

Managing Pest Resistance to Crop Protection Products

Weeds, insects, diseases and rodents all threaten crops and must be controlled to maximize food supplies. Biotech crops and crop protection products – including herbicides, insecticides, fungicides and rodenticides – are critical tools for pest control but they must also be managed in order to maximize their effectiveness and prevent pests from developing resistance to them.

Resistance is not new; it happens in all living systems and affects all agricultural production systems –

organic, conventional and biotech. It's a basic survival mechanism for pests that occurs through natural selection; a small proportion of a pest population may survive a pesticide due to its distinct genetic makeup. The resistant survivors pass resistance genes along to next generations and resistance among the population increases.

Since resistance appears to be random and unpredictable, and it can spread quickly, it's critical for farmers to remain vigilante and to rotate and vary products with different modes of action. They

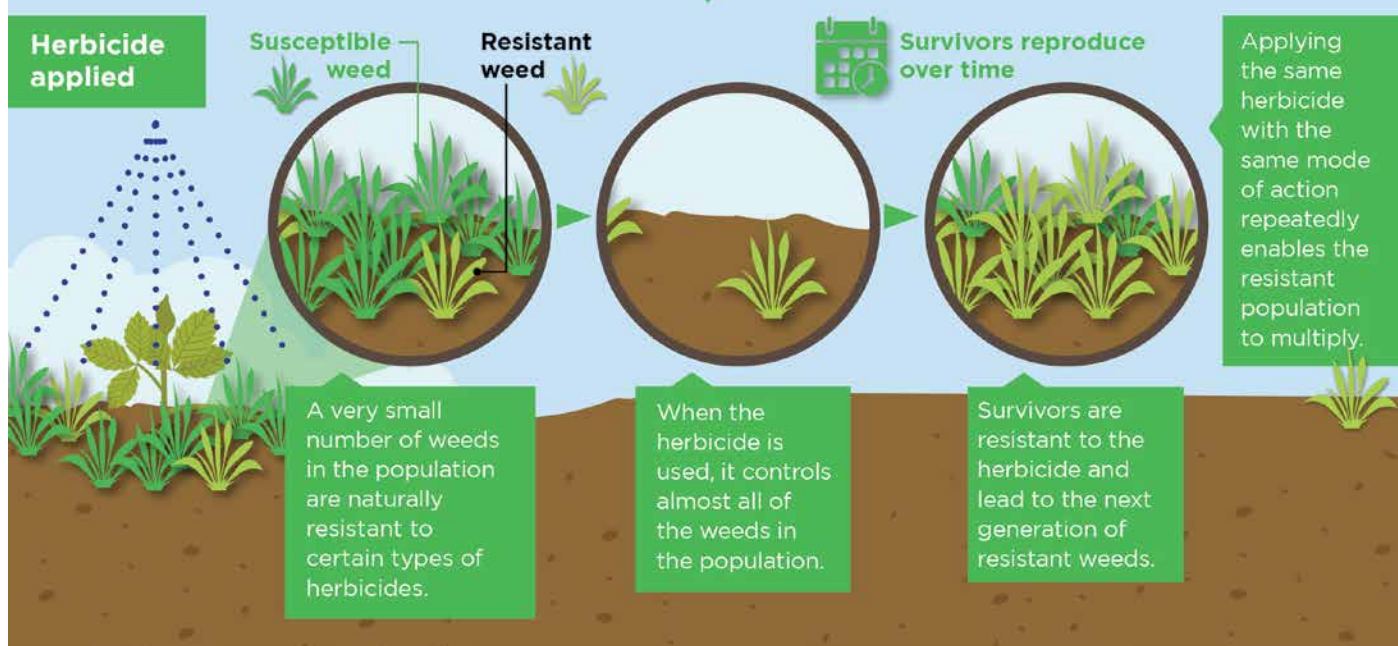
should also use other control methods, including non-chemical and biotech options to prevent or delay resistance.

Preventing Herbicide Resistance

If it weren't for weeds, farmers worldwide would grow on average 34 percent more crops per year. But when farmers rely too heavily on one herbicide to deal with the problem, weeds adapt quickly and become resistant. In fact, about 250 weed species have evolved to

HOW DOES HERBICIDE RESISTANCE EVOLVE?

Resistance is a natural, biological response that is heightened by overusing the same weed control methods instead of integrating chemical, agronomic and non-chemical tools.



resist 160 different herbicides over the past 60 years.

