IRM for Transgenic Crops in Small-Holder Agricultural Systems

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Introduction

As with any tool used to manage pest populations, deployment of transgenic insect-protected crops can select for insects with alleles providing resistance to the transgenic trait. Over multiple insect generations, resistance alleles can increase in frequency and spread through a pest population until that population is resistant and the effectiveness of the transgenic crop in providing protection from damaging populations is diminished.

Resistance is not a unique concern for transgenic crops, but has developed to most classes of insecticides and even to some cultural practices. Resistance may lead to lost revenue to growers due to yield loss as well as increased costs associated with more aggressive pest management measures and alterations to cropping practices. Many growers may accept the medium term risks of such costs in order to maximize short term profitability. However, it is in the interests of technology providers, who find the value of their products and return on investment diminished by resistance, to take proactive measures that delay its onset. The agricultural community also benefits from measures that improve the sustainability of the crop production system. The agricultural community, therefore, must balance short term needs for growers to raise a crop in an economically efficient way and maximize yield with the longer term need to promote economic and environmental sustainability of the crop production system.

Insect resistance management (IRM) is the set of practices deployed to slow or reduce the chance of resistant insect populations developing. Generally the goals of IRM are not specific (e.g. target number of years until resistance) but IRM is intended to extend the useful life of a particular insect protection trait or transgenic crop under conditions of field use. IRM programs balance the science of resistance evolution with practical and economic realities. An IRM program that does not accommodate practical and economic realities is unlikely to be successfully implemented. This document provides guidance for developing IRM programs in agricultural systems that are dominated by small holders where the economic and practical considerations can be very different from industrial agricultural systems.

Elements of a Proactive IRM Program

Scientific basis

The scientific basis of resistance management for insect-protected transgenic crops has been well established. The rate at which insect pest populations adapt to a transgenic crop depends on (i) the biology and ecology of the pest; (ii) the genetics of resistance; (iii) the insecticidal properties of the crop; and (iv) the properties of the agricultural system.

Key aspects of pest biology and ecology include the insect population's use of alternative host plants, including crops and natural vegetation; insect seasonal migration and over-wintering biology; adult insect dispersal within and among fields; larval insect feeding behavior including dispersal within and among plants; and density-dependent and density-independent factors affecting mortality, fecundity and dispersal.

Key elements of the genetics of resistance include the number of genes involved in resistance, the number of alleles that affect the expression of resistance, the dominance of the resistance alleles, the level of resistance that resistance alleles confer, and the fitness costs associated with resistance alleles.

Key considerations for the transgenic crop include the number of insect-protection traits that are active against the target pest population, the concentration at which the insecticidal active ingredients are expressed in tissues on which the insects feed, and the potency of the active ingredients.

The agricultural system considerations include the diversity of crops grown, their spatial distribution, the proportion of crops with the same and with different active ingredients and the proportion without insect protection, the availability and use of alternative pest management practices and tools.

Many of these biological, genetic, and operational factors are unknown prior to, and even during, the period of commercial use of a transgenic crop. Others are naturally highly variable or unpredictable. Research on some of these elements may help develop or refine the scientific basis of an IRM plan. Simulation models have been developed for some systems that integrate many of these factors enabling their relative importance and interactions to be investigated, as well as the effect of variability and uncertainty. These models have enabled the development of sound science-based IRM principles.

Refuge-based resistance management

The most common foundation of resistance management for insect-protected transgenic crops is the use of refuges. Refuges consist of host plants that do not contain insect-protection traits allowing a portion of the target pest population to escape exposure so that susceptibility to the trait can be maintained in the population. Depending upon what insect-protection traits, insects, and agricultural system is being considered, refuge can exist in many different forms. Refuge can consist of: the same species as the transgenic crop and be deliberately grown alongside or nearby the transgenic crop; different crop species that are suitable hosts and are deliberately grown near the transgenic crop; and/or natural vegetation and alternative host crops ("natural refuge"). In situations where the refuge is deliberately grown near to the transgenic crop, specific guidelines related to the size, proximity, structure, and management options may apply.

