UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF CHEMICAL SAFETY
AND POLLUTION PREVENTION

MEMORANDUM

SUBJECT: EPA Draft Proposal to Address Resistance Risks to Lepidopteran Pests of Bt Following the July 2018 FIFRA Scientific Advisory Panel Recommendation

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A. Scope and Summary of Proposal:

The Environmental Protection Agency's Office of Pesticide Programs (OPP) convened a Federal Insecticide, Fungicide, and Rodenticide (FIFRA) Scientific Advisory Panel (SAP) on July 17-19, 2018 (SAP 2018) to discuss scientific uncertainties with the insect resistance management program (IRM) for Lepidopteran pests of *Bacillus thuringiensis* (Bt) corn and cotton. This document provides a summary of the background leading up to the SAP meeting, the Charge Questions to the Panel, the SAP's response to the Agency, and OPP's post-SAP meeting planned actions as well as a draft proposal and request for comment to improve IRM for Bt traits (Plant-Incorporated Protectants, PIPs) targeting, specifically, non-high dose pests.

The intention of EPA's draft framework is to aid farmers by extending the lifetime of partially efficacious Bt traits and future new PIP products that reduce exposure to conventional pesticides in the environment and to humans. Though resistance cases to most Bt toxins for non-high dose pests have been documented, EPA anticipates that the proposed actions in the framework will function well in areas where resistance to these toxins is not as prevalent. In addition, EPA is highlighting parts of this document where additional stakeholder feedback is requested prior to a formal proposal by the Agency.

This proposal builds off the current IRM plan for Bt traits, which was implemented as part of the terms and conditions for Bt corn and cotton registrations when the products were initially registered (beginning in 1999). Existing IRM plans include provisions for non-Bt refuges to produce

susceptible insects to dilute the frequency of resistance genes in the pest population, resistance monitoring strategies, remedial action (mitigation) plans should Bt-resistant populations emerge, compliance assurance to ensure that growers plant refuges, and annual reporting to EPA. The draft framework discussed in this document proposes to change some of these current approaches as well as additional elements to reduce the risk of resistance in pest populations. EPA believes this revised framework is needed given the cases of lepidopteran resistance documented to date (see below and US EPA 2018) and the likelihood of additional resistance developing in future growing seasons without additional mitigation. Should lepidopteran resistance continue to proliferate, Bt corn and cotton PIPs could be lost to farmers as tools to address pest problems.

In developing this draft framework, EPA used the meeting minutes from the SAP (2018) as the primary source for the proposed mitigation herein. On areas where the panel did not formally opine or had contradicting opinions, EPA is seeking more feedback through the public comment process. During the deliberation period between the receipt of the SAP meeting minutes (SAP 2018) and the release of this draft IRM framework, EPA received further comments from the Agricultural Biotechnology Stewardship Technical Committee (ABSTC), a panel of independent academic scientists, National Alliance of Independent Crop Consultants (NAICC), and Syngenta Crop Protection, LLC. Although these stakeholder comments were not solicited by the Agency, they were considered in this draft proposal and will be posted alongside this memorandum in the public docket. The draft framework addresses concerns raised by commenters and allows for flexibility for growers, while incorporating sound scientific standards to improve the previous resistance management paradigm for Lepidoptera.

EPA's proposed new framework for Lepidopteran pests of Bt corn and Bt cotton (hereafter referred to as 'framework') is consistent with the recommendations received from the SAP and expert scientists, and addresses stakeholder comments thus far received from the public. The document outlines new mitigation options differing from the previous resistance management program:

1) Resistance reports for Lepidopteran pests of Bt PIPs: The Agency supports the unanimous consensus of the SAP regarding documented cases of Bt resistance for *Helicoverpa zea, Spodoptera frugiperda,* and *Striacosta albicosta* for specific Bt toxins.

2) Proposed new resistance definition for non-high dose pests: At commercialization, all non-high dose pests will be considered at a heightened risk of resistance. Practical resistance will be defined as unexpected injury (UXI) that exceeds established levels in Bt corn and cotton.

3) Proposed resistance monitoring: To monitor for UXI, sentinel plots will be implemented in high risk regions of the cotton belt for *H. zea* and parts of the corn belt for *S. albicosta*. The UXI levels will be synonymous with the economic threshold level for effective Bt traits. Resistance confirmation through bioassays will not be required following UXI but laboratory testing to confirm resistance will be accepted and companies may pursue testing to refute the practical resistance definition and subsequently triggered mitigation.

4) Proposed enhanced resistance mitigation: Mitigation is split into two sections encompassing tools for cases of confirmed resistance and those for remaining effective traits. One proposal includes best management practices (BMPs) prior to and after UXI as well as increased communications with stakeholders.

5) Proposed annual reporting: EPA will continue to require refuge compliance reports from ABSTC and UXI notification from individual registrants. Additionally, EPA is proposing as part of this draft framework to receive records of production documenting adequate amounts of refuge seed and total acres treated reports for insecticide oversprays targeted at Bt pests in various registered Bt crops.

Additionally, EPA is soliciting public comment on the options below, but will not take a position on them until it has reviewed all stakeholder input:

6) Phase Down of Single Traits and Non-Functional Pyramids: A short term phase down of single trait corn products controlling Lepidopteran pests and a long-term phase down of compromised pyramid corn and cotton products.

7) Increasing Percent Refuge in Seed Blend Products: An increase from 5% refuge-in-a-bag in Bt corn pyramid products to 10% refuge nationwide.

8) Refuge Compliance Monitoring: Mandatory registrant on-farm refuge compliance visits, measures for non-compliant growers, increased seed dealer record keeping. Registrants would be required to implement these measures with growers.

B. Background on Lepidopteran Resistance to Bt Traits in the Continental U.S.

Reports of Lepidopteran resistance to Bt (*Bacillus thuringiensis*) traits of corn and cotton in the continental United States have been published by academic scientists in 2014 for the fall armyworm (*Spodoptera frugiperda*) (Storer et al. 2010, 2012; Huang et al. 2014), in 2016 for the corn earworm (*Helicoverpa zea*) (Dively et al. 2016; Yang et al. 2017), and in 2017 for the western bean cutworm (*Striacosta albicosta*) (Ostrem et al. 2016; DiFonzo et al. 2016; Smith et al. 2017). All three of these pests are managed in cotton and/or corn using non-high dose Bt traits of either single or pyramided products. Similarly, a Bt corn registrant reported resistance for the southwestern corn borer (*Diatraea grandiosella*), originally identified as a high dose pest, in resistance monitoring reports submitted to the United States Environmental Protection Agency (US EPA) in 2016 (MRIDs 497854-01; 501749-01).

Of the above resistance reports, only one triggered EPA's current regulatory definition of pest resistance which relies on a demonstrated heritability of the resistant trait, higher survival of resistant individuals compared to susceptible individuals on Bt crops, and visible economic damage caused to Bt crops in the field (US EPA 2010). Resistance could only be confirmed for *D. grandiosella* using EPA's regulatory process, although the Agency's expert scientists agreed with published reports by academic scientists that resistance to Bt had also evolved in *H. zea*, *S. frugiperda*, and *S. albicosta* (US EPA 2018).

