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Evaluating the Economic Impact of Refuge Corn Planting in Cotton Production Systems

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Bacillus thuringiensis (Bt) is a naturally occurring soilborne bacterium found worldwide. A unique feature is its production of crystal-like proteins that selectively kill specific groups of insects and other organisms. When the insect eats these Cryproteins, its own digestive enzymes activate the toxic form of the protein. Cryproteins bind to specific receptors on the intestinal walls and rupture midgut cells. Susceptible insects stop feeding within a few hours after taking their first bite, and, if they have eaten enough toxin, die within three days. USDA states that the insertion of the genes from *B. thuringiensis* causes cotton plant cells to produce Cryproteins which are effective in killing some of the most injurious caterpillar pests of cotton, such as the larvae of tobacco budworms and bollworms.

Bt technology is a critical tool utilized by many farmers in attempting to mitigate pest pressure in agricultural production. One such crop, Bt corn, has been planted on millions of acres across the South, protecting plants from damaging insects (e.g., corn borers and corn earworms). But, to ensure that the technology remains effective, farmers in cotton-growing areas must plant a structured refuge alongside Bt corn. Hence, the preservation of Bt technology is critical for cotton producers across the U.S. Cotton Belt because of increasing insecticide resistance and production costs.

In any production system employing Bt technology, the importance of maintaining a suitable refuge as an integral part of an Integrated Pest Management (IPM) plan cannot be stressed enough. Experts argue that the benefits of Bt cotton would be very short lived should there be a rapid evolution of pest resistance.

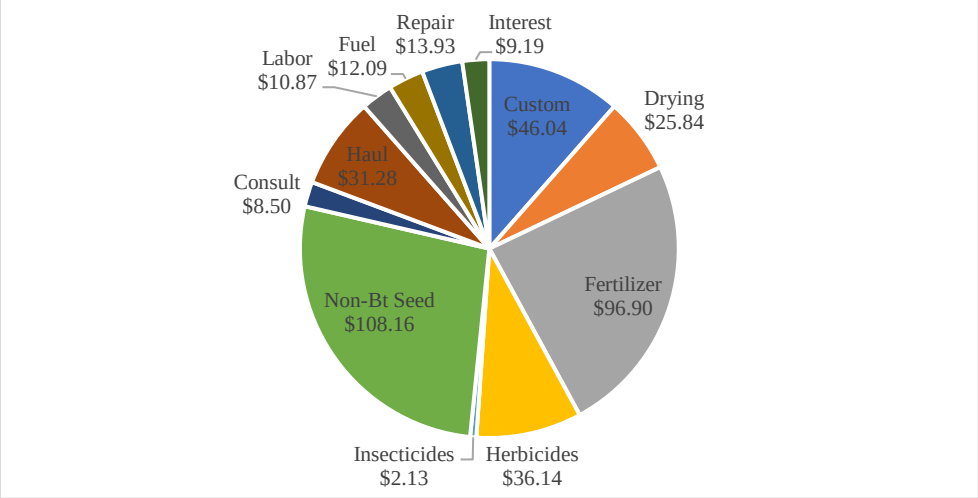
As producers seek to increase net revenues with the cultivation of Bt cotton, pesticide use, a major area of cost for cotton producers, is theoretically set to decrease, with the maintenance of a properly maintained non-structured refuge as it fosters an environment conducive to maintaining a non-Bt resistant host pest population. As pesticide use/application decreases, variable expenses decrease and, when combined with the possibility of increased lint yields (over that of conventional cotton), producers should realize a positive net revenue increase. To establish the economic effectiveness of Bt cotton, and, more namely, the economic effectiveness of a properly maintained refuge, one should discuss pesticide use and cost under both a Bt production system and a conventional (non-refuge) cotton production system. Also, breakeven analysis on a pound per lint basis should be conducted in determining Bt cotton's effectiveness as a means of increasing producer net revenues.