Other elements of an IRM plan

Other elements of an IRM plan should include:

- Pest/crop/region-specific guidelines for integrated pest management of the target insect populations
- Grower education on resistance management, product performance, field scouting for unexpected damage by target pests, and guidelines for use of insecticides
- Monitoring grower implementation of refuges and best management practices
- Resistance monitoring and baselines
- Remedial action plans to deal with resistant populations

Practical and regulatory considerations

The guidelines for refuge establishment and management are developed based on the scientific considerations described above as well as practical and economic considerations. The scientific basis of IRM cannot be used alone to determine the refuge guidelines. Because, by definition, refuges consist of plants that do not contain traits that provide protection from the target pest, their implementation and management add cost and complexity to crop production and often result in pest injury and yield loss. This economic and logistical burden is borne by the growers. In small-holder situations, the growers' perceived and actual losses arising from refuge implementation can create a high barrier to refuge adoption. IRM programs therefore must accommodate both economic and practical realities. The developers of these programs must take into account economic and social impacts on the rural agricultural community and effects on broader societal goals. Where appropriate, regulators should encourage technology providers to harmonize IRM programs for similar products. Complex differences among IRM programs discourage adoption and undermine the overall goal of sustaining the utility of these crop protection tools.

Recommendations for IRM in small-holder agriculture systems

Refuge Guidelines

1) Unless biological data (e.g. natural refuge, migration) indicate a structured refuge is unnecessary, providers of transgenic insect-protected seed should include refuge seed with the traited product.
   - Natural refuge may be sufficient if abundant alternative crop or wild hosts are demonstrated to be reliably available in the area of cultivation at the same time as the transgenic crop.
   - Refuge may be unnecessary for a pest species with annual migration that does not persist year-round in the region where the transgenic crop is grown unless there is significant return migration.
2) The refuge seed proportion should be harmonized across products with similar attributes, where possible.
3) The refuge seed delivery mechanism should be harmonized across products with similar attributes, where possible.
   - For example, if a situation favors seed blends, this approach would be preferred.
   - Otherwise, refuge should be provided with the transgenic seed in a manner that enables growers to plant a separate refuge. This may be a "bag-in-bag" approach and should include recommendations for appropriate structure and proximity of the refuge area.
4) Under a separate refuge approach, a "community refuge" that combines the individual refuges for multiple farms within an area should be considered. The distance or area covered by such a refuge approach would be dependent upon the key target pests and should be limited to the pest most greatly impacted by distance.
5) A separate refuge can be treated with insecticides by the grower if unacceptable pest damage is occurring, but such treatment should not include active ingredients with the same mode of action as the insecticidal trait and should be kept to a minimum.

Best Management Practices

6) Technology providers should develop pest/crop-specific best practices for managing target pest populations using the transgenic crop.
   - Include recommendations for cultural control practices to reduce pest populations.
   - Include routine field monitoring for target pest damage and intervention, e.g. insecticide applications, where damage thresholds are reached.

Education and Communication

7) Technology providers should develop comprehensive education and communication programs at the local and national level, within existing education/communication infrastructure, so growers understand what they need to do and why.
   - Include refuge instructions with every insect-protected transgenic crop seed delivery.
   - Include best pest management practice instructions with all products.
   - Leverage local CropLife and other seed industry associations to deliver common messaging, grower training, workshops.
   - Work with governments, extension, public sector scientists, and other respected authorities to deliver common and consistent messaging.
   - Identify community leaders who can deliver local education.
   - Train seed dealers on appropriate crop management practices.
   - Use available avenues for delivering messages, such as advertising, media, mobile phones, etc.

Monitoring

8) Technology providers should develop programs for measuring education effectiveness and adoption of refuge and best management practices.
9) Technology providers should develop resistance monitoring programs for key target pests, including baseline susceptibility where practical:
   - Baseline susceptibility – ideally prior to launch, but within the first two years of commercial use;
   - Monitoring based on product performance; collection and bioassay of insects in unexpected damage situations. Conducted as a collaboration between seed provider, growers, grower advisors, and public and private researchers as appropriate;
   - In certain circumstances, monitoring based on random insect collections may be useful.
10) Monitoring programs should be linked to responsive actions should evidence of developing resistance arise.

On-going Research

11) Before and/or after commercialization, technology providers should facilitate development of biological and resistance genetics information relevant to the system and adapt the IRM program, if warranted, to any significant new findings.