The cases of resistance demonstrated by field failures and academic reports did not trigger mitigation by EPA because resistance to non-high dose Bt toxins could not be confirmed using standard diet bioassay methodologies, used by registrants required by EPA for resistance monitoring in the terms and conditions of registration for these Bt PIP products. EPA concluded that the following risk factors were likely the main causes leading to increased resistance development in the three non-high dose pests:

- **Risk factor 1**: Single trait Bt corn in the presence of pyramided products in the landscape;

- **Risk factor 2**: Limited number of highly effective Bt traits;
- **Risk factor 3**: The shift of dominance of resistance in ear-feeding pests of corn with exposure to Refuge-In-The-Bag (RIBs) corn products in the southern US;
- **Risk factor 4**: Non-compliance with refuge plantings in the southern US;
- **Risk factor 5**: Non-functional, non-high dose pyramided Bt products where individual traits control less than 95% of susceptible insect;
- **Risk factor 6**: Resistance monitoring does not allow tracking the same populations year after year;
- **Risk factor 7**: Lack of standardized unexpected injury (UXI) thresholds;
- **Risk factor 8**: Selection pressure on effective traits (e.g., Vip3A) in pyramids with less effective or compromised traits;
- **Risk factor 9**: Use of diet bioassay methods for non-high dose pests;
- **Risk factor 10**: Mitigation of resistance when field failure occurs; and
- **Risk factor 11**: Protracted mitigation in response to field failure;

Given the resistance occurrences and 11 identified risk factors, EPA developed an issue paper and proposed to consider changes to its Lepidopteran IRM program (US EPA 2018). The goal of the modified IRM program would be to reduce resistance risks for non-high dose pests, increase the longevity of currently functional Bt traits and future technologies, and improve the current Lepidopteran resistance management program for Bt corn and cotton.

The following management options were listed in the White Paper (US EPA 2018) as possible actions that would lower the risk of resistance to Bt PIPs:

- Eliminate single trait Bt corn in the presence of pyramided products in the landscape;
- Limit or otherwise manage single trait commercial products;
- Transition from single trait products to Bt corn pyramids;
- Adoption of intervening actions at “early warning resistance” in addition to actions when field failure occurs (see “molecular assay” option);
- Potential changes to the corn breeding program to move away from hemizygous parental corn lines, introduce pollen incompatibility between Bt and non-Bt cultivars, self-pollinating mechanism, etc.;
- Manage the use of Bt corn RIB products in the southern US;
- The development of incentive programs to increase compliance with block refuge requirements for Bt corn in the southern US;
- Non-functional, non-high dose pyramided Bt products where individual traits control less than 95% of susceptible insects;
- Implementation of best management practices (BMPs) consistent with the tenets of Integrated Pest Management (IPM) practices for fields with Unexpected Injury (UXI);
- Manage the use of non-functional pyramids;
- Increasing the amount of refuge;

- Use of sentinel plots to monitor the same populations from year to year;
- Development of such standards in corn and cotton would expedite insect collections, reporting to EPA, and early mitigation;
- Focus on risk in Bt corn which drives the resistance risk to Bt cotton;
- Development of novel assays to monitor for "early warning" resistance that allow expeditious resistance confirmation followed by early implementation of mitigation actions;
- Establish an early intervening threshold that would create a greater likelihood of success for mitigation of resistance and to delay occurrences of field failure;
- Encouragement of IPM with IRM for Lepidopteran pests of Bt corn and cotton at the onset of a new trait deployment and throughout its commercialization;
- Implement mitigation actions when field failure is apparent instead of after resistance is confirmed (i.e., practical resistance);
- Use of BMPs consistent with the tenets of IPM to reduce UXI field occurrences and delay resistance development;
- Increased scouting for pest densities;
- Use of alternate control methods when economic threshold on Bt crop is reached;
- Increased tilling where possible;
- Crop destruction methods;
- Multi-year management plans to control lepidopteran pests including rotation of Bt pyramided products (different modes of action), rotation to conventional corn with insecticide use, etc.;
- Use of standardized regulatory thresholds defining unexpected injury levels that trigger grower reporting to seed/trait providers;
- Improved and timely communication by Bt registrants through notification to growers, state extension agents, and crop consultants of areas with early warning resistance, unexpected injury fields, and confirmed resistance cases.

The Agency identified risk factors and considerations for improvements to the IRM plan were brought before an independent expert panel in July 2018.

C. Scientific Advisory Panel Meeting and Recommendations to the US EPA

The US EPA's Office of Pesticide Programs convened a FIFRA SAP meeting held on July 17-19, 2018 in Arlington, Virginia, to discuss Lepidopteran resistance cases of non-high dose pests in the continental US and options to improve detection of and delaying resistance evolution to Bt traits, especially in the southern states where Bt corn and Bt cotton are planted and traits are shared between the two transgenic crops. The Agency's charge posed to the SAP asked for guidance on the following identified topics:

1) Certainty of resistance in non-high dose pests reported by academics;
2) Resistance monitoring for non-high dose pests;
3) Seed blended corn and resistance risks in the southern US;

4) Options to mitigate resistance risks due to shared Bt traits in corn and cotton;
5) Resistance management options for Western bean cutworm;
6) Mitigation of resistance for Noctuid Lepidoptera;
7) Grower non-compliance with refuge plantings in the south; and
8) New IRM framework for lepidopteran pests of Bt corn and Bt cotton.

Public commenters, consisting of academic researchers, Agricultural Biotechnology Stewardship Technical Committee, a consortium of the Bt corn companies, National Cotton Council, National Corn Grower Association, National Alliance of Independent Crop Consultants, National Cotton States Pest Management Working Group, and biotechnology companies made presentations and/or submitted written comments to the Panel on issues related to the Charge Questions (issues identified above as topics 1-8).

EPA/OPP presented the SAP with a historical background of EPA's Insect Resistance Management (IRM) program and current resistance issues with non-high dose Lepidopteran pests, including the scientific uncertainties associated with the current resistance management program for Lepidoptera and Bt corn and Bt cotton. The full Panel report, Agency supporting materials, and public written comments can be accessed on regulations.gov (https://www.regulations.gov/docket?D=EPA-HQ-OPP-2017-0617).

EPA's charge questions and the SAP's response and recommendations are summarized below:

1) Resistance reports for Lepidopteran pests of Bt PIPs: The Panel agreed with EPA that three resistance reports for the non-high dose pests were convincing. The experts concluded that the underlying causes as well as the degree of field resistance were different for each pest. The Panel noted that environmental effects and knowledge of the mechanisms of resistance could aid in slowing the spread of and mitigating resistance to Bts and future traits.

