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Growing Pains Associated With Adoption of *Bollgard*™ Technology into Current IPM Practices in Oklahoma

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In 1996, Oklahoma cotton producers planted approximately 30,000 acres of NuCOTN cotton varieties. Stormy weather in June reduced the acreage to less than 15,000 acres, or 18.75 percent of the irrigated acres planted. Results from research and demonstration plots of NuCOTN cotton showed that seedling vigor was not reduced by insecticides applied in-furrow at planting. Plant mapping revealed NuCOTN varieties were slightly slower in initiating fruiting; retained more first position fruiting sites; and produced slightly smaller bolls. NuCOTN produced more lint than conventional varieties regardless of the management scheme.

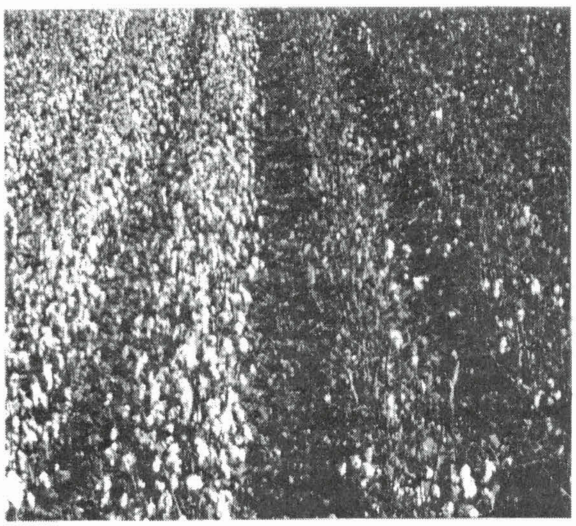
Bollgard™ cotton was commercially available to Oklahoma producers in 1996. *Bollgard*™ cotton contains a gene (Bt toxin) which is highly effective against immature stages of Lepidopterous insects. NuCOTN cotton containing *Bollgard*™ is the first of a long list of new biotech products to reach the farmer. Monsanto required interested producers to pay a $32 per acre surcharge for the "right-to-grow" *Bollgard*™ cotton. This price is close to the average spent across the cotton belt annually to combat the bollworm/tobacco budworm complex. Unlike other production areas across the Cotton Belt, the majority of the moth flight throughout the summer in Oklahoma consists of bollworms (Figure1).

Growing pains (problems) associated with the adoption of the Bollgard™ technology include:

- seedling vigor
- buildup of bollworms and horror stories from other areas
- unknown economic thresholds to trigger control measures and scouting techniques
- boll weevil havens
- cotton aphid buildups
- boll size