“Herbicide resistance is a serious threat to crop production around the world,” says Mark Peterson, chair of CropLife International’s [Herbicide Resistance Action Committee](#) (HRAC) and global product development leader for corn and soybean herbicides at DowDuPont in Indianapolis, USA. “While the extent of resistance is difficult to quantify, some farmer surveys in major crop producing areas indicate that 60-70 percent of farmers report problems with herbicide resistant weeds to some degree.”

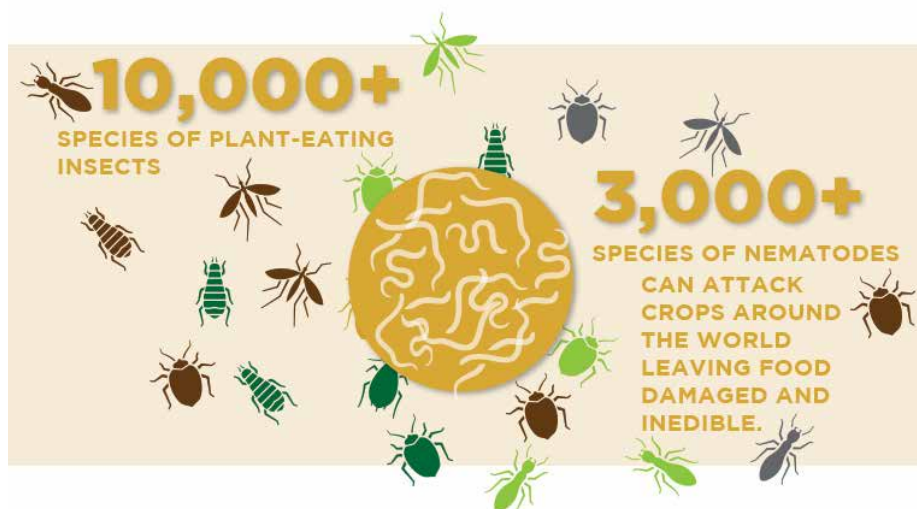
Integrated Pest Management (IPM) elements that combat herbicide resistance include crop rotation, harvest weed seed management and cultivation, and the use and rotation of herbicides with different sites of action. Herbicide label directions also call for farmers to scout fields for any weed survivors and eliminate them before they set seed.

“Diversification of management tools is the best way to combat the problem,” Peterson says. “Farmers need advice on how to manage current resistance issues and avoid further resistance problems on their farms. For some, this is an immediate, economic issue that affects their livelihoods. Also, actions taken today can have significant impacts on the spread of resistance around the world in the future. It is important that we preserve the valuable herbicide tools we have and maintain a productive, efficient system of agriculture.”

Managing Insecticide Resistance

In the United States alone, insect resistance is estimated to cost \$40 million in additional chemical treatments and alternative controls for insects, resulting in more expensive food for consumers.

“As pest populations are exposed to insecticides, those individuals with a



genetic predisposition to withstand the insecticide are better able to survive and pass their genes on to the next generation,” explains Nick Storer, global leader for scientific affairs, Biotechnology Regulatory and Government Affairs, at DowDuPont and vice chair of CropLife International’s [Insecticide Resistance Action Committee](#) (IRAC). “Over the last 100 years, resistance has evolved to every insecticide that has been developed. Fortunately, most pest populations can be controlled by one or more insecticides and/or insect-resistant biotech crops. That’s why it’s critical diverse products are available to growers to maintain this situation.”

Consistently using insecticides with the same active ingredient as well as in enclosed areas, such as greenhouses, increases the risk of resistance. One of the challenges with insecticides is that while many are available, they often have the same mode of action – therefore if resistance develops to one product, it will likely occur with other products in the same class. So, it’s critical for farmers to identify and change insecticides with different modes of action. They can easily identify the mode of action with a classification number on product packaging. There are currently 27 insecticide modes of action.

“In addition to rotating modes of action, the industry is looking at ways to integrate plant biotechnology traits with insecticides to provide more robust solutions for growers that

reduce the pressure for resistance to each one,” Storer says. “Rotating crops can reduce pest populations that target one crop. Managing weeds at the time of planting can reduce the source of insect infestations into a new crop. Allowing a fallow period between crops similarly reduces the size of the resident insect pest populations.”

