeds *a, b,* and *c* in rice when applied at 2 ounces per acre with a level of control nearing 95 percent.
- The compound results in five percent injury to rice, with no expectations of crop rotation restrictions.

- Probability for weed resistance to the molecule appears low.
- Environmental and toxicological profiles appear to conservatively meet expectations of regulators.

Marketing professionals turn technical assumptions into sales projections. For example, controlling weeds *a, b,* and *c* should result in the product capturing 10 percent of the market for rice herbicides. Marketers and financial planners use technical attributes developed specifically for each crop to analyze and predict how much of the revenue the crop will contribute to the total projected worth of the molecule over its expected market life.

Making the Case to Management: Benefits/Risks of Advancing a Molecule

The case for moving a molecule forward is presented to upper-level company managers. Presenters of the data make recommendations regarding their estimated success potential of the compound and its importance to the company. They present the unique characteristics of the product: what it does; the markets in which it will be positioned; its expected financial returns; and the assumptions on which they based all calculations, estimates, and predictions.

Management expects complete details, backed by documentation, with particular interest in whether field or greenhouse studies raised any red flags; that is, whether there were any inconsistent results that might preclude the product from success in the competitive market.

Many complex and interrelated factors enter into the decision to invest in a new product.

Management now has a difficult decision to make. Not only does the cost of research, discovery, and development rest on their decision, but the costs of further development and marketing present added risks. They can choose to halt development and shift their investment dollars to more promising pipeline products; or they can advance the compound to registration and gamble that it will generate enough revenue to cover its own costs and those of numerous discontinued projects as well. Another option would be to put the project on hold until additional tests are completed and questions raised by data insufficiencies are answered satisfactorily.

Management's Decision to Move Forward: Completing the Field Evaluations

During the final years of field tests, researchers simulate grower practices in terms of application and crop culture. Experiments are expanded geographically. Application rates and timing are more defined. Field research at this point examines tank mixture with other pesticides, tolerance of different crop varieties, new formulations, control of secondary pests, crop rotation issues, and secondary market uses. Comparison to competitive products becomes more intense.

Field testing in the late stages of product development lasts three or four years and usually is conducted in 10-foot by 30- to 40-foot plots; three or four replications are performed at all locations to allow thorough statistical evaluation of the data. Field researchers might use a trap crop to attract insects or establish diseases in the area; it normally would be placed in the middle of the crops being evaluated. The use of indigenous pest pressures where multiple flushes of weeds or insects may occur during the crop cycle allows more realistic testing of the product. Additional field studies are used to refine existing information on the molecule.

Refining the Rates

Refined product rates used in these tests are based on the population density and growth stages of pests present. For example, the dose range applied in initial field studies may have been 0.1 to 1 pound per acre, as indicated by greenhouse trial results and limited early field tests. Additional field tests may refine the effective range to between 0.2 and 0.5 pound per acre. During follow-up field studies, project coordinators evaluate application rates to determine the optimal use rate of the product, often with a variety of optimized formulations. The lowest effective rates may reduce application costs, but these results must be balanced against product reliability and company reputation.

Testing on Other Pests

Certain information in earlier field studies may have been collected on unplanned, incidental, or secondary pests. As field-testing moves forward, work may be expanded to develop detailed information on such secondary pests. Broadening the pest spectrum facilitates comprehensive labeling, which adds value for the customer and the company.

Evaluating Timing of Application

The timing of pesticide application is critical. Various experiments are conducted to evaluate pest response to the candidate product based on application timing. Application timing evaluations for weeds include preemergence, early postemergence (weeds 3–4 inches tall), and later postemergence (weeds 6–8 inches tall) trials. The timing of application for insect control is evaluated against both small and large larvae. Evaluation for diseases requires application before and after infestation to determine whether the molecule has curative and/or preventive properties. All of this information is critical to label wording that will provide customers the latitude to use the product to it fullest advantage.

Identifying Soil Type Responses

The performance of some molecules is affected by soil type. Some bind tightly to soil particles while others hardly bind at all. Variation in binding characteristics involves organic matter, clay content, pH, etc., and determines whether application rates will have to be adjusted. Soil type also may influence the persistence of the compound in soil. These factors are critical to pesticide performance and environmental safety.

Determining How to Position the Product

Company business managers and agricultural scientists meet to discuss the experimental product once field testing is complete. They offer insights on continually evolving customer needs, competitive products, and steps the company can undertake to make the product more attractive to customers. Their input is used to build a business model and plan for the experimental product.

The Make-or-Buy Decision

The company that decides to market the product commercially must decide whether to make the compound or buy it. If the manufacturer owns facilities with the necessary capacity, equipment, and personnel—or if it is feasible to build a new plant—the decision may be to make the product. If not, production may be outsourced to another company.

Writing a Product Label

A label can be written and submitted to EPA before a marketing decision is made. Assembly of use directions for the product begins during the predevelopment phase. For instance, information from field tests may show that a herbicide label should allow application only as a postemergent treatment for controlling foxtail grasses up to 4 inches tall. About 80 percent of the label information is prepared during field testing; the remainder is written according to EPA-required human toxicological, ecotoxicological, and environmental fate testing data.

