EMBEDDED BT-COTTON REFUGES: CONSIDERATIONS AND CONSTRAINTS

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Introduction

Beginning in the 2001-planting year, refuge options for planting Bt-cotton have been changed. The 80/20 option where at least 20% of the total crop must be planted to a non-Bt cotton variety remains in place but with the additional restriction that all Bt-cotton fields are within one mile of the refuge. The 4% unsprayed option has been replaced with two 5% options. Both 5% options have the restriction that they must be at least 150ft wide. One 5% option is an unsprayed option that is similar to the 4% unsprayed option with the exception of a distance requirement that all Bt-cotton fields associated with the refuge must be within one-half mile of the refuge.. The other option is a 5% embedded option. Mullins (2000) describes the 5% embedded option as follows:

"5% embedded Option – a third option has been added for 2001 which is the "embedded" option. Unlike the 5% Unsprayed Option, this option allows the refuge to be treated with any insecticide at the same time as the Bollgard is treated, as long as the refuge is "embedded" in the field or "field unit".

For large fields, 5% of the field would be planted to a nonBollgard variety, the rest with Bollgard. If the Bollgard field needed treatment for bollworms (or any other pest), the entire field, including the refuge, could be sprayed with the same insecticide at the same time (i.e., within the same 24hr period). The refuge could not be treated with any insecticide labeled for lepidopteran control independently of the associated Bollgard field(s). For very large fields (more than one mile long or wide), multiple refuge blocks across the field should be used.

For smaller field situations, fields could be grouped into "field units" so that one of the smaller fields, or a part of one of the fields, would serve as the "embedded" nonBollgard refuge. Likewise, this embedded refuge could be treated with the same insecticide at the same time that all of the associated Bollgard fields were sprayed, but could not be treated with any insecticide labeled for lepidopteran control independently of the associated Bollgard fields. Any Fields contained within a one mile square area (one mile by one mile) can be considered a "field unit".

As required for the 5% untreated option, the embedded refuge within a field or "field unit" must be at least 150 feet wide in all areas where cotton bollworms or tobacco budworms are a potential pest."

Evaluation of Embedded Refuge

In preparation for this manuscript, the embedded option was evaluated at six locations in Northeast Louisiana. These evaluations were slightly different from the 5% option previously mentioned in that the embedded refuge was defined as 10% (90:10) of the field unit and were at least 80 rows (250 ft) wide. Each 90:10 embedded refuge was planted such that no associated Bt-cotton plant was further than on-half mile from the refuge. An associated 96:4 option was also planted near each 90:10 embedded option for comparison. Parishes and acreage's of the 10% embedded option were as follows: Concrodia – 20 acres, Madison – 20 acres, Morehouse – 17 acres, Ouachita – 13 acres, Richland – 21 acres, and Tensas – 50 acres. All locations were compared a 4% untreated refuge planted by the grower for their farm.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:846-847 (2001)
National Cotton Council, Memphis TN

Designing refuge placement required some thought and preparation. At one location where the 90:10 option was applied to 500 acres in eight adjacent fields, refuge sites were first selected on field maps. Visual observation of the site followed to ensure the design logically fit the objective. In the selection criteria for location, priority was placed obtaining the necessary 10% size and on methods to take advantage of any potential localized suppression of tobacco budworm populations. Methods used to take advantage of any localized suppression included isolation of refuges from other refuges and field borders, maintaining refuge sizes as small as possible and maintaining maximum separation of refuges without compromising distance requirements (one-half mile maximum from any one Bt-cotton plant to the nearest non-Bt cotton plant).

Logistics of planting were not that difficult because of the limited number of refuges being placed on a given farm. Planting logistics, however, could become very time consuming as the number of available planters decreases and the distance between fields increases. Changing seed in hopper boxes required less than 20 minutes at each of the locals. Coordination of planters, when multiple planters were used required some close supervision.

The grower selected varieties used for refuge plots. Most selected a non-Bt variety similar to the Bt-cotton that the refuge represented. Roundup Ready varieties were used in fields of stacked gene Bollgard Roundup-Ready. The grower with the 500 acre evaluation selected Fibermax 832 (okra-leaf variety) for ease of determining refuge site. This selection of an okra-leaf worked very well because the refuge plots were easily visible throughout the growing season. Cultural and agronomic management for the refuges were the same as the surrounding Bt-cotton at all locations.