The objective of this study is to estimate the net economic benefit (dollars per acre) associated with the establishment of a corn refuge within a cotton production system. Using enterprise cost data sourced from the LSU AgCenter, per-acre variable costs are estimated for a production system utilizing a corn refuge system and for one that does not. It is hypothesized that the failure to maintain an adequate refuge will adversely impact grower net returns in cotton production mainly due to reductions in lint yield per acre as a result of increased insect pressure from the absence of a suitable refuge. Based on collaboration with LSU AgCenter personnel, cotton yield impacts stemming from this failure can result in reductions

ranging anywhere between 5% to 30% in lint yield per acre, relative to the type of cotton being cultivated (i.e., Bt-2-gene vs Bt-3-gene).

According to the 2021 projected cost for Round-up Ready (RR) corn production in Louisiana, as published by the LSU AgCenter, the variable cost for one acre of RR corn refuge in Louisiana is approximately $401.07 per acre. RR corn is selected as it is non-Bt, thus making it a most suitable candidate for refuge planting. Insecticides account for a relatively small portion of total variable costs, with a majority of expenses accruing in the areas of seed ($108.16 per acre or 27% of total variable cost) and fertilizer ($96.90 per acre or 24% of total variable cost). Figure 1.

Figure 1. Projected costs for RR corn (non-Bt) produced in Louisiana.

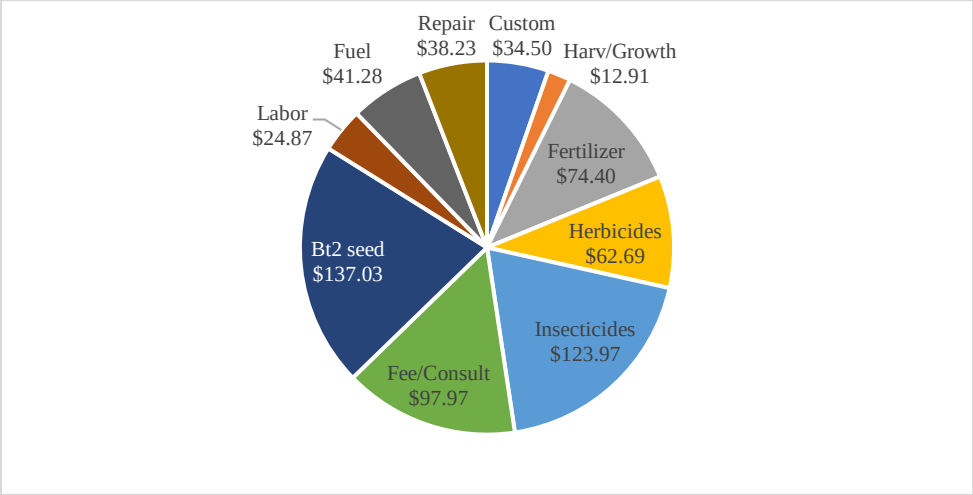


A refuge system (which in our case is a field planted to non-Bt corn) is established to serve as a proper environment in which to host a suitable susceptible insect population that is not resistant to Bt technology. It is theorized that if a refuge hosts a suitable amount of Bt susceptible insects, those insects that have partial Bt resistance will breed with the susceptible population thus prolonging the efficacious nature of Bt in limiting residual insect pressure by delaying the development of full Bt resistance in subsequent pest populations. Should this not be the case, producers could potentially be faced with the scenario of having to increase insecticide applications as a means of dealing with increased insect pressure. It is hypothesized that yields for RR corn will be lower than that of Bt varieties which, in turn on its own merit, carries economic implications for the whole farm. One such implication could be that the overall economic benefits from a refuge system with non-Bt corn may outweigh the economic returns from a corn-only production system as the non-Bt crop may lessen insect damage from an adjacent cotton crop, albeit producing a lower net return for the farm. On the other hand, cultivation of Bt corn can produce at a higher yield (~15%) at a slight cost premium to that of non-Bt corn ($447.15 per acre vs $401.07 per acre). One must keep in mind that this comes at the possible risk of decreased cotton yields due to increased insect pressure in cotton. This further supports justification for analysis of the economic impact within a whole-farm, multi-crop context.