2) Resistance monitoring for non-high dose pests: The Panel acknowledged the inherent challenges with variable diet bioassay results, especially for *H. zea*. Thus, it was recommended that diet bioassays are standardized across laboratories and results should be used to provide biological relevancy for Unexpected Injury cases (UXI). To determine the genetic relevancy of resistance, the Panel recommended that future molecular approaches be considered. Meanwhile, the F2-screen was recommended for diet bioassays until those tools were available. Three categories of putative resistance were proposed: 1) at risk of resistance, 2) heightened risk of resistance, and 3) observed practical resistance. Categorized in one of the definitions is based on bioassay results to determine the resistance allele frequency levels in the population alongside UXI, a shift from heightened to practical resistance may be triggered. For non-high dose pests, heightened resistance should be the null hypothesis.

3) Resistance risks of seed blend corn in the southern US: The Panel concluded that seed blends in the south pose a greater risk to ear-feeding pests than stalk borers. They recommended not to allow seed blended products with Vip3A where, for example, *H. zea* overwinters and cotton is grown. Furthermore, the panel stated that seed blended refuge should be increased from 5% to 10% in the northern Corn Belt to protect functional pyramids. Long-term, seed development should make use of germplasm with native resistance for Bt; the transgene portfolios should be

expanded to include other bacterial and fungal entomopathogenic traits. Short-term, the Panel recommended adopting the Plus hybrid seed, preventing cross-pollination between Bt and non-Bt traits, and endophytic entomopathogenic seed treatments for Lepidoptera control.

4) Bt traits expressed in corn and cotton: The Panel asserted that most traits deployed in corn were also expressed in cotton and presented a continuous selection problem for *H. zea.* Thus, resistance management options were limited *per se*. The number of efficacious traits were few, and their deployment in compromised pyramids could substantially shorten their lifespan. The Panel recommended developing high yield non-PIP field corn hybrids for use as refuge corn, developing a model to assess the economic impact and resistance durability when Vip3A was not planted in southern field corn, maintaining sufficient non-Bt refuges for stalk borers and non-target Bt pests, and that EPA and seed industries find ways to incentivize growers to plant refuge. Meanwhile for cotton, the natural refuge paradigm should be maintained.

5) Resistance management for *S. albicosta* (Western bean cutworm): The Panel agreed that a separate Corn Belt-wide IRM plan for *S. albicosta* could interfere with plans for *O. nubilalis* (European corn borer) and *Diabrotica virgifera virgifera* LeConte (Western corn rootworm). Instead it was recommended that in those areas where *S. albicosta* was a significant pest that a locally-appropriate Best Management Plan (BMP) be implemented. Additionally, some Panel members suggested that EPA should require that monitoring for Vip3A resistance occur in those problematic areas. This guidance should, however, be re-evaluated should *S. albicosta* become a pest of concern over a wider area in the Corn Belt.

6) Mitigation of resistance: The Panel recommended that proactive use of regionally adjusted IPM/mitigation plans should be considered to delay resistance occurrences in *H. zea* and *S. frugiperda*, as such was more practical than mitigation of resistance cases. This recommendation was based on considerations such as the pests' dispersal propensity and cross resistance between Bt traits. A program should be established by which clear and coordinated communication occurred between all involved parties when implementing management tactics. This would facilitate building trust, decrease complexity and uncertainty, and increase the likelihood that adopted IRM tactics worked within an IPM framework.

7) Grower non-compliance with refuge in the southern US: The Panel expressed that grower compliance with refuge was a function of perceived likelihood of being sanctioned and the severity of such sanctions. They found it problematic for biotech companies owning the traits/seeds (i.e., ABSTC) to monitor regulatory compliance. The Panel could not determine whether denying future Bt seed was an effective strategy in response to non-compliant behavior. Recommended actions to increase grower compliance included: tailoring marketing programs to smaller farms; using focus groups lead by extension experts to communicate importance of refuge; seed dealer established discounts/subsidies on refuge seed; and/or agricultural subsidy incentives.

8) New IRM framework for Lepidopteran pests of Bt: The Panel recommended strengthening the proactive approaches relying on broad-based, multi-tactic, biologically sound principles of IPM with deploying PIP products targeting high dose and non-high dose pests (e.g., before, during, and

after resistance). The Panel agreed that for non-high dose pests, pyramids and refuge strategies were best at delaying resistance. Among other recommendations were: convening key stakeholders to establish 1) spatial and dynamic pattern of resistance and 2) cost-effective tactics for sustainable IRM in each crop production region; strengthening scouting and monitoring programs with shared private and public resources; area-wide approach to implement new IRM framework tailored to each area's socio-ecological and biophysical conditions; appointment of trusted leaders in each area to facilitate grower adoption of community-driven IRM programs; and building an integrated network of responsibilities, incentives, compliance requirements and penalties while relying on public and private funding.

D. Comments Received in Response to the SAP Report

Subsequent to the receipt of the SAP (2018) meeting minutes and prior to the release of this draft IRM framework, EPA received comments from the ABSTC, academic entomologists, NAICC, and Syngenta Crop Protection LLC. Although these comments were not solicited by the Agency, they were considered in this draft proposal. These comments will be posted in a public docket with this draft framework for transparency and are referred to in the below proposal. For additional information on the content of each comment, please see the full text in the docket (EPA-HQ-OPP-2019-0682). The following comments were received and considered in this proposal:

Agricultural Biotechnology Stewardship Technical Committee (ABSTC). 2019a. Agricultural Biotechnology Stewardship Technical Committee Comments on the Panel Recommendations from the Scientific Advisory Panel "Resistance in Lepidopteran Pests to Bt PIPs in The United States" (EPA-HQ-OPP-2017-0617. Correspondence from Dr. Matthew Carroll on June 14, 2019.

Agricultural Biotechnology Stewardship Technical Committee (ABSTC). 2019b. Agricultural Biotechnology Stewardship Technical Committee Proposal for an Insect Resistance Management Plan (IRM) Framework for Lepidopteran Pests. Correspondence from Dr. Matthew Carroll on June 14, 2019.

Dively, Galen. 2019. Resistance monitoring for non-high dose pests: field reports of unexpected damage (UXI) and sentinel plots (SAP charge question 2). Correspondence on June 19, 2019.

Jurat-Fuentes, J. 2019. Resistance monitoring for non-high dose pests: lab bioassays (SAP charge question 2). Correspondence on June 18, 2019.

Porter, P. 2019a. Resistance risks of the Vip3A trait and refuge-in-a-bag (RIB) in the southern US. Correspondence on June 18, 2019.

DiFonzo, C. 2019. Resistance management for western bean cutworm *Striacosta albicosta* (SAP charge question 5). Correspondence on June 19, 2019.

Porter, P. 2019b. Communication and refuge compliance (SAP charge question 7) Correspondence on June 17, 2019.

National Alliance of Independent Crop Consultants (NAICC). 2019. Resistance of Lepidopteran

pests to Bt PIPs in the United States. Correspondence with Jim Steffel on June 12, 2019.

Syngenta, LLC. 2019. Syngenta comments related to the recommendations from the 2018 Scientific Advisory Panel (SAP) on "Resistance of Lepidopteran Pests to *Bacillus thuringiensis* (Bt) Plant Incorporated Protectants (PIPs) in the United States" (Docket No: EPA-HQ-OPP-2017-0617). Correspondence with Paul Miles on June 5, 2019.