Writing a Marketing Plan

Preparing the marketing plan is the next step. It can include the following sections:

- Market assumptions
- Competitive product strengths and vulnerabilities
- Internal assumptions and estimates on development and manufacturing costs, registration timetables, and pricing
- Distribution channels
- The "Five Ps of Marketing": product, placement, price, promotion, and positioning
- Technology transfer strategy to train company representatives and customers on proper use and handling

Development Stage: Getting the Product Registered

The principal focus during the development stage is to collect and summarize data and write official reports to provide EPA the registration information required by the Federal Insecticide, Fungicide, and Rodenticide Act as amended by the Food Quality Protection Act. Registration submission and approval normally begins six to eight years into the development process and ends in years eight to ten.

Commercial Stage: Preparation for Product Launch

While the product is undergoing review for registration, work on producing, marketing, and positioning the product continues. Details are added to the marketing plan as information from additional studies becomes available.

During this phase, experimental products are placed in university trials and on-farm demonstration plots under code numbers or agreements of confidentiality. Distributors, sellers, buyers, and consultants can tour the plots and learn about the product and how it performs. These additional trials build a strong efficacy history for the product and indicate how it will fit into an integrated crop production system.

Developing a brand name for the new product is a critical step in the marketing process. Trademark laws and industry groupings make this process highly complex and challenging. Pesticide products are in the same category as veterinary and pharmaceutical products, so it can be difficult to find a brand name that does not conflict with others currently in use. Each company is looking for something easy to remember that reflects the desired positioning.

Finalization of all product manufacturing details also must be addressed. If an outside vendor is used, the manufacturer's process engineers begin working with the contractor to make sure it has the plant capacity, equipment, and processes in place to meet label specifications; stringent environmental health and safety requirements must be satisfied as well.

Introducing the Product to the Customers

The Food Quality Protection Act and the Federal Insecticide, Fungicide, and Rodenticide Act prohibit the manufacturer from advertising or promoting any product before an EPA registration number is assigned. This includes distributing promotional caps or other forms of advertisement bearing the product logo. However, the manufacturer is allowed to distribute educational bulletins to dealers who will sell the new product.

Once the product has an official EPA registration number, the company activates a multimedia advertising campaign focused toward potential customers, primarily, but also distributors and dealers.

The manufacturer's research and development staff work closely with the sales force—usually a year before the company expects to launch the product—to make sure they thoroughly understand the product's strengths and weaknesses.

End users and company representatives often evaluate future product candidates in the field prior to product launch.

The sales staff will listen to classroom presentations and visit demonstration plots, learning details about the product's

- performance expectations,
- potential niche in the market,
- projected competitiveness against competitors' products,
- advertising,
- availability (which markets will get it first), and
- promotional programs used for advancement into channels of trade.

Extending the Product to Other Markets

As previously discussed, most products are developed and marketed initially for large-scale agriculture since its financial base is large enough to underwrite the necessary research. The active ingredient is provided to scientists in noncrop markets—urban pest control, greenhouse, aquatic, ornamental, turf, right-of-way, etc.—during the second year of field testing. Customers outside traditional agricultural markets have needs driven by some of the following factors:

- Resistance or loss of performance of current products
- Loss of EPA registrations for some uses of existing products
- Customers looking for newer solutions perceived as safer for human health and the environment
- Customers seeking better integrated pest management solutions

Needs in noncrop markets and smaller agricultural segments tend to differ from traditional agricultural uses:

- Formulations designed to fit the agricultural market do not always align with smaller-use customer needs; they may be highly concentrated, requiring dilution, and packaged in large quantities. Over-the counter products for small uses tend to come ready to use or in less concentrated form—and in smaller packages—because this is what small-use customers prefer.

Right-of-way weed control is a common extended use for herbicides originally developed for the agricultural market.

Extending a product into niche markets helps create new revenues. Right-of-way (p. 56), turf (above and below), aquatic (right), and mosquito pest management (below, right) are examples of extended markets.

- Packaging often depends on the concentration and recommended dose, but agricultural pesticides are packaged in large quantities for large scale applicators, and they are very expensive. Purchasers of over-the-counter products are advised to purchase only the amount of pesticide they can use within a reasonable amount of time, especially since most do not have access to proper methods of disposal for outdated products.
- Regulations stipulate highly specialized use precautions for some products, and properly trained professionals must apply them. Since labels for agricultural crops do not address these issues, a small-use customer would not have label instructions for his intended use.
- Risk is a primary consideration. Even though a need may exist for the new product in some of the smaller market segments, the proposed uses may be too risky for the company to pursue. The segment may be of so little value that the company would never realize a return on its development costs. Perhaps the use would allow pest resistance to develop very quickly; or there might be environmental and/or human health risks that make these uses unattractive.