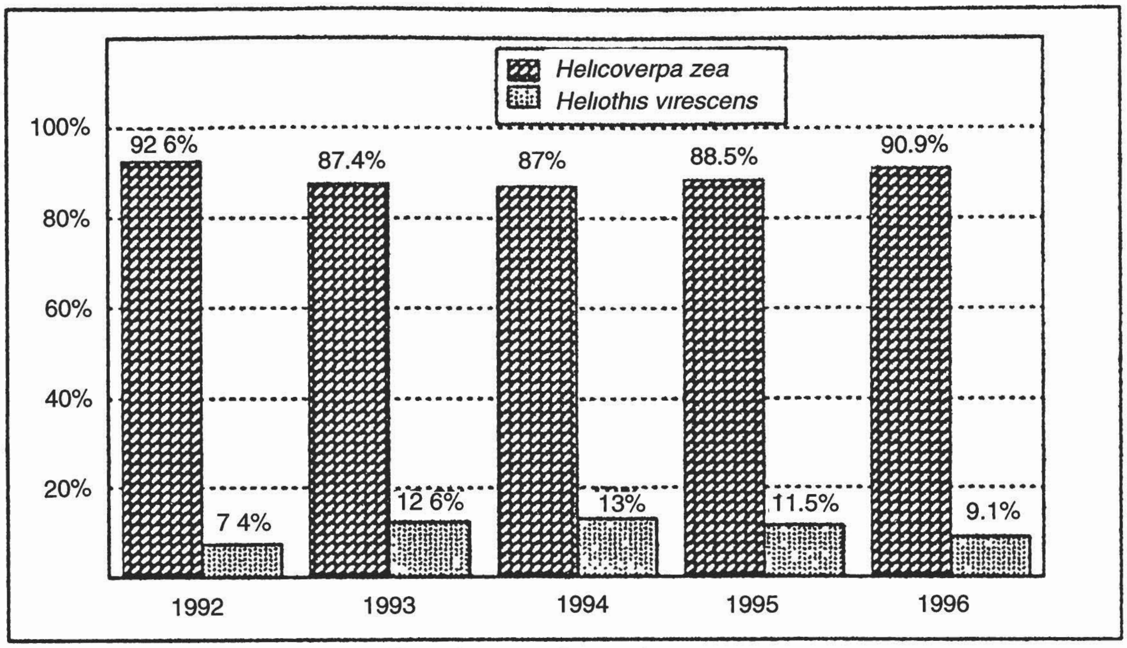
No Bollworm Protection

NuCOTN 33B DP 90



Normally, between $25.00 and $40.00 per acre is spent to control bollworms in irrigated cotton under intense management. This annual expense barely equals the rental for the *Bollgard*™ technology. However, Oklahoma producers were eager to see if this highly advertised technological breakthrough could increase profit margins. Most producers planting NuCOTN varieties hoped the reduction in spraying would conserve beneficial insects, curtailing the total number of insecticide applications, especially those aimed at controlling secondary pest outbreaks, for example, cotton aphids.

A lingering drought forced producers to change original NuCOTN planting intentions. Approximately 30,000 acres were projected to be planted across the state. The Altus Irrigation District, located in Jackson and Greer Counties, was the center of the NuCOTN acreage. Stormy weather in June forced widespread replanting. Many producers switched to earlier maturing varieties or sorghum to compensate for a shortened growing season. NuCOTN's share shrunk to less than 15,000 acres, or 18.75 percent of the irrigated acreage planted in 1996.



[1] Pheromone traps maintained from June 1 to September 1.

Figure 1. Species composition of moths trapped[1] across Oklahoma, 1992-1996.

Several "growing pains" (problems) were encountered with NuCOTN varieties in 1996. Many of the problems were similar to those seen any time a new product or technique is introduced. Since NuCOTN cotton had never been evaluated under Oklahoma conditions, the Oklahoma Cooperative Extension Service had to speculate about its performance and place in the state's production system. Prior to planting, several questions remained unanswered, including how *Bollgard*™ might affect other insect species (beneficial and pest) present The greatest challenge centered around adapting current scouting techniques and bollworm economic thresholds to fully utilize *Bollgard*™ technology without sustaining economic loss.

At planting, seedling vigor became an issue. Much of the cotton in the Altus Irrigation District was "watered up" because of limited soil moisture. Poor germination, seedling vigor, and stand establishment were noticed in fields planted to NuCOTN. Initially, in-furrow insecticide applications were a possible culprit, but results of a replicated study showed NuCOTN 33B to have better stands than DP 5690 (Figure 2). Temik had no adverse effect on seedling vigor of NUCOTN plants. Further investigation of cotton fields with reduced germination and plant stands revealed that salt deposited while irrigating was probably at fault.

The damage inflicted by the boll weevil in the last five years forced many producers to switch to sorghum and corn on thousands of acres across Southwest Oklahoma in 1996. This large tract of sorghum and corn resulted in higher numbers of bollworms in June, resulting in the heaviest July moth flight in cotton in 15 years (Karner, 1997).

At the start of the season, the economic threshold for *Bollgard*™ cotton was; **Spray only if 10 or more larvae (≥ 1/2 long) are found per 100 plants. If larvae are less than 1/4 inch long, recheck field in 2 to 3 days to see if worms are killed by consuming the *Bollgard*™ gene.** This recommendation was based on the current pre-bloom threshold for bollworms. The major difference pertains to the size of the larvae that signal the use of control measures. Normally, treatment is initiated within two or three days of egg hatch to control the infestation before bollworms reached five days old or 1/2 inch long.

Control measures are not recommended in *Bollgard*™ fields unless bollworms are approaching 1/2 inch long. This extra two to three days insures sufficient time for infected larvae to die. *Bollgard*™ performed as advertised with no fields requiring insecticide control for bollworms in July Despite *Bollgard*™ performance, many producers were reluctant not to spray NuCOTN fields when counts of eggs and first instar larvae were similar to those of conventional varieties.

