

EVALUATION OF COMPLIANCE TO THE EPA REFUGE REQUIREMENTS FOR BT CROPS WITH A FLEXIBLE, AUTOMATED PROGRAM

Christa Ellers-Kirk, Kamlesh Kumar, and Yves Carrière
The University of Arizona, Department of Entomology, Tucson, AZ 85721

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Introduction

The refuge strategy is central in delaying the evolution of insect resistance to *Bacillus thuringiensis* (Bt) crops (Carrière et al. 2005). Because the ecology, life history and genetics of resistance to Bt differ considerably among pests, different refuge strategies are implemented for different pests. We have developed a flexible program that allows rapid and easy assessment of compliance to any refuge strategy mandated by the US Environmental Protection Agency (EPA). The program uses as input a Geographical Information System (GIS) map of transgenic and non-transgenic crop fields and basic information on refuge strategies to determine regional compliance. Carrière et al. (2005) have demonstrated that this program can be used to precisely monitor compliance as determined by the EPA. In this paper, we provide guidelines to run the program (available upon request from YC at ycarrier@ag.arizona.edu).

Installing the Compliance 1.2 Extension for ArcView

Compliance1.2 was written for use within the GIS software ArcView (ESRI 1998). The program, Compliance1.2.avx, will need to be placed in the EXT32 folder. If ArcView was allowed to self-install, EXT32 is found at C:\ESRI\AV_GIS30\ARCVIEW\EXT32.

Data Collection and Input

The objective of data collection is to create a shapefile and an attribute table for all Bt crop fields and all non-Bt crop fields respectively, within the area to be examined. To do this, choose a coordinate system where meter is used as a unit of measure. Once the shapefiles have been created for the Bt and non-Bt crop fields, their attribute tables will be populated with the following information: the crop field identifier (string), area of that field (decimal), and section identifier (decimal). The crop field identifier is user-defined and unique. This number must not appear more than once within either data set. The area of the crop field can be user-defined, or generated within ArcView by creating a new field, and then using

the calculate function: new field = [shape].returnarea. The area is expressed in square meters. The section identifier is used to identify proportion compliance within a user-defined area (e.g., counties, research sites). The section identifier is a necessary component, although it can characterize a single section if multiple sections are not required.

Manipulations and use of Compliance 1.2 within ArcView

In the File menu, choose *Extensions* and select *Compliance1.2*, *Geoprocessing*, and *Spatial Analyst*. Once this is completed, open a new view (see flowchart, Fig 1.). Under the View menu, choose *Properties* and set *Map Units* and *Distance Units* to meters. Add the Bt.shp (shapefile containing all Bt crop fields) and nonBt.shp (shapefile containing all non-Bt crop fields) themes to the view. Next, buffer the crop fields in Bt.shp. The extension *BufferWithAttribute* written by Thad Tilton can be found at the ESRI website (www.esri.com): it needs to be downloaded and installed before continuing. This extension will allow for the user-defined crop field identifier to be maintained in the buffer attribute table. In the Theme menu, choose *Create Buffers*. Buffer the features of the theme Bt.shp, in meters, using the maximum distance allowed between a Bt crop field and a refuge, as mandated by the EPA guidelines. For example, for Bt cotton used against the pink bollworm, such maximum distance is currently 0.5 miles (805m) for an unsprayed refuge at least 5% of the area of a Bt cotton field, or 1 mile (1600m) for a sprayed refuge at least 20% of the area of a Bt cotton field. Do not dissolve between buffers, buffer inside and outside the polygons, and save this as a new theme. When the next window appears, select the user-defined crop field identifier as the attribute to add to the table. If this window does not appear, reload the *BufferWithAttribute* extension and then create the buffers again.

In the View menu, choose *GeoProcessing Wizard*. Select *Intersect two themes*. The newly created buffer theme will be the input theme to intersect and nonBt.shp will be the

overlay theme. Specify the output theme and select *Finish*. Once this is completed, open the attribute tables for Bt.shp and the newly created intersect theme. Select *Compliance* from the Analysis menu. Choose the option that represents the Bt.shp theme, and then the option that represents the intersect.shp theme. Next, select the option that represents the user-defined crop field identifier, and then the option that represents the area of the crop fields. Name the table that will be created. The default name is Compliance. Enter the number of sections to be evaluated (this can be one) and then select the option that represents section in the attribute table.

The next series of prompts begins with the question, *Do you want a range of values?*. Depending on the response, the program will output one of three tables using the user-specified buffer distance. If yes is selected, the table created presents a set of ranges for the proportional acreage of refuges found within the buffer distance, and then assigns the number and proportion of Bt crop fields that fall into each range for each section (Fig 2a). If no is selected, the user needs to define the threshold value (i. e., proportional area of each Bt crop field that must be planted to a refuge) that will distinguish between compliant and noncompliant Bt crop fields, and then supply a name for the table that

will contain the identifier for noncompliant Bt crop fields. This will result in two tables. The first table presents the number and proportion of fields that are compliant or non-compliant to the considered option of the refuge strategy (Fig 2b). The final table outputs an identifier for each field that does not comply with the strategy considered (Fig 2c). The program will execute and the new table(s) will appear in the ArcView project window. The generated files will be in .dbf format and will automatically store in the same folder as the other newly created files. They can easily be opened and saved in spreadsheet format.

References Cited

- Carrière, Y., C. Ellers-Kirk, K. Kumar, S. Heuberger, M. Withlow, L. Antilla, T. J. Dennehy and B. E. Tabashnik. 2005. Long-term evaluation of compliance with refuge requirements for Bt cotton. *Pest Management Science*. 61: 327-330.
- [ESRI] Environmental Systems Research Institute, Inc. 1998. ArcView GIS version 3.3 for Windows. 380 New York Street, Redlands, CA.