Insect management highlighted the potential problems/confusions associated with an embedded refuge. On 13 July at the Madison parish location, field scouting indicated a bollworm/tobacco budworm infestation of 46% live larvae in terminals in the refuge plot and 2% live larvae in bloom in the associated Bt-cotton. The grower opted to spray the Bt-cotton and refuge plot (~200 acres) with Tracer 4SC at 0.067 lb(AI)/A. Subsequent evaluation 5 days later indicated that larval infestation had declined to 4% live worms in square, 2% live worms in bolls, and 0% live worms in terminals in the refuge field. No live worms were found in the Bt-cotton. Bollworm/tobacco budwom infestations in the refuge did not reach a significant level again after this application.

At the Morehouse parish location, bollworm/tobacco budworm populations reached 6% live worms in terminals with 6% eggs in terminals and 26% worm damaged squares in the refuge plot on 14 Jul. Sampling of the associated Bt-cotton indicated a bollworm/tobacco budworm infestation of 1% live larvae in blooms. After discussion with the grower, the refuge and associated Bt-cotton was treated with Curacron at 0.5 lb(AI)/A. Subsequent evaluation on 19 Jul indicated that larval populations had not declined (10% worms in terminals, 26% worm damaged squares and 8% worm damaged bolls). On 20 Jul, the grower opted to spray the field with Karate at 0.032 lb(AI)/A. Larval infestation and damage levels on 26 Jul were similar to those of the 19 Jul sample. No substantial bollworm/tobacco budworm infestations were observed after this infestation.

At the Ouachita parish location, samples on 25 Jul indicated that the bollworm/tobacco budworm infestation in the 10% embedded refuge area was 6% worms in terminals, 11% worm damaged squares with 4% live worms in squares and 12% worm damaged bolls with 5% live worms in bolls. In the 4% refuge on 25 Jul bollworm/tobacco budworm infestations were 8% worms in terminals, 21% worm damaged squares with 4% live worms in squares, and 14% worm damaged bolls with 4% live worms in bolls. Boll samples for worm damage were taken after cutout on 16 Aug. Boll damage count indicated 20% worm damaged bolls in the embedded refuge and 17.5% worm damaged bolls in the 4% refuge.

No insecticide applications for bollworm/tobacco budworm populations were applied to the Ouachita parish, Richland Parish or Concordia parish locations. A single insecticide application was applied for bollworm/tobacco budworm populations at the Tensas Parish location. Bollworm/tobacco budworm populations in the embedded refuges did not exceed more than 10% infestation during the entire year.

Comparison of the 10% refuge with an associated 4% refuge indicated that some localized suppression could occur. At the Morehouse parish location during the period 14 Jul to 3 Aug, average infestation levels were 2% and 4% live larvae in terminals, 7% and 21% worm damaged squares, 3% and 13% worm damaged bolls in the 90:10 refuge and 96:4 refuge, respectively. The 90:10 refuge did, however, receive two insecticide applications (previously mentioned) that the 96:4 refuge did not.

Comparisons of yields at the different locations indicated that the associated Bt-cotton usually yielded higher than the either the 90:10 or 96:4 refuges, as expected. Lint yields at the Ouachita parish location were 299 lbs/acre for the 10% embedded, 416 lbs/acre for the 90:10 Bt-cotton, 583 lbs/acre for the 4% refuge, and 995 lbs/acre for the 96:4 Bt-cotton. At the Tensas parish location lint yields per acre were 306 lbs/acre for the 10% embedded refuge, 409 lbs/acre for the 90:10 Bt-cotton, 288 lbs/acre for the 4% refuge, and 421 lbs/acre for the 96:4 Bt-cotton.

Considerations for Embedded Refuges

Utilizing an embedded refuge presents several logistical and management difficulties. These difficulties will require more planning on the part of the producer planting an embedded refuge. Considerations for utilizing an embedded refuge can be broken down into location, logistics, variety selection, agronomic management, and insect management.