Western Bean Cutworm Summit. 2018. Meeting minutes of academic, industry, and EPA scientists at the National Entomological Society of America Meeting. November 11, 2018. Vancouver, Canada.

E. EPA's Draft Proposal for an Improved Lepidopteran Resistance Management Program

After the official Panel recommendations were submitted to the Agency on September 27, 2018 (SAP 2018), EPA began to develop the below draft proposal to improve the Lepidopteran resistance management program for Bt corn and Bt cotton. The primary source for developing the proposed IRM framework was the SAP meeting minutes (SAP 2018). EPA also considered additional comments submitted by stakeholder groups (e.g., ABSTC 2019, letters from independent academic entomologists, NAICC 2019, Syngenta 2019) in the process to complete the draft framework below.

This draft framework and comments received during the deliberation period will be made available in a docket on regulations.gov. The Agency will also open a 60-day comment period on the proposal and will solicit input from stakeholders such as corn and cotton growers, crop consultants, academic experts, non-governmental organizations, the Bt PIP industry, and the general public. There are key sections of the document below where EPA is highlighting issues that merit solicitation of additional feedback (e.g., product phase down and seed blend refuge increase, see section F). During the comment period, EPA will provide public outreach to discuss the proposal and answer questions via webinar with stakeholders.

Following the comment period, analogous to a revised framework for corn rootworm and Bt corn completed in 2016 (US EPA 2016), EPA plans to revise this draft proposal after consideration of the written comments submitted to the docket and additional discussion with the affected biotechnology companies to produce a final new framework for Lepidopteran pests of Bt traits. The final framework and agreements will be incorporated into new terms of registration for Bt corn and cotton products (i.e., those expressing Lepidopteran traits).

EPA's draft framework and recommendations are summarized below in a stepwise fashion from resistance definition, confirmation, mitigation, and annual reporting requirements. Each section includes an introduction, the key changes in the IRM framework as bullet points, and the background on the decision-making process.

Resistance Definition for Non-High Dose Pests

The first step to mitigating resistance in Bt corn and cotton is to develop a proactive resistance

definition. The primary goal of resistance monitoring is to detect shifts Bt susceptibility before the onset of widespread resistance and Bt crop failure. However, due to challenges with EPA's current regulatory definition of resistance for non-high dose pests the Agency has failed to detect early warnings of resistance in a timely way for proactive mitigation (US EPA 2018). EPA's current regulatory definition of pest resistance relies on a demonstrated heritability of the resistant trait, higher survival of resistant individuals compared to susceptible individuals on Bt crops, and visible economic damage caused to Bt crops in the field (US EPA 2010). Below EPA proposes a new resistance definition for non-high dose pests (e.g., *H. zea, S. frugiperda, S. albicosta,* etc.) modified from the SAP (2018) and based on stakeholder comments (see ABSTC 2019a; Dively et al. 2019). This definition acknowledges that all currently registered Bt crops targeting non-high dose pests are at risk of resistance and that putative resistance cases will most effectively be mitigated through investigations of unexpected injury (UXI) in Bt fields:

- **'Heightened risk of resistance'**, the presumed baseline resistance category for all non-high dose pests of Bt crops. The following actions are implemented by ABSTC at commercialization: sentinel plots for resistance monitoring in high risk areas, traits commercialized with voluntary best management practices (BMPs) for resistance management (see ABSTC 2019b; Table 1 below), mandatory on-farm visits to assure refuge compliance in Bt cotton-growing regions[1]
- **'Practical resistance'**, occurs when UXI is identified. This will trigger investigation to confirm the level of field damage. Following confirmation of the UXI threshold, the following mitigation steps will be triggered: BMP recommendations (see ABSTC 2019b; Table 1 below) and an enhanced communications strategy

Under this new proposed resistance definition, resistance mitigation will begin when UXI is reported at economic injury levels, thus initiating a BMP process and communications plan. A proactive and effective response to UXI may lessen the impact of resistance in the non-high dose pest population if immediately implemented rather than waiting for confirmation of resistance via bioassays.

The proposed definition above differs from the SAP (2018) recommendation. The SAP proposed a three-level resistance definition centered on damage thresholds and confirmed by F2 screens. After the SAP report, ABSTC (2019a) commented that F2 screens have been historically unreliable and proposed the use of sentinel plots and damage-based thresholds. EPA agrees that F2 screens may impede expedient resistance detection (US EPA 2018) and response to UXI reports are more efficient way to monitor for resistance. The details of a proposed sentinel plot program will be described in the subsequent section. Note, EPA will accept reports of practical resistance from industry submission or peer reviewed academic reports.

Resistance Monitoring and Investigation of Reports of Unexpected Damage

[1] Cotton-growing areas include the following states: Alabama, Arkansas, Georgia, Florida, Louisiana, North Carolina, Mississippi, South Carolina, Oklahoma (only the counties of Beckham, Caddo, Comanche, Custer, Greer, Harmon, Jackson, Kay, Kiowa, Tillman, Washita), Tennessee (only the counties of Carroll, Chester, Crockett, Dyer, Fayette, Franklin, Gibson, Hardeman, Hardin, Haywood, Lake, Lauderdale, Lincoln, Madison, Obion, Rutherford, Shelby, and Tipton), Texas (except the counties of Carson, Dallam, Hansford, Hartley, Hutchinson, Lipscomb, Moore, Ochiltree, Roberts, and Sherman), Virginia (only the counties of Dinwiddie, Franklin City, Greensville, Isle of Wight, Northampton, Southampton, Suffolk City, Surrey, Sussex) and Missouri (only the counties of Dunklin, New Madrid, Pemiscot, Scott, Stoddard)

Monitoring: Sentinel Plots and Investigation of Reports of UXI

The proposed changes to resistance monitoring will have a two-pronged approach using sentinel plots and/or grower-reported UXI. Growers will continue to report UXI in their fields for investigation, but EPA proposes an additional sentinel plot program for resistance monitoring. Companies will submit an annual report detailing activities related to investigations of UXI fields and sentinel plot management to EPA (see annual reporting section).