In addition, [insect resistance management](#) practices may include the use of biological insecticides, beneficial insects and cultural practices. Good management also calls for monitoring fields for insects, choosing control methods that have a minimal impact on natural pest enemies and implementing refuge areas with insect-resistant biotech crops. A refuge involves planting a specified proportion of a crop without biotech trait(s) to prevent future generations of pests from building up immunity by ensuring a small and controlled population of insects without resistance are always present. Refuge areas can be a border around a field or strips or a section within a field and will generally comprise 10-20 percent of a field.

“In the short-term, and of local importance, resistance to an insecticide can be costly to farmers,” Storer notes. “If they apply an insecticide that doesn’t perform as expected, application of another insecticide is needed or yield is reduced or both. Managing resistance ensures the continued availability of effective insect control products so that pests can be managed the following year. ↓

“Over the longer term and at larger spatial scales, loss of insecticide efficacy to resistance can build across multiple products with different modes of action, potentially jeopardizing the ability to produce a crop economically. For example, cotton production in the U.S. and Australia in the 1990s was close to being lost because of resistance to pyrethroid insecticides in key pests.”

Mixing Up Fungicides

By controlling fungal plant diseases, farmers can save 125 million tons of food each year – enough to feed 600 million people. But when not managed properly, substantial financial losses can occur, which can be very high for certain crops, according to Dr. Hermann Dietrich, chair of CropLife International’s [Fungicide Resistance Action Committee](#) (FRAC) and global head of research biology at Syngenta Crop Protection in Basel, Switzerland.

“In the short term, the importance of managing resistance is to prevent crop damage and loss of earnings while in the longer term, we strive to protect future crops and extend the life of highly active compounds which may otherwise be lost to the industry,” Dietrich says. “We often cannot fully prevent resistance – selection is a natural mechanism, but the selection causing performance issues in the field can be delayed and managed. Some modes of action have had resistance issues for decades but they can still be used for effective disease control if the right resistance management measures are in place (for example, [phenylamides](#)).”

Managing fungicide resistance is a combined effort of chemical options (such as limiting exposure time and alternating with different modes of action), using biologicals, the correct selection of cultivars (resistant or tolerant) and cultural practices (such as irrigation, cropping method and pruning). There is a code system for fungicide product labels to help farmers easily identify which chemicals have the same mode of action. It’s also important farmers follow label instructions, including rates and water volumes, as well as to replace spray nozzles when needed to ensure uniform product application.

“Avoiding multiple use of fungicides from the same cross-resistance group is a main measure to delay resistance spread,” Dietrich says. “We strongly recommend use of product label rates – use of very low rates in some cases can accelerate resistance selection or cause performance issues related to resistance. We encourage local FRAC groups to analyze the situation in their geographies and to issue more specific recommendations that may be stricter and more locally adapted.”

FRAC has global recommendations on how to use fungicide mixtures and alternatives to delay and manage resistance. It publishes an annually updated list of modes of action plus a poster indicating cross-resistance risk between different fungicides, and will soon be publishing a mobile phone app that will enable users to quickly check cross-resistance groups for active ingredients of fungicides, which can also be found on [FRAC’s website](#).

Reducing Reliance on Rodenticides

While rodents can disrupt crop production, they are particularly troublesome post-harvest with stored crops. For example, in India, up to 30 percent of harvested grains are lost due to rodents. These animals can also spread human and animal diseases as well as damage property and the environment.

There are cases of proven resistance in some rodents, notes Dr. Stefan Endepols, chair of CropLife International’s [Rodenticide Resistance Action Committee](#) (RRAC) and biologist in crop science research and development at Bayer in Monheim, Germany. Rodents are considered pests in tropical crops like rice and palm trees in southeast Asia. And commensal rodents – in particular, the Norway rat and house mouse in Europe – are hygiene pests for livestock farming and the food chain.


Fifty years of research shows that the use of anticoagulant rodenticides is the most effective method for controlling rodent infestations. But some animals have a naturally occurring genetic mutation that protects them from certain anticoagulants. Surviving rodents can become resistant over time, passing the resistance gene to offspring.

Rodent infestations can be prevented on farms in the first place by eliminating any obvious items that could feed or shelter rodents. Should an infestation occur anyway, IPM options include using physical control techniques such as traps; blocking access to food, water or shelter by modifying environmental structures and food storage; and using anticoagulant and non-anticoagulant rodenticides according to label directions. In addition, industry experts have conducted studies to combat [rodenticide resistance](#) in different geographies and have developed several resources, such as a checklist for when to use rodenticides.


