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REFUGE REQUIREMENTS FOR TEXAS BT CORN TARGETED AT CATERPILLAR PESTS

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Bt corn is genetically altered to produce insecticidal proteins in its tissues. One important way these plant-incorporated protectants differ from traditional insecticides is that they are produced season-long and, because they are always out there, expose multiple pest generations to the same toxins. Bt corn was introduced in 1996 and is now planted on over 85 percent of United States (US) corn acres. Moreover, most of the cotton planted in Texas produces similar Bt insecticidal toxins. As a result, field populations of target pests have been selected for resistance generation after generation and year after year for the same Bt proteins. Repeated exposure to the same insecticides over multiple generations is a good way to hasten resistance.

Seed companies, university scientists, and the Environmental Protection Agency (EPA) knew resistance would occur. When Bt corn was first marketed, stewardship plans were made to delay that resistance for a reasonable amount of time; the target was 20 years. As expected, there is now widespread or regional resistance to some Bt toxins in corn earworm (cotton bollworm), southwestern corn borer, European corn borer, western bean cutworm, fall armyworm, and western and northern corn rootworm.

HOW RESISTANCE MANAGEMENT PLANS WORK

When a new Bt toxin is introduced, it is assumed that a few extremely rare individuals in a population have some genetic ability to withstand that toxin. A gene is comprised of two alleles, one from each parent. Upon introducing a new Bt toxin, the assumption is that most of the population is completely susceptible and has two copies of alleles for susceptibility (SS) and that there are almost no insects with both alleles for resistance (RR). It is also assumed that insects with just one copy of a resistance allele (RS) are very rare but are out there. It is hoped that these RS offspring with one allele for susceptibility and one allele for resistance will be killed on Bt because a high dose of toxin would overwhelm the partial resistance conferred by just the one allele.

The scenario above, wherein a high dose of Bt kills the insects with only one resistance allele (RS, heterozygous-resistant insects), is called the high-dose/refuge strategy. A high dose of toxin essentially kills almost all the RS heterozygotes and keeps the resistance allele rare. This, in turn, greatly reduces the odds that there will be any completely resistant (RR) insects that result from the mating of two RS insects. The critical part of this strategy is to plant some percentage of the crop as a "refuge"—or place of non-Bt corn that lets some insects develop on plants where they are not selected for resistance—and the allele for susceptibility can be maintained at a high frequency.

When refuges are properly deployed, the unselected insects will be available to mate with nearby insects selected on Bt. Selected insects that survive development on Bt corn are presumed to have two resistant alleles (RR). The mating of RR and SS will "dilute" resistance alleles that might be carried by insects that survived on the Bt crop. If the offspring from these matings are RS (rather than RR), then there is a good chance the high dose of Bt will kill them, avoiding the spread of resistant alleles to future generations and, therefore, delaying the evolution of Bt resistance.

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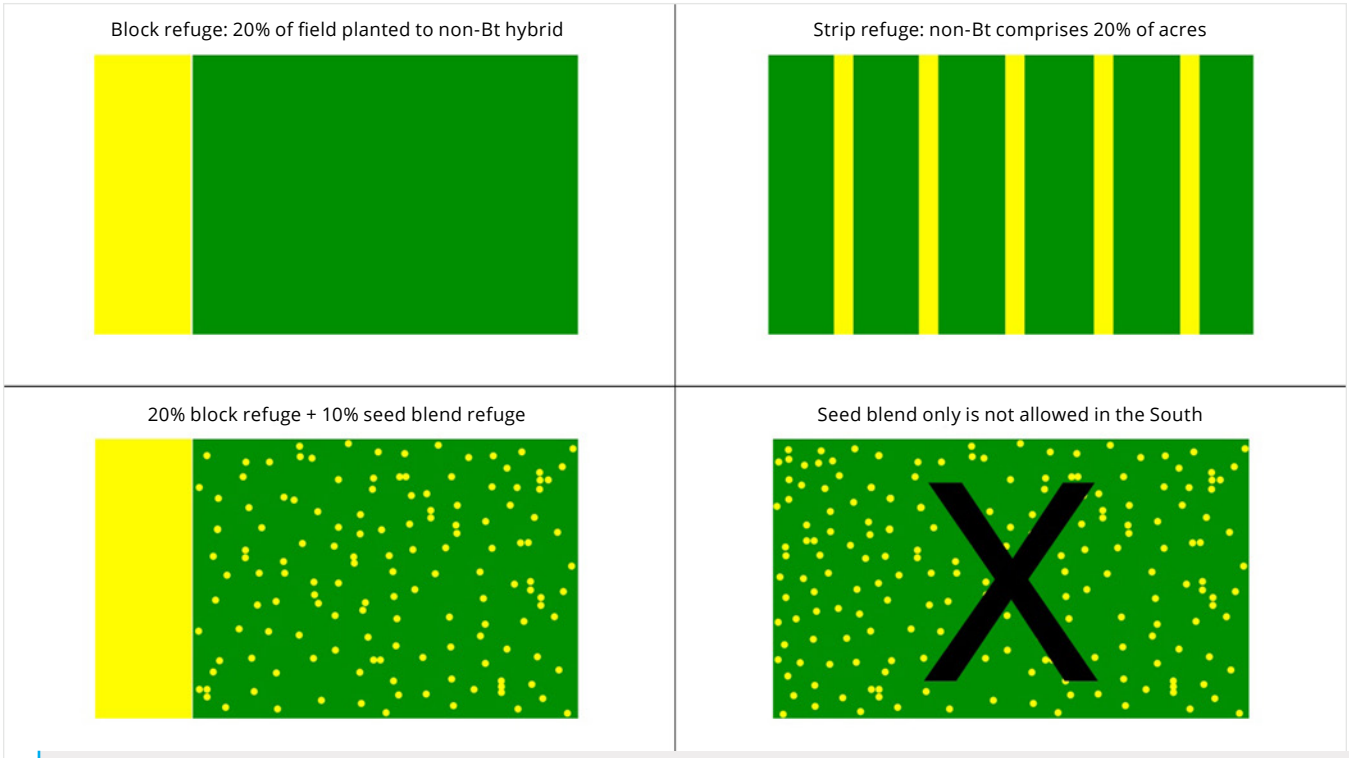