- To monitor for resistance, EPA proposes to implement corn sentinel plots throughout the cotton belt for non-high dose pests as well as in the Great Lakes Region/Nebraska for *S. albicosta*. Sentinel plots will be scouted regularly for UXI and if injury is above the threshold level set below, the pest will be classified in the practical resistance category and subsequent mitigation will be triggered. Sentinel plots may be managed by industry or academic partnerships. EPA will accept industry data submissions or reports from peer-reviewed literature. ABSTC (2019a) has volunteered to support a sentinel plot program. EPA will work with ABSTC to determine the specific number of plots, locations, and details of the sentinel plot program at a later date.
- EPA proposes BMPs for sentinel plot management to ensure fields are effectively monitoring at-risk of resistance toxins and highly attractive to pests: 1) sweet corn sentinel plots will be established with hybrids producing Cry2Ab and Vip3A toxins alongside non-Bt isogenic hybrids, established at the same locations annually, 2) damage and survival evaluation occurs at the milk stage for *H. zea,* and 3) sentinel plots will be planted later in the growing season. These BMPs are supported by Dively et al (2019).
- UXI thresholds triggering practical resistance mitigation are the same whether the report originates from a grower field or a sentinel plot report.
- Bt cotton: The below UXI thresholds will trigger a "practical resistance" definition for *H. zea* in Bt cotton and subsequent mitigation actions. Cotton fields will be sampled from 100 bolls/fruits/squares for specific injury levels and presence of second instar larvae.
    - Vip3A cotton: 6% injury
    - Cry2 cotton: 12% injury
- Bt corn: The below UXI thresholds will trigger a "practical resistance" definition for *H. zea* and *S. albicosta* in Bt corn and subsequent mitigation actions.
    - Vip3A corn for *H. zea* and *S. albicosta*: a 30-ear sample, 10% of ears have second instar larvae or an exit hole and 60 damaged kernels (2 kernels/ear) or more than 75 cm^2 injury (~2.5 cm^2/ear) with second instar larvae present or exit holes.
    - Cry2 corn for *H. zea*: a 30-ear sample, 50% of ears have second instar larvae or an exit hole and 600 damaged kernels (20 kernels/ear) or more than 240 cm^2 injury (~8 cm^2/ear) with second instar larvae present or exit holes.
- Sentinel plots may also confer benefits for resistance monitoring in high dose pests, the following UXI thresholds are proposed for *Ostrinia nubilalis* and *Diatraea grandiosella*.
    - In a 30-plant sample from the affected area of field, more than 2 places with more than 2 inches of tunneling (stalk, ears, ear shanks).
    - Note, other resistance requirements for high dose pests remain unchanged (see US EPA 2010).
- Thresholds for UXI in Bt fields are independent of the condition of the refuge or claims of unusually high pest populations.

The above proposal deviates from the SAP (2018) recommendations. Due to financial and logistical constraints associated with sentinel plot deployment, the SAP (2018) did not fully consider sentinel plots for resistance monitoring. However, following the SAP, ABSTC (2019a) committed to establish and implement sentinel plots for resistance monitoring. Additional stakeholders, Dively et al. (2019) and NAICC (2019), are in concurrence that sentinel plots are an effective means to monitor for resistance cases.

The proposed UXI thresholds above are modified from the SAP (2018) conclusions. The SAP (2018) stated that UXI for Bt cotton should be reported when third instar larvae are present, and a sample of fruiting forms are damaged at 9-12% for Vip3A or 12-18% for Cry2. The SAP (2018) did not propose UXI levels for Bt corn. ABSTC (2019b) proposed the upper limits of the range of UXI levels discussed by the SAP for Bt cotton as well as novel Bt corn UXI thresholds to pair with the corn sentinel plot program. However, both the SAP and ABSTC proposed UXI levels above the economic threshold level for insecticide sprays. Both Dively et al. (2019) and NAICC (2019) agreed that UXI thresholds should be at or below the economic threshold level. Thus, the EPA proposed the above UXI threshold levels which are at the lower range of the thresholds suggested by the SAP for Cry2 toxins, at the economic injury level for Vip3A, and presence of second instar larvae as the trigger for both toxins. EPA is highlighting the need for additional feedback on the proposed UXI levels in both corn and cotton from stakeholder groups.

For *H. zea*, the SAP (2018) proposed damage-based thresholds for Cry2 and Vip3A resistance monitoring. The thresholds vary between these two toxins because resistance has been detected for Cry2 but not Vip3A, therefore, the Cry2 thresholds for UXI are higher than the economic injury level. Additionally, no UXI thresholds were proposed for Cry1 toxins for *H. zea* because resistance is widespread. A phase down of Cry1 products will be discussed instead in a subsequent section.

Given the resistance cases documented for *S. albicosta* (Smith et al. 2017) and stakeholder concerns, EPA has also proposed sentinel plot resistance monitoring for this pest. The SAP (2018) stated that BMPs should be in place for *S. albicosta* but no additional burden should be placed on growers to add complexity to their resistance management paradigm. ABSTC (2019a) and DiFonzo et al. (2019) are in concurrence that monitoring strategies for *S. albicosta* should be in place.

EPA is seeking comment for this draft proposal specifically regarding whether the above UXI thresholds should apply to *S. frugiperda* as well. Currently, *S. frugiperda* is a labelled pest of Bt corn and cotton but resistance monitoring is only triggered in counties in which Cry1Ab sweet corn acreage exceeds 5,000 acres and the pest is capable of overwintering. EPA is considering applying the above UXI thresholds denoted for *H. zea* to *S. frugiperda* also and removing the sweet corn minimum acreage requirement. EPA is seeking comment regarding the use of the above UXI thresholds for *S. frugiperda*.

Investigation of Populations of Concern: Bioassays for Non-High Dose Pest (i.e., S. frugiperda and H. zea)

EPA's previous resistance definition required bioassay confirmation and EPA has historically had received bioassay submissions for *H. zea* and *S. frugiperda*. However, bioassays did not reliably

demonstrate resistance for non-high dose pests. Under EPA's proposed resistance definition above, sentinel plots will be used for resistance monitoring and UXI will be the trigger for mitigating practical resistance in Bt pests. If registrants wish to refute the determination of practical resistance, individual companies will have the option to use F2 screens to demonstrate low resistance allele frequency and thus discontinue resistance mitigation efforts. Additionally, EPA will accept reports published in peer-reviewed literature regarding changes in Bt susceptibility in target pests if they meet the below specifications and use Bt proteins closely related to those expressed in PIPs.

In contrast to EPA's proposal herein, the SAP (2018) recommended that F2 screens be used to monitor for arising resistance cases instead of UXI alone. Under the SAP (2018) recommendations, practical resistance for non-high dose pests would be defined as UXI occurrence, F2 screens indicating heritable resistance, and a greater than 2% allele frequency. The SAP (2018) supported ongoing resistance monitoring and random insect sampling for F2 screening purposes.

Following the SAP, ABSTC (2019a) commented that F2 screens are difficult for non-high dose pests and volunteered to implement a sentinel plot program. EPA proposes to adopt a sentinel plot program and agrees F2 screens may not be timely for annual monitoring for resistance mitigation purposes. However, EPA disagrees that F2 screens are impractical for non-high dose pests. Such screens have been effectively applied for resistance monitoring in *Helicoverpa* spp. in Australia (SAP 2018). EPA proposes below that F2 screens will be an optional route for registrants seeking to refute resistance based on UXI.

Below EPA defines parameters for F2 screen methodology. If bioassay results cannot be obtained for any reason, the population will be presumed resistant to all toxins in the Bt pyramid in subsequent growing seasons and the mitigation action plan will be maintained. EPA will accept F2 screen submissions for *H. zea* and *S. frugiperda* but currently bioassays for *S. albicosta* are not feasible due to lack of a laboratory strain, diet, and other variables.