Location selection for embedded refuge placement is most easily accomplished by planning placement using scale maps followed by on site evaluation of location selection. Considerations for location selection should include: size, will the refuge represent at least 5% of the total area planted; obstructions, are there any obstructions that will impact pheromone movement or insecticide efficacy; isolation to take advantage of any localized suppression that may occur; and assuring that location allow for refuge to be treated similar to the associated Bt-cotton.

There will be a tendency to place refuges on field margins and consolidate refuges to sizes that minimize the number of refuges. The tendency to consolidate refuges into as few units as possible reduces the logistical problem associated with planting multiple varieties in a single field. Large embedded refuges, however, are less likely to take advantage of any localized suppression of bollworm/tobacco budworm populations that may occur because of the surrounding Bt-cotton. Thus, larger embedded refuges may sustain higher yield losses than smaller refuges.

Placement of refuges near field margins should be avoided for both resistance management and insect management purposes. Obstructions (trees, fencerows, other crops, etc.) near field margins will disrupt pheromone movement from the refuge area, thus fewer individuals from the surrounding Bt-cotton will immigrate into the refuge. Obstructions also increase the difficulty of insecticide applicators to apply the appropriate amount of insecticide to the area, thus higher yield losses are likely to occur than if the refuge were planted away from field margins.

Variety selection can be critical but can also be used to help with insect management. Roundup Ready varieties should be used where the refuge is embedded in a field of stacked gene Bt-Roundup Ready. An okra-leaf variety non-Bt variety is highly recommended for an embedded refuge in fields of strictly Bt-cotton. The okra-leaf variety allows for easy identification of the refuge throughout the season by consultants and field scouts.

Agronomic management for the embedded refuge should be similar to that of the surrounding Bt-cotton that the refuge represents. If the surrounding Bt-cotton is irrigated the refuge cotton should also be irrigated. If the refuge is not managed similarly to the surrounding Bt-cotton, then it is likely not to reach full potential of an effective refuge. Management decisions that delay maturity of the refuge compared to the associated Bt-cotton should increase the effectiveness of the refuge for delaying resistance.

Insect management in embedded schemes may require some creativity specifically when considering bollworm and tobacco budworm. There may be a tendency to scout and make decision on the refuge alone without considering that the refuge comprises only 5% of the total area that will be sprayed. Ideally, the refuge should represent no more than 5% of the samples taken for the field unit. In other words, the embedded refuge should represent more than 5% of the insect management decision for a given field.

There is a point where bollworm/tobacco budworm infestation in the embedded refuge alone can justify an insecticide treatment over the entire field unit. This infestation, however, is likely to be an infestation of at least one larva per plant. Most state extension services recommend that live larvae be treated when five- percent live larvae are found. Thus, an infestation of at least one larva per plant in the refuge should equal five larvae per 100 plants when the field unit is considered.

Not sampling the embedded refuge for insect populations and basing insect control decisions solely on the associated Bt-cotton is likely to be the best option. Because the embedded refuge represents only a small portion of the final decision, reporting infestation levels in the refuge will likely result in excessive excitement. Thus, reporting insect infestations in the embedded refuge will likely result in an increased tendency to make insecticide applications that are not economically justifiable.

Species determination can be estimated by comparing the population density in the refuge vs. the density in the Bt-cotton. High larval populations in the refuge with very low populations in the associated Bt-cotton are likely to indicate that the infestation is predominately tobacco budworm. A uniform infestation in the refuge and associated Bt-cotton is likely to indicate an infestation that is predominantly bollworm.

Conclusions

The 95:5 embedded refuge option definitely required more time and thought than implementing a 96:4 unsprayed refuge. Little thought, however, was required to implement the 96:4 unsprayed option. A better understanding of embedded refuges will develop with time and the potential benefits of embedded refuges may change initial perceptions about it.

Complaints about the embedded refuge will likely come from the lack of realization that the purpose of a refuge is to forestall resistance development to Bt-cotton. Selection of either 5% option should be done with the understanding that final lint yield in the refuge may be zero and that any gains from the refuge are intended for the future and not for today.

Literature Cited

Mullins. W. 2000. New Bollgard Refuge Requirements for 2001. IN Cotton Incorporated Crop Management Seminar 2000. Cotton Incorporated Memphis, TN.