In a refuge system, a refuge corn yield (non-Bt) of 136 bushels per acre is assumed with a Bt corn yield of 160 bushels per acre. This represents a 15% yield increase that is appropriate with the yield characteristics of Bt corn. A corn price of $4.00 per bushel was assumed for both refuge and non-refuge systems. Therefore, the per-acre net returns for refuge corn was $142.93 as compared to $192.85 per acre for the non-refuge corn system. From this corn-only crop comparison, non-refuge Bt corn outperformed the refuge (non-Bt) corn system. However, these returns must be combined with the subsequent cotton returns for the farm so that the efficiency of the refuge system can be estimated.

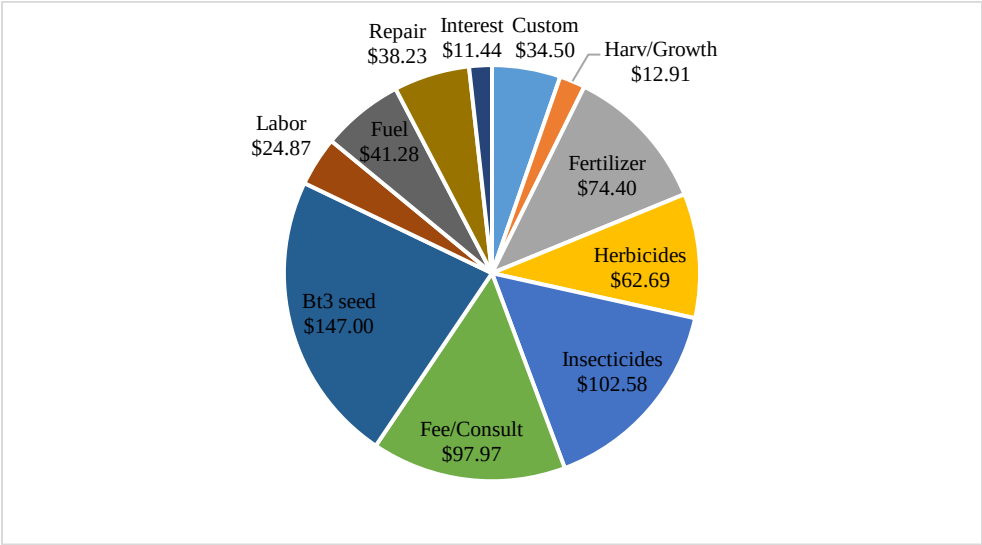
According to the 2021 projected costs for cotton production in Louisiana, it is estimated that the variable cost for one acre of Bt-2 (2 gene) cotton in Louisiana is approximately $659.29 per acre. Insecticides account for $123.97 per acre (or 19% of total variable cost) with the remaining major categories of expenses accruing in the areas of seed ($137.03 per acre or 27% of total variable cost), technology/ consultation fees ($97.97 per acre or 15% of total variable cost), fertilizer ($74.40 per acre or 11% of total variable cost), and herbicides ($62.69 per acre or 10% of total variable cost). Figure 2.

Figure 2. Projected costs for Bt-2 cotton produced in Louisiana.



The enterprise budget for Bt-2 cotton was subsequently modified after consultation with LSU AgCenter entomology faculty to more accurately reflect the variable costs associated with cultivation of 3-gene cotton (Bt-3). Utilizing assumptions based upon their recommendations, it is estimated that the variable cost for one acre of Bt-3 cotton is approximately $647.87 per acre with insecticides accounting for $102.58 per acre (or 16% of total variable cost) with the remaining major categories of expenses accruing in the areas of seed, technology/consultation, fertilizer, and herbicides. Figure 3.

Figure 3. Projected costs for Bt-3cotton produced in Louisiana.