Constant bollworm pressure and rumors of *Bollgard*™ failures in the Brazos River Bottom in Texas and the mid-South kept producers and consultants concerned about possible failures. As bollworm numbers increased and damage became obvious, producers and consultants started to doubt *Bollgard*™ performance. Much of the concerns centered around excessive fruit shed from bollworm feeding before death occurred. Consultants threatened to raise fees because of the number of repeated visits required to monitor bollworm development on NuCOTN.

Economic thresholds changed throughout the season in an attempt to allow *Bollgard*™ a chance to regulate bollworm infestations and prevent economic loss. By August, the larvae/plant threshold had been amended to reflect the discovery of larvae surviving in flowers. **In addition to the larvae/plant threshold, producers and consultants were urged to consider spraying when 6 or more larvae 1/4 inch**

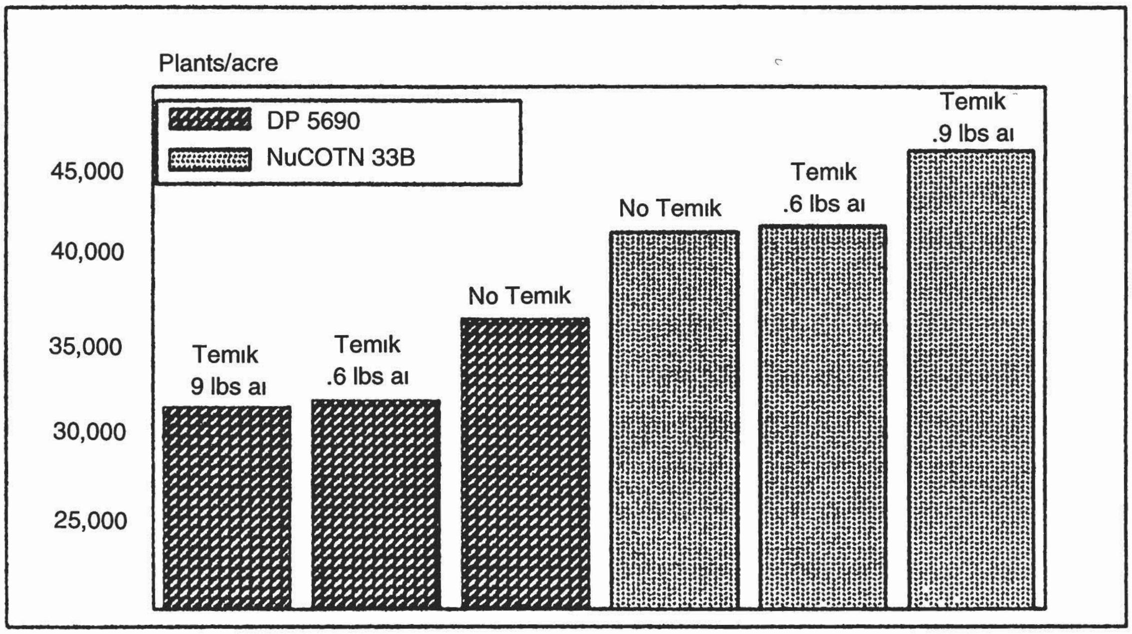


Figure 2. Effect of Temik applied infurrow at-planting on seedling vigor of NuCOTN 33B and DP 5690 cotton; Altus Research Station, Summer 1996.

or larger were found in 100 flowers pulled at random (similar to sampling for boll weevils). Neither of these thresholds were ever reached or exceeded in research or extension demonstration plots of NuCOTN during 1996.

No larvae larger than 1/4 inch were found. In-season spray histories reflect this trend (Tables 1 and 2) NuCOTN plots were treated identically to conventional varieties for all other cotton pests except bollworms. Conventional varieties average 6.7 applications to prevent insect loss compared to 3.9 applications for NuCOTN plots, a savings of 2.8 applications (cost = $11.00/appl.) or $30 80/acre. However, this savings in insecticide costs did not cover the rental fee, resulting in an average loss of $1.20/acre.