- Insect collections should be made from UXI fields and surrounding fields, each population collection shall attempt to target 400 insect genomes, but a successful population collection will contain a minimum of 100 genomes. This is the current standard for Lepidopteran insect sampling under the existing terms of registration (US EPA 2010).
- The F2 screen is conducted by sampling mated females from natural populations; rearing the progeny of each female as an isofemale line and sib-mating the Fl offspring; rearing eggs from the F1 parents and testing the F2 larvae using an appropriate bioassay screening procedure (see Andow and Alstad 1998).
- Industry will develop standardized F2 screen techniques based on the protocol described in Andow and Alstad 1998. The protocol will include the following criteria: establish common, publicly accessible resistant and universal susceptible insect strains (e.g., Benzon strain for *H. zea*), collect insects from Bt fields or surrounding fields where UXI is under investigation, use a standardized/commercially available diet in bioassays (e.g., Southland diet for *H. zea*), implement diet overlay assays as a standard operating procedure over diet incorporation, standardized environmental conditions, standardize assay duration (see Jurat-Fuentes et al. 2019), and statistical method for estimating the resistance allele frequency. The Agency will review and approve the protocol prior to any testing.
- If the estimated resistance allele frequency from the F2 screen is than less than 2% than the

pest population will no longer be considered at practical resistance and the mitigation actions will be withdrawn. Otherwise, the F2 screen will support the trigger of practical resistance and confirm the observed resistance is heritable.

- If an insect population and subsequent F2 screen cannot be conducted following a UXI determination, the population will be assumed to be resistant and appropriate mitigation must be implemented/maintained. F2 screen results will not be accepted for subsequent years to refute resistance claims in the area where UXI occurred due to the capacity of the pests for high dispersal.
- Companies must inform the Agency of F2 screen results (see annual reporting section)
- EPA will consider other bioassay or resistance screening protocols but they must have prior approval by the Agency before implementation.
- The bioassay protocols for high dose pests and triggers for mitigation (US EPA 2010) remain unchanged.

As noted above, mitigation will be triggered at the UXI stage and practical resistance will be assumed without the confirmation of resistance through diet bioassays. Historically, it has been difficult to collect enough insects for a bioassay and subsequent assays have been difficult for the Agency to interpret and thus delayed the onset of mitigation (US EPA 2018). EPA understands the academic value of regular resistance monitoring and bioassays but from a regulatory perspective such testing has delayed and diluted the ability of the Agency to react proactively to resistance reports.

While diet bioassays are the current standard for resistance confirmation, EPA encourages on-plant bioassay methodologies for use in F2 screening for Bt pests. Additionally, EPA strongly encourages industry to provide standard toxin stocks and traited seed available to private sector researchers for independent confirmation of resistance bioassays.

Enhanced Mitigation Strategies

An important goal of EPA's proposal is that affected stakeholders be made aware of the detection of UXI and that measures are put in place to reduce the likelihood of a practically resistant population from spreading. Therefore, for any resistant population, EPA is proposing companies take the following steps: implementation of BMPs in response to UXI (see Table 1), and an enhanced communications plan.

The implementation of all BMPs and the communications plan discussed below will be implemented regionally at UXI confirmation. Regions are defined as the county in which UXI occurred and the surrounding counties. The SAP (2018) was unable to define mitigation action areas for pests like *H. zea* which is highly mobile and capable of overwintering in broad areas. The SAP (2018) stated that the region should on a broad geographic scale. The Agency is seeking comment on the scale of the mitigation action area for the below BMPs.

BMPs for New Resistance Cases

Following the documentation of UXI for emerging resistance cases, the Agency proposes the below BMPs to delay the spread of resistance. Under the proposal, the below BMPs would be instated by

modifying the current terms of registration and will be communicated to growers by registrants as a part of their grower guides or other grower IPM educational materials (see communications section for description of outreach proposal):

Table 1. BMPs for *H. zea, S. frugiperda,* and *S. albicosta*[1] in Bt corn and cotton PIP products

Timing of BMP	**BMP in Cotton and Corn**
Current growing season	Review with the grower their Lepidopteran pest management practices and provide IPM recommendations, including an assessment of fields adjacent to the affected field with similar trait(s) Inform regional extension/local crop consultants of UXI in the county where damage occurred and the surrounding counties. The registrant will initiate a communications campaign targeting growers, consultants, extension agents, seed distributors, university cooperators and state/federal authorities (see communications section). Where in-season management tactics are possible, the recommended management options include, but are not limited to the following: 1. Apply an appropriate foliar chemical insecticide (only if economically viable in corn) 2. If additional pest management is needed, additional control tactics as appropriate (e.g., additional foliar insecticide applications, tillage practices, etc.)
Next growing seasons in perpetuity or until bioassays demonstrate susceptibility	Review with the grower their Lepidopteran pest management practices and provide IPM recommendations, including an assessment of fields adjacent to the affected field with similar trait(s) Review refuge compliance obligations with the grower (applies to Bt corn only) Inform regional extension/local crop consultants of UXI in the county where damage occurred and the surrounding counties. The registrant will initiate a communications campaign targeting growers, consultants, extension agents, seed distributors, university cooperators and state/federal authorities (see communications section). Recommended management options include, but are not limited to: 1. Switching to a different Bt mode of action or planting non-Bt 2. Encourage timely planting to avoid primary risk window for target pests 3. Encourage growers to monitor for adults and intensify field scouting for injury 4. Use of an appropriately timed foliar insecticide application based on field scouting for insect injury 5. If additional pest management is needed, additional control tactics as appropriate (e.g., additional foliar insecticide applications, tillage practices, etc.)

[1]The recommendations for *S. albicosta* are intended for corn alone, and not cotton
The above table is modified and reproduced from ABSTC 2019b
These BMPs are also recommended following resistance confirmation in ECB/SWCB in Bt corn with the addition of post-harvest stalk destruction (ABSTC 2019b)
EPA modified numerical one of the "next growing season…" section which was not present in ABSTC 2019b

The above table of BMPs was informed by ABSTC (2019b). The Agency added an additional recommendation that growers are encouraged to switch Bt trait packages in the following year. Also, the Agency has proposed to apply the above BMPs to UXI confirmation in *S. albicosta* if UXI thresholds for these pests are reached. EPA is seeking feedback during the draft IRM framework comment period for any additional BMPs to effectively delay the spread of resistance following identification through UXI. EPA is also seeking feedback whether the BMPs described above should be regionally applied to *S. frugiperda* as well.

Communication

Since all registered Bt PIPs for non-high dose target pests represent a 'heightened resistance risk,' IPM practices implemented with the IRM strategy will be crucial to preserve the longevity of Bt traits. However, overall IPM options for non-high dose pests are limited. Thus, a communications plan must be implemented at commercialization of non-high dose traits. Additionally, communication following UXI determination will be required (see Table 1).