For the cotton production system considered in this project, a base yield of 1,100 pounds of lint per acre was assumed for both Bt-2 and Bt-3 cotton along with a cotton lint price of $0.70 per lb. The estimated net returns above variable for cost for Bt-2 cotton was estimated to be $110.72 per acre and $122.14 for Bt-3 cotton. Additional insecticide applications for Bt-2 cotton account for the slight difference in production costs and hence, net returns per acre.

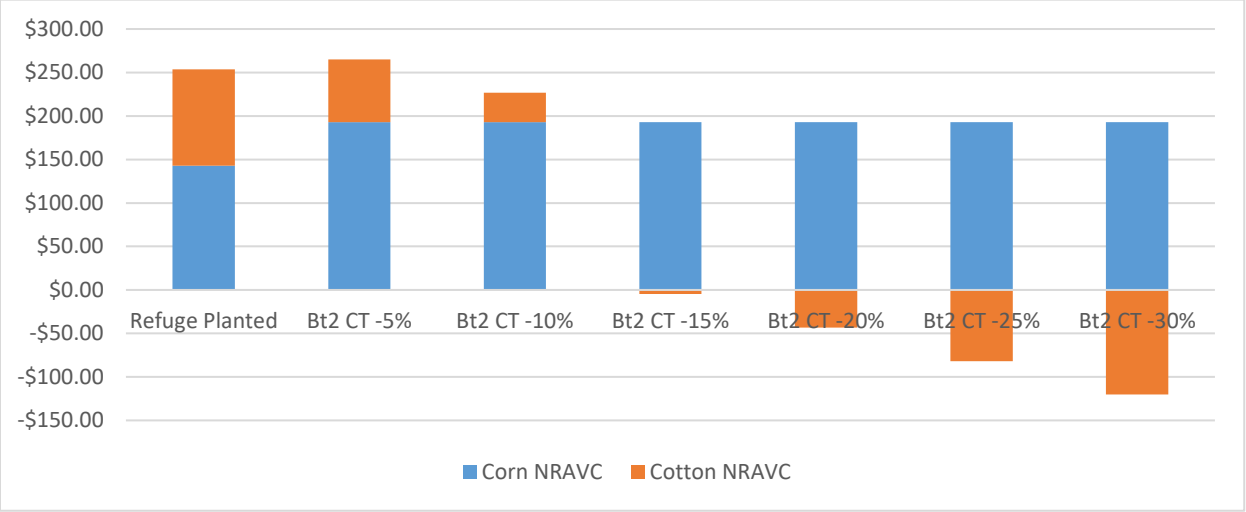
The basis for the economic comparison of a refuge versus a non-refuge system estimates the grower's net returns above variable costs on a per-acre basis. For the refuge system, the grower's NRAVC are estimated to be $142.93 per acre from the RR corn crop and $110.72 for Bt-2 and $122.14 for Bt-3 cotton. For a non-refuge system, a Bt corn crop was assumed to have a higher yield thus generating a higher grower net return per acre, which in this case was $192.85 per acre. However, a limitation of this production system is that should Bt resistance evolve rapidly in the insect population, this would increase insect pressure on that cotton crop, possibly reducing Bt cotton yields. As Bt cotton yields are reduced, grower net returns above variable costs from both corn and cotton are reduced. Table 1. Results in Table 1 are less than base Bt cotton net returns above variable costs at $110.72 per acre for Bt-2 and $122.14 per acre for Bt-3 cotton produced in a refuge system.

Table 1. Grower's Cotton Enterprise NRAVC Under a Non-Refuge System.

	Percent Cotton Yield Reduction from non-Refuge System					
	5%	10%	15%	20%	25%	30%
Bt-2-gene Cotton	$72.22	$33.72	-$4.78	-$43.29	-$81.79	-$120.29
Bt 3-gene Cotton	$83.64	$45.14	$6.63	-$31.87	-$70.37	-$108.87

Figure 4 presents a graphical comparison between a refuge and non-refuge system on combined farm returns from both the corn and Bt-2 cotton enterprises. The net returns from a refuge system are $142.93 for RR corn and $110.72 for Bt-2 cotton (combined $253.65 on two acres). What is interesting is that when cotton incurs yield losses of greater than 5%, the economic importance of a refuge system become clear, as cotton revenue starts to drastically decline. Although the returns from the non-refuge corn (Bt) are higher on a crop-only basis, the decline of cotton net returns begin to offset any gains in corn revenue.