During 1996, only one field of NuCOTN sustained significant bollworm damage. Oddly, damage was confined to a 20 acre portion of a 100 acre field planted to NuCOTN 35B. Monsanto was requested to bioassay the cotton to determine the genetic origin of plants. Bioassay results of 10 heavily infested and damaged plants on August 20, 1997, revealed all plants contained the *Bollgard*™ gene. Within five days of this verification, 95 percent of NUCOTN acreage planted in the state was sprayed for bollworms Protection continued the remainder of the season. Most NuCOTN fields received two to four insecticide applications to prevent bollworm damage.

NuCOTN fields not sprayed for bollworms became havens for boll weevils. The most obvious explanation for this

Table 1. Insect populations which triggered bollworm applications, selected tests.

	Number of first and second instar larvae per 100 plants					
Variety	*1st Application*		*2nd Application*		*3rd Application*	
	CBT[2]	*CAT*[3]	*CBT*	*CAT*	*CBT*	*CAT*
Infurrow Insecticide						
DP 5690(s)[1]	14	0	20	0	32	4
N.C 33B(c)	16	0	8	0	28	0
Bollworm Development - Tagged Plants						
DP 90(s)	15	0	19	0	33	3
N.C. 33B(c)	18	0	7	0	48	0

[1]( ) indicates if variety was protected from bollworms, s = sprayed and c = check

[2]CBT = Check before treatment

[3]CAT = Check after treatment

Table 2. Comparison of three sampling methods to assess bollworm population trends prior to and following insecticide treatment, farm demonstrations, Summer 1996.

Variety	*Number of first and second instar larvae per 100 plants*			
	Terminals	*Squares*	*Blooms*	*Eggs*
Murray Williams "Gentry"[2]				
		7/15		
N C 33B(c)[1]	2	0	na	30
DP 5690(s)	2	0	na	24
		7/22		
N.C 33B(c)	0	0	4	6
DP 5690(s)	6	6	4	28
		8/2		
N C. 33B(c)	4	4	2	24
DP 5690(s)	6	6	4	28
		8/5		
N.C. 33B(c)	10	10	0	4
DP 5690(s)	4	8	0	0
		8/19		
N.C 33B(c)	8	10	28	68
DP 5690(s)	10	10	24	72
		8/23		
N.C 33B(c)	2	2	8	30
DP 5690(s)	0	4	2	24
Danny Robbins "Rogers"[3]				
		7/29		
N C. 33B(c)	2	0	4	36
		8/5		
N C. 33B(c)	0	4	4	12
		8/26		
N C. 33B(c)	4	0	8	8
		9/3		
N.C. 33B(c)	4	0	8	8

1( ) indicates if variety was protected from bollworms, s = sprayed and c = check

2 Plots sprayed on 7/19, 8/3 and 8/19

3 Plots sprayed on 7/30 and 8/29

rapid buildup of boll weevils was the lack of pyrethroid applications in July to control bollworms. Producers had taken for granted the impact of these pyrethroid applications on sub-economic infestations of boll weevils. Once established, boll weevil infestations were very difficult to control In fact, in some NuCOTN fields, insecticide expenditures exceeded conventional fields' insecticide costs Also there was no difference in cotton aphid buildup between NuCOTN and conventional varieties. Ninety percent of the NuCOTN acres received one to two applications to control cotton aphids.

As fields neared cutout, producers began complaining about boll size of NuCOTN. Plant mapping of research and extension demonstration plots revealed NuCOTN varieties were slightly slower in fruit initiation, retained more first position fruiting sites, and produced slightly smaller bolls than conventional varieties (Table 3).

Producers were cautioned to withhold judgment until

Table 3. Comparison of NuCOTN 33B and conventional cotton varieties' plant characteristics under various insect management schemes; Southwest Oklahoma, Summer 1996.