- EPA supports ABSTC's (2019a, see Take Action campaign) outreach plan for IRM that includes widespread messaging to encourage increased stewardship of agricultural technologies through national and targeted news releases, paid media (print and digital), social media (Facebook and Twitter), technical resources and a dedicated website.
- EPA has modified ABSTC's (2019b) proposed BMP outline (see Table 1, with modifications discussed in the table footnotes). These BMPs will be conveyed at the point of sale through grower guides, published online, and provided to growers via written communication annually separately from the grower technical guide that is distributed by the registrant. EPA is actively seeking comment regarding the BMPs in the table above.
- In response to UXI, the affected registrant will establish a regional communication platform to alert growers, consultants, extension agents, seed distributors, and state/federal authorities about where resistance was identified, the affected trait, implemented actions, and multi-year management plans. The region will encompass that county where UXI occurred and the surrounding counties.
- The EPA will coordinate regular teleconferences with stakeholders (e.g., growers, crop consultants, academic entomologists, commodity organizations, industry) to facilitate information sharing amongst stakeholders regarding arising resistance concerns.

One of the key messages from the SAP (2018) meeting was the difficulty of establishing early warning of resistance in non-high dose pests, thus a critical piece of the new framework must be increased communications between government, growers, crop consultants, extension personnel, academic researchers, industry partners, and other stakeholders (see also Porter et al. 2019b).

Annual Reporting

Currently, the Agency requires ABSTC as a consortium to make refuge compliance reports and IPM stewardship reports on an annual basis. Also, the Agency mandates individual registrants to report UXI cases and investigations annually. EPA will continue requiring the submission of the previously described reports and is proposing for comment components for the IPM stewardship and compliance reports:

- IPM Stewardship Program: Activities conducted under the IPM stewardship program, include an anonymous survey of grower practices and adoption level of BMPs submitted before January 31 annually. This report will now also include a survey of incidence of insecticidal oversprays for primary pests in Bt fields from agricultural market research data. This information will overlay specific Bt proteins with incidence of overspray specifically targeted at *H. zea*. Any grower reported oversprays for *H. zea* will also be discussed in the annual report.
- Refuge Compliance Reporting: Compliance assurance program activities, survey results for the previous year, and plans for the current year are required before January 31 annually. This report is proposed to also include documentation of adequate seed production of refuge for block refuge products and reports on mandatory on farm visits.
- UXI Investigations: Activities related to investigations of UXI, including number and location of cases, insect sampling, bioassays, and final state of UXI fields (i.e., mitigation measures taken) from the most recent and prior growing seasons must be submitted before January 31 annually. The report must also discuss a communications strategy and remedial action. UXI reports must be submitted by county and state, but must exclude sensitive business and customer information.

For the IPM Stewardship report, EPA proposes the addition of reports on incidences of insecticide sprays in Bt fields specifically targeted at Bt pests as an early warning indicator of UXI. Where growers may not have reported UXI for specific Bt pests, information on such oversprays from agricultural market research data may serve as an early warning indicator of practical resistance to Bt toxins. EPA will communicate the general findings of such reports to stakeholders in regular teleconferences to facilitate information sharing regarding resistance management (see communications section). The details describing the decision-making process for inclusion of reports on refuge seed production and mandatory on farm visits are described above (see mitigation section).

F. Discussion of options for which EPA is seeking additional stakeholder input

As part of this proposal, EPA is seeking comment from stakeholders on the additional risk mitigation options described below. However, EPA will not take a position on these options until it has reviewed all stakeholder input. These include a product phase down, increased percent refuge in RIB products, and strengthened refuge compliance measures.

Phase Down of Single Traits and Non-Functional Pyramids

The SAP (2018) reached consensus that the following insects are resistant to the following toxins: *H. zea* for Cry1 and Cry2 toxins, *S. frugiperda* for Cry1F, and *S. albicosta* for Cry1F. Given the documented resistance cases for these toxins and the heightened risk of resistance of non-host pests to these traits, EPA is seeking additional feedback on the possible option of a short-term phase down

of single trait Bt corn plants. Additionally, the Agency would like comment on the option of a long-term phase down of non-functional pyramids (i.e., compromised Bt pyramids where less than 95% control is provided by one or more of the toxins expressed therein, as defined in Roush 1998) to a limited acreage cap (e.g., a maximum number of acres planted per year).

- Short-term phase down (e.g., approximately 3-year timeframe) of single toxin corn products from the market to a minimal acreage cap.

Table 2. Single Trait Corn Products for Short Term Phase Down

Single Trait Corn Products	**Registration Number**
Cry1F	29964-3, 29964-5, 29964-6, 29964-13, 29964-17; 68467-2, 68467-6
Cry1Ab	524-489, 29964-15, 29964-18; 65268-1, 67979-1, 67979-8

- A longer-term (e.g., approximately 5-year time frame) phase down to minimal acreage in cotton and corn products that only contain non-functional traits in pyramids.

Table 3. Non-Functional Pyramid Registrations for Long-Term Phase Down

Non-functional pyramid	**Registration Numbers**
Cry1F + Cry1Ab	29964-7, 29964-8, 29964-11, 29964-12, 29964-14, 29964-16, 29964-21, 29964-22, 29964-23, 29964-24, 67979-17, 67979-20, 67979-24, 67979-25, 67979-31, 67979-33; 68467-3
Cry1Ac + Cry2Ab	524-522
Cry1A.105 + Cry2Ab2	524-575, 524-576, 524-597, 524-606
Cry1A.105 + Cry2Ab2 + Cry1F	524-581, 524-585, 524-595, 524-612, 524-631, 524-632; 68467-7, 68467-12, 68467-16, 68467-21, 62719-706, 62719-707
Cry1Ab + Cry2Ae	264-1096

- Below, EPA has also listed the toxin combination registrations that would be unaffected by any phase down option.

Table 4. Pyramid products with no phase down option

Non-functional pyramid	**Registration Numbers**
Vip3A + Cry1Ab + Cry1F	29964-19, 29964-26, 67979-15, 67979-19, 67979-23, 67979-26, 68467-19
Cry1A.105 + Cry2Ab2 + Vip3A	524-625, 524-626
Vip3A + Cry1Ab	67979-12, 67979-13
Cry1A.105 + Cry2Ab2 + Vip3A + Cry1Ab	67979-32, 67979-34, 67979-35, 67979-37, 62719-704, 62719-716
Vip3A + Cry1Ac + Cry2Ab2	524-613
Vip3A + Cry2Ae + Cry1Ab	264-1179

A phase down was not specifically discussed by the SAP (2018) but was listed as an optional mitigation by the EPA white paper (2018). ABSTC (2019a) has submitted information to EPA

indicating there is low acreage of single trait crops targeting Lepidopteran pests currently planted nationwide. However, EPA noted an overlap of plantings of single trait corn varieties (ABSTC 2019a) in the areas where the first resistant *H. zea* populations were documented.

EPA is seeking additional stakeholder comment regarding lowering acreage of single trait corn products and non-functional Bt pyramid registrations which threaten resistance management for *H. zea* as well as other primary pests. Single trait products contain the same or highly similar toxins as Bt pyramid products thereby providing a "stepping stone" to resistance (US EPA 2018). In 2016, EPA and ABSTC worked collaboratively to phase down single trait Bt products as part of a similar effort to update the corn rootworm resistance management framework. Registrants also previously voluntarily phased out single trait Bt cotton to support the use of natural refuge in Southeastern cotton-producing states (Matten et al. 2013).