In an effort to address pesticide needs in a smaller potential market, manufacturers may begin development for that market following the decision to develop the compound for agriculture. There are several options the manufacturer can pursue if it lacks the expertise required:

- Develop internal capabilities to enter these market segments.
- Partner with or acquire a company that has the expertise.
- Out-license the compound for a third party to develop these segments.
- Decide that the compound will not be developed and used in that segment.

The active molecule is likely to be developed and marketed if the opportunity is attractive to the basic manufacturer and the risk is manageable.

Conclusions

The decision of a company to invest in the discovery, development, and launch of a new pesticide carries a high level of risk. It begins with an expectation or assumption of future needs and gets translated into goals which, if innovative discoveries are made, transform into actionable projects.

Much of that risk is inherent to two major factors: the time between goal development and eventual product launch is long; biological systems and the markets around them fluctuate unpredictably. These two factors may create market space for a new product. Another risk factor that differentiates pesticides from typical consumer products is the highly regulated environment in which they participate. This requires the company to invest in a wide range of technical disciplines and predict regulatory outcomes and time lines; i.e., they have to predict how global agencies like EPA will review the testing data and whether those agencies will levy additional testing requirements.

Companies seek collaborative relationships with universities and independent researchers—and sometimes other companies—to assist in the development process. This enhances the company's understanding of business opportunities and effects a greater understanding of pesticide risks and the mitigation measures that can be used to reduce risks.

Undertaking pesticide discovery, development, and launch is very high-risk, and successful recovery of investment is never guaranteed. No manufacturer commits without diligently assessing all the risks, and only a few large enterprises sustain a presence in the pesticide market. Exceeding customers' needs and expectations is mandatory for the success of any new technology. Successful companies continually introduce innovative, lower risk technologies to minimize the impact of pests, provide for our safety, and promote a healthy environment for all of us to enjoy.

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Further Reading

These publications are accessible online at www.btny.purdue.edu/PPP/.

Crop Production Recordkeeping System (PPP-18)

Annual Field Records (PPP-19)

Pesticides and Personal Safety (PPP-20)

Pesticides and Container Management (PPP-21)

Pesticides and Food Safety (PPP-22)

Pesticides and the Label (PPP-24)

Pesticides and Applicator Certification (PPP-25)

Pesticides and Their Proper Storage (PPP-26)

Pesticides and Commercial Vehicle Maintenance (PPP-27)

Pesticides and Spill Management (PPP-28)

Pesticides and the Home, Lawn, and Garden (PPP-29)

Pesticides and Wildlife (PPP-30)

Pesticides and Formulation Technology (PPP-31)

Pesticides and Community Right-to-Know (PPP-32)

Pesticides and the Balancing Act (PPP-33)

Pesticides and Pest Prevention Strategies for the Home, Lawn, and Garden (PPP-34)

Pesticides and Water Quality: Principles, Policies, and Programs (PPP-35)

Pesticides and the Law: A Guide to the Legal System (PPP-36)

Pesticides and Material Safety Data Sheets (PPP-37)

Pesticides and Personal Protective Equipment (PPP-38)

Pesticide Safety and Calibration Math for the Homeowner (PPP-39)

Pesticide Toxicology: Evaluating Safety and Risk (PPP-40)

Pesticides and Ecological Risk Assessment (PPP-41)

Pesticides and Environmental Site Assessment (PPP-42)

Pesticides and Epidemiology: Unraveling Disease Patterns (PPP-43)

Pesticides and Planning for Emergencies (PPP-44)

The Quick Response Emergency Plan (PPP-45)

Lawncare Pesticide Application Equipment (PPP-46)

Landscape Pesticide Application Equipment (PPP-47)

Pesticides and Human Health Risk Assessment (PPP-48)

The Insurance Policy (PPP-49)

Managing Farm Chemicals (PPP-50)

Stay on Target: Prevent Drift (PPP-51)

Pesticides and Risk Communication (PPP-52)

Children and Poisoning: Seconds Matter (PPP-53)

The Why's & How-to's of Pesticide Recordkeeping (PPP-54)

Company Bulletin Boards (PPP-55)

Conflicts with Wildlife Around the Home (PPP-56)

Managing Farm Emergencies (PPP-57)

Pesticides and Fleet Vehicles: Transporting Pesticides Safely (PPP-58)

Pesticide Regulations that Affect Growers (PPP-59)

Communicating with the News Media (PPP-60)

Pesticide Safety Tips for the Workplace and Farm (PPP-61)

Offering Sound Pest Management Advice to the Public (PPP-62)

Bulk Pesticide and Fertilizer Storage on Indiana Farms (PPP-63)

Rural Security Planning: Protecting Family, Friends, and Farm (PPP-64)

DOT Rules of the Road (PPP-65)

Atrazine and Drinking Water (PPP-66)

Atrazine Use and Weed Management Strategies to Protect Surface Water Quality (PPP-67)

Carrying Farm Products and Supplies on Public Roads (PPP-68)

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The Benefits of Pesticdes: A Story Worth Telling (PPP-70)

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