Figure 1. Currently accepted refuge planting arrangements in Texas corn. (Counties north of Amarillo follow the less-restrictive northern Corn Belt rules.) Note: The refuge requirements are being renegotiated now (2024), and the required non-Bt refuge percentages might change.

TYPES OF REFUGE

The first Insect Resistance Management (IRM) plans in 1996 called for a separate planting of non-Bt corn adjacent or very close to the Bt corn. This type of refuge is called a block refuge or structured refuge. An evolution of this was to plant several contiguous rows of non-Bt corn in strips bordered by Bt corn, and this is called strip refuge. A later type of refuge was obtained by mixing non-Bt seeds with Bt seeds to have a certain percentage of the plants in a field that did not express Bt toxins. This type of refuge is called seed blend refuge or integrated refuge. (Some people call this "refuge in the bag," but that is a marketing term from one of the seed companies, and it merely refers to seed blend refuge.)

Block refuge (structured refuge)

- For caterpillar pests, delays resistance development longer than seed blend or strip refuge
- Is logistically more difficult to plant than seed blend refuge
- Can be treated with insecticides if necessary

Strip refuge

- Is inferior to block refuge for delaying resistance in ear-feeding insects because of cross-pollination with nearby Bt plants
- Modern planting equipment can make strips difficult to plant
- Strips can be treated with insecticides, if necessary, but this is difficult

Seed blend refuge

- Is inferior to block refuge for delaying resistance in ear-feeding insects because of cross-pollination with Bt plants
- Easy to plant because refuge corn seed is mixed with Bt seed
- In cotton-growing regions, none of the non-Bt (refuge) seed in the bag counts toward the refuge requirement
- Is impractical to treat the refuge corn for pests not controlled by the Bt

WHY THE SOUTH HAS LARGER REQUIRED REFUGES THAN THE CORN BELT

All the refuge types listed above are in use today, but there are geographic differences in EPA regulations on what percentage of corn must be non-Bt. These regulatory differences exist in part because Bt cotton is also grown, and many corn pests, like fall armyworm and corn earworm, do not overwinter in the northern Corn Belt; they overwinter only in the southern US. Their first annual generations develop on southern crops like corn, and then they migrate north. Critically, these northern migrants are not thought to return south at the end of the year, so what happens to them by way of selection for Bt resistance in the North does not matter because their offspring will be killed by winter. However, southern insects that overwinter will continue to evolve resistance for as long as they are exposed to Bt corn or cotton. In the South, cotton also has the same or very similar Bt toxins as those used in Bt corn, so pests are selected for resistance over multiple generations on both crops.

This is why the EPA has established two "zones" in the IRM strategy. Northern states that produce no or very little cotton—and in which some caterpillar pests cannot overwinter—have less stringent refuge requirements than the southern cotton-producing states. Northern IRM requirements now rely heavily on seed blend refuge. **Southern refuge requirements for Bt corn allow seed blends to be planted, but none of the non-Bt kernels in the bag count toward refuge. A block refuge must still be planted in, or very closely adjacent to, the field of seed blend refuge corn.**

The refuge requirements mentioned in this document apply to Bt corn active against caterpillar pests. Because of its biology, corn rootworm resistance to Bt is best delayed by using a seed blend refuge, and this applies nationwide. Bt corn active against both corn rootworm and caterpillar pests will have to follow the refuge requirements for caterpillar pests.

REFUGE PLANTING MONITORING AND COMPLIANCE

As part of registering their Bt corn hybrids, seed companies are required to have an IRM plan approved by the EPA. Corn growers must sign a seed company document (Stewardship Agreement) each year that attests they understand the requirements of the plan and will follow the guidelines. In EPA terms, growers who do not strictly follow the IRM requirements for the corn hybrids they plant are considered to be "out of compliance." As part of their registration, the EPA mandates that seed companies monitor or audit a certain percentage of growers each season for refuge compliance. The percentage of growers audited each year is much higher in the southern cotton-growing regions, in part because this area has a history of very low refuge compliance.

Complying with the IRM rules is easy in areas where seed blends alone meet refuge requirements, but it becomes more difficult in southern areas where block or strip refuge must be planted for fields of wholly Bt corn or fields with seed blend refuge. Growers found to be out of compliance will be visited by seed company representatives for at least 2 years after their noncompliance is determined. If the noncompliance continues after that time, growers will be denied access to Bt corn hybrids from that seed company. This penalty is written into the registration agreements each seed company has with the EPA, and companies will not violate those agreements. At present, there are no direct financial penalties for corn growers found to be noncompliant with the IRM rules. However, this might change when the new rules are issued in late 2024 or 2025.

Seed company representatives will help develop a refuge planting plan if requested. Grower Technology Use Guides are available online from every company that sells Bt corn.

The best way to know which Bt toxins are in any corn hybrid—and which insects are resistant to those toxins—is the Handy Bt Trait Table. This publication is updated annually to reflect changes in corn hybrids and EPA regulations. The refuge requirements in the table are for the Corn Belt, so consult seed company personnel for the requirements in Texas.