	Average		
Variety	*Fruit Initiated (node)*	*Fruit Retention %*	*Boll weight ounces*
	Irrigated		
NuCOTN 33B(c)[1]	8.6	76.0	.47
NuCOTN 33B(s)	8.8	73.4	.42
DP 5690(s)	7.8	60.2	60
DP 90(s)	6.8	71.3	.51
DP 90 (c)	7.1	41.2	.46
HS - 26(s)	6.1	70.2	.68
	Dryland		
NuCOTN 33B(c)	8.1	72.5	.39
HS - 26(s)	6.2	61.5	.65
Holland 1379(s)	6.2	53.6	.65

1 ( ) indicates if variety was protected from bollworms, s = sprayed and c = check

after harvest. Regardless of the spray regime, NuCOTN produced more lint than conventional varieties (Table 4). NuCOTN cotton produced between 31.6 lbs and 446.7 lbs more lint per acre than conventional varieties.

Adoption of new technology into current production practices depends on many factors, which will vary depending on individual preferences. Value of the technology however, is the most important item used by producers to decide if the change is of any merit.

NuCOTN returns varied However, regardless of the management scheme, cotton producers profited. The only exception occurred in Danny Robins' "Rogers," where in-season bollworms did not enhance yields Spraying sub-economical infestations of bollworms resulted in a loss of $34.60/acre.

Dryland production limited NuCOTN gains to $1.96/acre and $23.56/acre; the lowest profit margin recorded in 1996. Instead of irrigated plots NuCOTN cotton was compared to stripper varieties — Paymaster H-26 and Holland 1379. The determined nature of these varieties may have offset insect losses due to limited accumulation of heat units in 1996.

Returns increased substantially for NuCOTN when compared to picker varieties with similar indeterminate characteristics. NuCOTN returns ranged from $51.04/acre to $236.02/acre. This increase in profit seems to well justify the risk and growing pains experienced by cotton producers planting NuCOTN in 1996.

Conclusions

Producers agreed that NuCOTN cotton produced as good or better yields than conventional varieties. However the extra cost for seed, rental, and other contract requirements will limit the acres planted to NuCOTN in 1997. Adoption of Bollgard TM technology into current cotton IPM practices will be slow until resistant problems surface.

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Table 4. Economics of NuCOTN compared to conventional cotton varieties under various insect management schemes, Oklahoma, 1996.

Variety	*Lint lbs/acre*	*Crop Value[1] ($)*	*Insect[2] Control (+)*	*Return[3] ($)/acre*	*Difference ($)*
Infurrow					
DP 5690(s)[4]	606.7	364 02	64.00	300.02	113.62
N.C. 33B(c)	794 4	476 64	63.00+	413 64	
Spray Regimes					
1 DP 90(s)	582.5	349 50	25.00	324.50	60.70
N.C. 33B(c)	737.9	442 20	57.00+	385 20	
2 DP 90(s)	588.6	353.16	43.00	310.16	51.04
N.C 33B(s)	727 0	436.20	75.00+	361 20	
3 DP 90(s)	574.4	344 64	70.00	274.64	87.88
N C. 33B(s)	774 2	464.52	102.00+	362 52	
4 DP 90(s)	629.1	377.46	76.00	301 46	119 26
N.C. 33B(s)	881.2	528.72	108 00+	420 72	
NAWF					
Irrigated					
HS-26(s)	741.8	445.08	64.00	381.08	44.44
DP 90(s)	608.9	365.34	64.00	301.34	124.18
N.C. 33B(c)	814.2	488.52	63.00	425.52	
Dryland					
HS-26(s)	317.8	190.68	33.00	157.68	1.96
H. 1379(s)	281.8	169.08	33.00	136.08	23.56
N.C. 33B(c)	349.4	209.64	50.00	159.64	
Tagged Plants					
DP 90(s)	546.8	328.08	64.00	264.08	85.90
DP 90(c)	241.8	144.96	31.00	113.96	236.02
N.C. 33B(c)	688.3	412.98	63.00	349 98	
"Gentry"					
DP 5690(s)	675.0	405.00	76.00	329.00	91.00
N.C. 33B(c)	825 0	495 00	75.00	420 00	
"Roger"					
N.C. 33B(c)	896 3	537.78	64.00	473 78	-35.08
N.C. 33B(s)	874.5	524.70	86.00	438 70	

1 Crop value = lint production (lbs/acre) x 60 lbs/acre

2 Insecticide Inputs, (+) = Rental fee ($ 32 00/acre) included

3 Return ($)/acre = Crop value minus insecticide inputs

4 ( ) indicates if variety protected from bollworms s = sprayed and c = check

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