Figure 4. Impact of a refuge versus a non-refuge system with alternative cotton yield reductions.



We now examine the central idea of maintaining a refuge versus no refuge within the context of whole farm production. Results in Table 2 indicate that for a refuge system, whole farm grower net returns above variable costs can range from $126.82 to $132.35 per acre, relative to the type of cotton being cultivated (i.e., Bt-2 or Bt-3). These net return estimates include the economic contribution of a RR corn crop refuge. In contrast, whole farm net returns for a non-refuge system are higher when less than a 10% cotton yield loss is sustained. For both Bt-2 and Bt-3 cotton, net returns are higher for a non-refuge system when minimal (5%) cotton yield damage is incurred. It is estimated that approximately a 7% cotton yield damage threshold generates lower whole farm net returns. This places a premium on the economic returns from a refuge system. As cotton yields start to decrease at an amount greater than the threshold to 10% of the base yield, advantages of the refuge system become apparent. For example, when 20% of the cotton yield is lost, grower net returns are $74.78 to $80.49 per acre, drastically less than the $126.82 to $132.53 of the refuge system sustains no such loss. (It should be noted that there are several agronomic and environmental factors that can impact insect pressure and yield reduction percentage are presented for educational purposes in this report.)

Table 2. Grower's whole farm (corn and cotton enterprises) NRAVC for a non-refuge and refuge system.

	Percent Cotton Yield Reduction from non-Refuge System					
	5%	**10%**	**15%**	**20%**	**25%**	**30%**
No Refuge BtRR CR + Bt2 CT	$132.54	$113.29	$94.04	$74.78	$55.53	$36.28
No Refuge BtRR CR + Bt3 CT	$138.25	$119.00	$99.74	$80.49	$61.24	$41.99
	0%	**0%**	**0%**	**0%**	**0%**	**0%**
Refuge nonBt CR + Bt2 CT	$126.82	$126.82	$126.82	$126.82	$126.82	$126.82
Refuge nonBt CR + Bt3 CT	$132.53	$132.53	$132.53	$132.53	$132.53	$132.53

Results contained in the aforementioned tables are predicated upon price and yield assumptions made in the base scenario. Changes in one or both variables will produce different net return estimates, and hence, a different magnitude of impact ascribed to refuge establishment. Recall that the corn price was set at $4.00 per bushel and the cotton lint price was set at $0.70 per pound. As an alternative, the result in Table 3 assume that the corn price is $3.75 per bushel and the cotton lint price remains the same. The same general observation from Table 2 can be applied to these results. As cotton yields start to decrease greater than 5% of the base yield, advantages of the refuge system become apparent.

Table 3. Grower's whole farm (corn and cotton enterprises) NRAVC for a non-refuge and refuge system with an alternative corn price ($3.75 per bushel).

	Percent Cotton Yield Reduction from non-Refuge System					
	5%	**10%**	**15%**	**20%**	**25%**	**30%**
No Refuge BtRR CR + Bt2 CT	$112.54	$93.29	$74.04	$54.78	$35.53	$16.28
No Refuge BtRR CR + Bt3 CT	$118.25	$99.00	$79.74	$60.49	$41.24	$21.99
	0%	**0%**	**0%**	**0%**	**0%**	**0%**
Refuge nonBt CR + Bt2 CT	$109.82	$109.82	$109.82	$109.82	$109.82	$109.82
Refuge nonBt CR + Bt3 CT	$115.53	$115.53	$115.53	$115.53	$115.53	$115.53

In efforts to model another price scenario, assume that the price of cotton lint is increased to $0.75 per pound. In this case, the grower can only afford to sustain a yield loss of approximately 5% in a non-refuge system as compared to the whole farm returns from the refuge system. Table 4. As cotton yields are

reduced further, the magnitude of the decrease in grower net return above variable costs is more pronounced. This illustrate the importance of a refuge system.