Increasing Percent Refuge in Seed Blend Products

EPA has identified concerns for resistance management arising from seed blends which increase the risk of cross-pollination creating a mosaic of toxin expression in kernels juxtaposed with the lack of compliance with block refuge requirements in the south (US EPA 2018). Along these lines, the SAP (2018) recommended a prohibition of Refuge-in-the-Bag (RIB) products in southern corn-growing regions. In light of these concerns, EPA is seeking additional stakeholder feedback on the following option:

- Increased refuge in all pyramided RIB products to 10% nationwide and maintain current requirements to plant a separate 20% block refuge in cotton producing states.

The SAP (2018) proposed a prohibition for Vip3A seed blends in the cotton belt and an increase to at least a seed blend of 10% RIB in the Corn Belt. ABSTC (2019a) proposed an increase to 20% refuge in RIB products containing Vip3A and removal of the block refuge requirement. However, Syngenta LLC (2019), the developer of the Vip3A trait in corn and cotton, supports an increase for all Bt RIB products to 20% and not just Vip3A. On the other hand, NAICC (2019) commented that an increase in the percent seed blend beyond 10% will impede scouting efforts and effective UXI monitoring. Porter et al. (2019) stated that the best near-term approach to IRM for non-high dose pests in cotton-growing areas is to continue requiring a structured refuge for Vip3A and taking steps to improve refuge compliance. EPA has determined that while RIB products are not ideal IRM best practices, they provide an improvement over block refuge products in terms of compliance. An increase to 10% refuge in seed blends nationwide could be an option to protect the durability of effective traits for non-high dose pests including *H. zea* while allowing for effective scouting for resistance monitoring.

EPA is aware that increasing refuge percentage in seed blends for Lepidopteran Bt products will affect more than non-high dose Lepidoptera alone and will affect products with combined control for corn rootworm (*Diabrotica spp.*). EPA does not anticipate that an increase to 10% refuge in seed blends will negatively affect IRM for other Bt pests nationwide. For *Diabrotica virgifera virgifera* and *O. nubilalis*, blended refuge provides similar, if not longer, delays in the evolution of resistance compared to separate block refuges (Onstad et al. 2018).

Given the mixed stakeholder feedback regarding an increase in percent refuge in seed blends, EPA is seeking additional public comment.

Refuge Compliance

Numerous legal obstacles limit EPA's capacity to incentivize growers for refuge compliance. EPA has no authority under FIFRA to tax or reward growers, contrary to requests for such action by stakeholder groups (SAP 2018; Carrière et al. 2019). EPA's sole focus is on the registrant's obligations under the terms and conditions of the registration. Within these limitations, EPA has identified the following options for stakeholder comment during the public process:

- Sales of Bt corn products requiring block refuges must be followed up with on-farm visit by the seed industry for compliance monitoring by ABSTC during the growing season. This will be conveyed to growers at the point of sale and be included in the grower agreement. Visits will be reported to the Agency (see annual reporting section).
- For farmers out of compliance with block refuge standards in the cotton belt for one year, the registrant will withhold all the company's Bt corn products, including RIB and block refuge, for two years.
- Registrants must ensure that seed dealers obtain signed grower agreements that set forth the terms of the IRM program. If a seed dealer fails to ensure that at least 95% of customers sign grower agreements, registrants will restrict the availability of Bt seed to that dealer. Registrants must ensure that seed dealers keep a record of signed grower agreements for a period of at least three years from sale.
- Industry must ensure availability of non-Bt elite corn hybrids for refuge (see annual reporting section).

Several stakeholder groups suggested or explored various means to increase refuge compliance. ABSTC (pers. comm.) has claimed that refuge seed cannot be bundled with the purchase of Bt technology due to anti-trust laws and would require special exemption from the Department of Justice. ABSTC (2019a) has met with USDA's Risk Management Agency and determined discounts for planting of refuge in federal crop insurance programs are not possible since the risk of resistance is long-term. In the private sector, crop insurance discounts for growers in compliance with the refuge paradigm are not offered. Porter et al. (2019) proposed an increase in on farm visits to assess refuge compliance as a possible strategy. Both Porter et al. (2019) and NAICC (2019) expressed that in some cases there is a lack of desirable non-Bt germplasm available for growers opting to plant non-Bt corn or for block technology refuge plantings (see Reisig and Kurtz 2019). Thus, the EPA is seeking public input the following mitigation options: an increase in mandatory on-farm visits (conducted by registrants) to assess refuge compliance as well as an annual reporting for refuge production.

Also, the EPA is seeking comment on the possibility of increasing restrictions for growers that are out of compliance with block refuge requirements in the cotton belt. Historically, EPA has adopted a phased compliance approach, where if an individual grower is found to be significantly out of compliance for two years in a row, that grower would be denied access to an individual registrant's Bt products the following year (US EPA 2010). However, this approach has not resulted in increased refuge compliance in the cotton belt (US EPA 2018). Full compliance has been between 7-46%,

while zero compliance (no refuge planted) ranged between 11-44% from 2011-2016. Thus, EPA is seeking comment on a "full compliance" measure, where if growers do not comply with refuge requirements for one year, then that grower will lose access to Bt technology from the individual registrant for two years.

EPA has received anecdotal reports over the years that seed dealers may not emphasize the importance of compliance with the IRM program due in part because they are not incentivized to sell block refuge seed due to the lower cost and correspondingly lower commission rate. EPA has mandated industry keep records of the required signed grower agreements for IRM. However, EPA is now seeking comment on the mitigation option whereby industry would maintain a record of these signatures for a period of at least three years. If the sign rate or record keeping were amiss, seed dealers may be audited by registrants at any time and without such records will lose the opportunity to sell Bt seed. This process would be entirely enforced by Bt product registrants.

EPA did not propose similar changes to refuge compliance enforcement with the prior revised framework to address resistance to Bt PIPs in corn rootworm (US EPA 2016). Corn rootworm biology is more amenable to a seed blend refuge dynamic than Lepidopteran pests. Since Lepidopteran pests are more at risk of resistance in seed blends, the block refuge has added importance to preserve durability. Therefore, EPA is seeking comment on these measures to improve block refuge compliance especially in areas where compliance has been low (i.e., the Southeastern US). There is general stakeholder consensus that refuge compliance needs improvement from key stakeholders including crop consultants and extension entomologists.

G. NEXT STEPS

A Federal Register Notice of Availability will be published to announce the opening of the public comment period for the draft proposal, which will be posted to a public docket (EPA-HQ-OPP-2019-0682). The comment period will be open for 60 days. The Agency is seeking information from stakeholders such as corn and cotton growers, crop consultants, academic experts, non-governmental organizations, the Bt PIP industry and the general public. During the comment period, EPA will provide public outreach to discuss the proposal and answer questions via webinar with stakeholders. Regarding the product phase down plan, seed blend refuge increase, and refuge compliance measures, EPA is highlighting a specific need for stakeholder comment. After the comment period, EPA will consider all comments received and negotiate a finalized framework with the Lepidopteran Bt corn and Bt cotton PIP registrants (also working with ABSTC), to be implemented as revised terms of registration for all affected PIP products. Then, EPA will release the finalized IRM framework to the public docket.

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