“Resistance management is important because only a very limited number of chemical compounds remains available, with increasing restrictions”

WHAT ARE FUNGICIDES?
Fungicides are chemicals that can **inhibit the growth or development of fungal pathogens**. They are important tools that farmers use proactively to protect and maintain plant health, quality and yield.

By controlling fungal plant diseases, farmers can save **125 M TONS** of **FOOD** each year – enough to **FEED 600 MILLION PEOPLE**.



Certain species of fungi can become resistant to fungicides. This not only diminishes the fungicide’s long-term effectiveness, but can reduce the amount of food brought to market.



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to use them,” Endepols says. “On the other hand, requirements for safe food production call for the exclusion of rodents, which often carry dangerous diseases.”

RRAC works to characterize resistant rodent strains; leads research on genetics and ecology; provides guidance on the nature and occurrence of resistance and how to prevent and combat it; contributes to scientific and technical conferences, such as the European Vertebrate Pest Management Conference; and offers an interactive website and [detailed brochure](#) on preventing rodenticide resistance.

Staying Ahead of Pests

The plant science industry continues to develop products that combat pest resistance. For example, more and more crop protection products have multiple modes of action and new

modes of action. Stacked trait biotech crops slow or reduce the impact of resistance by defending plants against multiple types of pests.

Through recommendations and resources on pest resistance management, the plant science industry works with farmers to maintain the longevity and effectiveness of agricultural technologies, encourage sustainable pest control and improve food security. The industry conducts ongoing research to better understand resistance risks, even during product development; implements intensive monitoring programs; and proactively develops strategies to prevent resistance. This commitment to stewardship helps ensure that resistance management strategies are effective now and stay ahead of pests in the future. 💧

Tactics to prevent pest resistance aim to:

- Allow products to remain effective and last longer
- Reduce the need for farmers to switch to more expensive or less preferred methods of control
- Maintain yield expectations and ensure sustainable production
- Save farmers time and money by reducing the need for repeated applications
- Avoid product residue risks on produce by ensuring applications are consistent with regulatory requirements
- Reduce farmer effort and worry trying to achieve effective pest control
- Increase farm worker safety and protect the environment

Perspective

Stewardship Key to Continued Biotech Success

In 2008, a group of 11 pioneering companies involved in the research and production of plant biotech products established [Excellence Through Stewardship \(ETS\)](#), a global not-for-profit organization to promote the universal adoption of stewardship programs for plant biotechnology around the world.

While the idea of good product stewardship was not new, the creation of ETS as a global organization focused the industry’s efforts on a worldwide set of auditable best management practices. The goal is to assist members in the implementation (or improvement) of stewardship programs and quality management systems and for the first time, facilitate independent, third-party audits to verify them.

“While strong stewardship within an organization is a great thing, these pioneering players in the industry recognized the benefits of stewardship being adopted throughout the plant science industry so they set out to spread the ideas of stewardship globally through ETS,” says Eric Frank Van Ausdal, director of projects, outreach & membership for ETS in Washington, D.C.

The first round of audits was performed in the United States during 2008-09 and expanded to include global operations in 2009-10. Today, ETS has more than 40 members across the globe. These members range from large seed companies doing international business to smaller seed retailers and non-profits in the CGIAR network. CGIAR is a global research partnership for a food-secure future. ⬇️



With the help of industry experts, ETS assists members in developing and implementing stewardship programs and quality management systems that work with existing organization procedures and programs over the entire lifecycle of a product.

“ETS membership is structured so that after an implementation period using a suite of tools, a third-party auditor assesses an organization’s operations to ensure the stewardship program has been properly implemented,” says Van Ausdal. “ETS publicly recognizes those that have successfully completed the process.”

ETS stewardship best practices have aspects that touch all levels of operational activities – from those at headquarters, storage facilities and fields to greenhouses and laboratories. The applicability to each member company is assessed on a case-by-case basis. The third-party audits are conducted at a system level every three years by ETS-trained auditors who examine objective evidence for each of the ETS elements relevant to an organization’s operations.

Benefits for Everyone

The plant science industry’s forward thinking in recognizing the crucial role that stewardship plays in the biotech business has helped in many ways, such as:

- Supporting overall industry regulatory compliance

- Helping prevent trade disruptions
- Maximizing the benefits and longevity of the technology
- Promoting stakeholder engagement

To date, 21 ETS members have been successfully audited to verify that they have established quality management systems consistent with ETS objectives, principles and management practices.

“The remainder are well on their way to being audited,” notes Van Ausdal.