Table 4. Grower's whole farm (corn and cotton enterprises) NRAVC for a non-refuge and refuge system with an alternative cotton price ($0.75).

	Percent Cotton Yield Reduction from non-Refuge System					
	5%	**10%**	**15%**	**20%**	**25%**	**30%**
No Refuge BtRR CR + Bt2 CT	$138.66	$118.04	$97.41	$76.79	$56.16	$35.53
No Refuge BtRR CR + Bt3 CT	$144.37	$123.75	$103.12	$82.50	$61.87	$41.24
	0%	**0%**	**0%**	**0%**	**0%**	**0%**
Refuge nonBt CR + Bt2 CT	$137.32	$137.32	$137.32	$137.32	$137.32	$137.32
Refuge nonBt CR + Bt3 CT	$143.03	$143.03	$143.03	$143.03	$143.03	$143.03

Another approach in measuring the economic impact of refuge plantings would be to examine the increase in the required breakeven cotton yield that would be needed in order to cover the cost of additional insecticide applications. This would be relevant in instances where a refuge system was not maintained. For example, under the base scenario ($0.70 per pound cotton) for a farm with Bt-2 cotton and production costs of $659.29 per acre and $648.87 per acre for Bt-3 cotton, the required breakeven yield to cover variable costs for Bt-2 cotton is estimated to be 942 pounds per acre and 927 pounds per acre for Bt-3 cotton, respectively. From the enterprise costs analysis presented in Figures 2 and 3, insecticide costs represent a substantial portion of the total direct costs per acre for cotton production. Given the chemical unit material cost of each insecticide coupled with a spraying cost of $2.16 per acre-per application, the results in Table 5 estimate the increased in breakeven yield for Bt-2 cotton per additional application for a variety of cotton insecticides. It should be noted that the magnitude of the additional pounds of lint required to cover increased production costs can be acerbated by a lower cotton lint price.

Table 5. Required increase in breakeven Bt-2 cotton yield for additional insecticide application.

Chemical	**Rate**	**Price**	**Additional pounds of Lint Needed**
Warrior 2	1.28 oz	$2.30	6.4
Bidrin	3.2 oz	$4.26	9.2
Transform	1.5 oz	$11.72	19.8
Bidrin	8.0 oz	$10.64	18.3
Diamond	6.0 oz	$7.32	13.5
Transform	1.5 oz	$11.72	19.8
Besiege	10.2 oz	$19.89	31.5
Transform	1.5 oz	$11.72	19.8
Diamond	6.0 oz	$7.32	13.5
Orthene	0.75 lb	$4.50	9.5
Bifenthrin	6.4 oz	$3.35	7.9
Orthene	1.0 lb	$4.50	9.5
Bifenthrin	6.4 oz	$3.35	7.9

For example, a grower with an additional application of Besiege would need to increase their breakeven yield by 31.5 pounds per acre to fully offset the insecticide treatment cost. On the other hand, an additional application of Warrior would only require an additional 6.4 pounds of lint per acre.

In summary, the viability of sustained cotton production in an economically efficacious manner will most certainly employ a Bt refuge as a part of any IPM system. The economics associated with the establishment and maintenance of a corn refuge system alongside cotton must be viewed over the long-term to better appreciate the secondary and tertiary economic benefits of such a production system. Refuge systems play an important role in helping ensure delayed Bt resistance in pest populations thus potentially guarding the future viability of both Bt-2 and Bt-3 cotton production.

As with any enterprise, many variables are in play and so it is in agriculture. Insect pressures vary by year as do economic markets. It is felt that corn refuge establishment is a vital component of any agricultural production system, non-separable from responsible stewardship. While competing prices for alternative crops (e.g., corn) produced in a cotton rotation may compete for farm acres, the risk of reduced cotton yields across the entire farm must be weighted against any short run economic gains from corn. It is felt that economic benefits do justify refuge establishment and maintenance.

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