“Organizations such as CropLife International and seed associations have been key to helping spread ETS messages around the world.”

A recent example of the impact of ETS is the successful rollout of its Insect Resistant Management (IRM) module. It provides guidance on the development and implementation of resistance management plans as components of an Integrated Pest Management strategy throughout a product’s lifecycle. The IRM section requires trait developers and licensees to have processes and procedures in place for:

- Conducting resistance risk assessments during product development
- Developing appropriate product and geography-specific resistance management plans
- Implementing IRM plans in a transparent manner, inclusive of all stakeholders
- Promoting farmer adherence to IRM guidelines
- Investigating and managing potential field resistance situations

Power of Partnerships

Van Ausdal says partnerships have been a cornerstone of ETS’ success.

“Organizations such as CropLife International and seed associations have been key to helping spread ETS messages around the world,” he notes. “This support has come in the form of help in identifying members and speaking opportunities, assistance in planning visits and workshops, and providing translation. Their local knowledge and commitment has been crucial to spreading awareness of ETS.

“We hope to continue the momentum and success by adding new members, improving the stewardship programs of current members, and offering additional benefits to all.”

Visit www.ExcellenceThroughStewardship.org for stewardship resources and more information. ◆

Helping Farmers Grow

Partnership Profile

Spray Service Providers in Ethiopia



Who:

In 2016, CropLife Africa Middle East started a partnership in Ethiopia with the International Fertilizer Development Centre (IFDC), which was funded by the Dutch government. The project, called [Toward Sustainable Clusters in Agribusiness through Learning in Entrepreneurship \(2SCALE\)](#), aimed to set up a network of Spray Service Providers (SSPs) for wheat and vegetable growers to promote responsible product use and Integrated Pest Management (IPM).

Where:

Activities were carried out in the Oromia region of Ethiopia, where the farmers' Meki Batu Union is active. This union has 150 cooperatives representing a total of 8,600 members. Members primarily produce wheat, vegetables and minor grains.

What:

A total of 59 farmers were trained in IPM and the responsible use of crop protection products. After passing written and practical exams, they all received personal protective equipment and a knapsack sprayer during a graduation ceremony. They also received an SSP identification card for easy recognition by farmers as well as a ledger in which to record their field activities. Following the graduation ceremony,



the SSPs began applying crop protection products for fellow farmers.

Results:

After about six months, an assessment of the SSPs revealed that they had served 600 farmers on a range of crops, including wheat, tomatoes, teff, barley and onion. In total, the SSPs covered 384 hectares and the project was named "Best Capacity Building Project" of 2016 by the Ethiopian Ministry of Cooperatives.

Next Steps:

CropLife Ethiopia is developing the SSP concept as part of a new, three-year project called Horti-LIFE (Horticultural Livelihoods, Innovation and Food safety in Ethiopia) in partnership with the Dutch international development organization SNV. The aim of the project is to improve food security and access to local markets for 30,000 smallholder farmers. 💧

Sharing the Story

Top 10 Innovations in Crop Protection Packaging

What goes into the packaging of a crop protection product? A lot of careful thought about farmer safety and usability, environmental protection and anti-counterfeiting.

“People don’t realize how much goes into packaging design to ensure shelf life (2-3 years) and safe transport,” notes Tim Cotter, head, Global Package Design & Innovation, at Syngenta in Greensboro, N.C., USA and chair of CropLife International’s Container Management Project Team. “Product exposure is a big concern and there’s more regulatory pressure. Packaging can provide safer solutions for growers and it can prevent counterfeiting with track and trace measures. We are always making improvements in the packaging sector.”

Like formulation research and development, packaging in the crop protection industry is based on continuous innovation. That’s partly because stewardship – the careful management of crop protection products from development to final disposal – is a top priority. Packaging design is a key to stewardship as it makes crop protection products easier and safer for farmers to use as well as protects the environment and product authenticity.

“For the agrochemical industry, innovation in packaging is important if it improves product use by farmers or prevents counterfeiting,” says Astrid Paulus, senior packaging expert at Bayer in Monheim, Germany, and chair of the European Crop Protection Association’s Packaging Expert Group. “It’s all about safety and performance.”

Here are 10 ways in which the crop protection industry safeguards farmers and the environment with packaging design and technologies:

1. Seal, lock and logo.

Safety seals, child-proof and spill-resistant caps and a manufacturer’s logo engraved into the caps of crop protection products protect against counterfeiting, leakage and getting into the wrong hands. Caps are thermo-formed with a logo and small ring on the side that breaks off to indicate a fresh bottle.

“You cannot seal a bottle that has already been sealed so it guards against counterfeiting,” notes Paulus. “The child-proof lock also prevents leakages, especially during transport.”

2. Measure up.

Built-in measuring devices minimize the risk of under- or overuse of crop protection products. Like a measuring cup, there are scales on packaging so farmers don’t have to use separate equipment to mix a product with water. A translucent strip on the side shows how much product is used with upside down and bottom up scales for ease of use. Gels have measured doses within their package.

“Farmers get multiple doses out of a product container so accurate measuring is essential,” Paulus says.



Built-in measuring devices

3. Aerate bottle necks.

Anti-splash and anti-glug bottle necks are large enough for air to come in while pouring to prevent splashing. The mouth is wide or there’s a molded-in feature that allows air in, Cotter notes.

4. Get a grip and pinch.

The handles of crop protection products are ergonomically designed for easy handling. In addition, pinched handles prevent product from staying in this hard-to-reach area when rinsed for disposal.



Standard and pinched handles

“Handles have been improved to save farmers’ time; the grip must be stable with ergonomic materials so that a farmer with a glove (possibly wet) can easily grab the product,” Paulus says.

5. Right-size.

Easy-to-manage containers that are appropriate for farm size discourage decanting products into unlabeled, inappropriate containers. For example, in South America and the U.S., where farms are large, containers



are large. But in India and China, farms are smaller so containers match to fit.

6. Smart label.

By incorporating unique visible and invisible features, such as a hologram with a company logo or invisible letters that can only be read by retailers with special equipment, crop protection manufacturers protect against counterfeiting.

“Holograms are expensive to produce but difficult to falsify,” Paulus notes. “We are making it as difficult as possible for counterfeiters. We inform retailers of our security measures who then inform farmers. Buyers also receive a brochure about anti-counterfeiting at the point of purchase.”

“Packaging can provide safer solutions for growers and it can prevent counterfeiting with track and trace measures.”

7. Raise the bar (code).

Bar codes are another way the crop protection industry authenticates products. They are read by farmers with a smart phone app to verify product origin. If the code has already been scanned (empty packaging taken by a criminal and refilled), then the farmer will know not to use it.

“It’s getting harder and harder to stay ahead of criminals so you have to be ahead of them with technology,” Paulus notes. “Not only is counterfeiting a production problem but it also affects whole supply chains supporting criminal activity.”

8. Lighten up and get stronger.

Stronger, lighter plastics and clever designs (i.e., plastic ribs in bottle walls) that create strength are being used in crop protection product packaging to lessen waste and cost.

“High-density polyethylene is the most common material as it’s recyclable,” Cotter notes. “It’s perfect for container management programs, which keep it segregated for industrial uses like pipelines and protective covering for cables. Recycling prevents waste.”

9. Layer and bulk-up.

In Europe, multiple layers (three to five depending on toxicity) of plastic are built into product containers to resist breakage with dropping or jostling. In the U.S. and Canada, refillable, returnable bulk containers for liquid products are used to cut down on waste and cost.

“Co-extruded plastic with layers ensures there are at least two barriers (up to four) in between the product, which is like a balloon inside, and outside packaging,” Paulus explains.

“Refillable, returnable bulk containers last for five years,” Cotter notes. “We calculated that in just four years, by reusing two containers in our Syngenta fleet distributed in the U.S. and Canada, we can eliminate 10 million pounds (4.5 million kilograms) of plastic and 15 million pounds of paper.”



Reusable bulk container

10. Close contact.


Products designed for a Closed Transfer System (CTS) prevent farmers from coming into direct contact with liquid chemicals. Farmers simply put a closed package into a machine that opens the packaging, properly doses it and puts it into a formulation.

Commercialized by agricultural machinery industry, only about 1 percent of large European and U.S. farmers are currently using CTS but its future potential is huge, Cotter estimates.

“CTS is only certified for use by large operations now but it’s forthcoming to smaller producers,” he says. “There is currently no certifying body for this equipment; it’s being worked on and the global industry is pushing for standards.”

What is involved in developing a new packaging feature or design altogether? It takes several million euros to change a single feature like the grip of the handle, Paulus says, plus two to three years of testing to meet United Nations requirements. Then about two months are needed to introduce the new feature into the global market; a brand-new package takes about a year.

Fortunately, “99 percent of the features we want are already there for good performance,” Paulus concludes. 💧


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