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2. Survey Evidence on Producer Use and Costs of Genetically Modified Seed

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Survey Evidence on Producer Use and Costs of Genetically Modified Seed

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Chapter 2

Survey Evidence on Producer Use and Costs of Genetically Modified Seed

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Soybeans and cotton are leading users of agricultural pesticides at a substantial cost to U.S. farmers. Average pesticide costs, at about $28 per acre, comprise about 35 percent of the variable cost of soybean production. Cotton costs average about $57 per acre, but are more than $100 per acre in areas with severe insect and/or weed pressure (USDA, ERS 1999). With concerns in production agriculture focused on low commodity returns and the environmental effects of pesticide use, genetically modified (GM) seed may be an alternative that can lower producer costs and reduce total pesticide use. Rapid adoption of GM seed suggests that these technologies are perceived to be more profitable than traditional methods. This study is the first to present national survey evidence about the impact on pesticide use, crop yields, and the costs associated with using GM seed in soybean and cotton production.

Background

Genetically modified seed was first widely marketed in 1995 for cotton and 1996 for soybeans, and was used on substantial acreage of both crops in 1997. The most widely discussed and adopted development in GM seed is the glyphosate-tolerant soybean line using the brand name Roundup™ herbicide developed by Monsanto. Glyphosate-tolerant soybeans are designed to allow farmers to limit herbicide treatments to as few as a single post-emergence application of glyphosate, while a conventional weed control program can involve multiple applications of several herbicides. Other advantages of glyphosate are its relatively low cost and favorable environmental features. Glyphosate binds to the soil rapidly, preventing leaching, is biodegraded by soil bacteria, and has extremely low toxicity to mammals, birds, and fish (Malik, Barry, and Kishore 1989). Also, because glyphosate-tolerant soybeans do not rely on preplant incorporated herbicides, they encourage the use of minimum tillage practices which reduce soil erosion and chemical runoff (Owen 1997).

Glyphosate-tolerant strains of cotton have also been introduced. Because pre-emergence herbicides seldom adequately control weeds season-long in cotton, post-emergence herbicides are routinely used. Various herbicides can be applied post-emergence directed if a height differential exists between cotton and weeds. However, most producers find it more convenient to apply herbicides over-the-top rather than directed. Glyphosate can be sprayed over-the-top of glyphosate-tolerant cotton to control a broad spectrum of weeds and thus provides a convenient weed control alternative that may also reduce total herbicide use and be less toxic to the environment (Wilcut et al. 1996).

Bt (*Bacillius thuringiensis*) technology has been developed for cotton to resist damage from the bollworm, tobacco budworm, and pink bollworm. The Bt technology is a novel approach to controlling insects because the cotton plant produces the insecticide throughout the plant over its entire life. The insecticide can't be washed off by rain and is not subject to breakdown by other environmental factors that affect many conventional synthetic and biological insecticides. In areas severely affected by damage from the target pests, Bt cotton has the potential to control pests at a lower cost, increase yields, and provide a more environmentally compatible pest control system (Benedict 1996).

Introduction

The introduction of GM seed varieties has expanded the pest control options available to farmers. Pest control programs including GM seed utilize specific seed-pesticide combinations. These combinations have been touted as strategies that can reduce pesticide use and lower the overall cost of pest control. However, due to their recent introduction, little published research documents actual producer use of these technologies and their impact on pesticide use and production costs.

Objectives

Specific objectives of this study are to: (1) present survey evidence on the extent and rate to which GM seed was used in soybean and cotton production during 1997, the most recent year for which survey data are available, (2) describe the crop production systems used with pest control programs using GM seed, (3) examine the crop production costs associated with pest control programs using GM seed, and (4) compare crop production systems and costs of programs with GM seed to those with traditional pest control methods.

Related Literature

The limited research to date has been favorable regarding potential yields and returns from herbicide-resistant soybeans. Prior to commercial release of the technology, yields from plots with a glyphosate-tolerant soybean line treated with glyphosate were compared to non-treated control plots at numerous sites throughout the northern and southern soybean areas (Delannay et al. 1995). No significant yield reductions resulted from the glyphostate applications at any of the locations. Results of the study indicated that the glyphosate tolerant soybean line was tolerant to applications of glyphosate at rates as high as twice the level needed to control most weeds, resulting in no negative impact on yields. Data from field trials in West Tennessee were used in an economic analysis of Roundup™ Ready soybeans (Roberts, Pendergrass, and Hayes 1998).

Comparing per acre net returns from 14 trials, the returns from the Roundup system were 13 percent higher than the returns for the second most profitable system. Higher returns from the Roundup system resulted from both higher yields and lower herbicide costs. Research results from trials in Mississippi (Arnold, Shaw, and Medlin 1998) also showed higher yields and net returns from Roundup Ready^{TM} soybeans versus conventional varieties.

Early research on herbicide-resistant cotton suggests that yields from glyphosate-tolerant varieties compare favorably with those used in standard weed control programs. Field tests from Arkansas and Missouri (Goldman et al. 1996), Georgia (Vencill 1996), and Texas (Keeling et al. 1996) indicated little differences in cotton yields between weed control programs including glyphosate and those using standard cotton herbicides. An economic analysis of glyphosate-tolerant cotton using field tests in North Carolina concluded that glyphosate applied to glyphosate-tolerant cotton is a convenient and effective alternative to traditional herbicides (Culpepper and York 1998). Yields and net returns with the glyphosate systems were similar to, but no greater than, those with the most effective traditional systems. However, fewer herbicide applications were required and less total herbicide was used with the glyphosate systems.

The effects on yields, input use, and costs of using the Bt technology for cotton production have received considerable attention since its recent introduction. Survey data from Georgia cotton growers indicated that Bt cotton produced an average yield of 104 pounds of lint per acre more than non-Bt varieties in similar production systems (Stark 1997). Spray applications for insect and plant growth control were reduced by 2.5 applications per acre on the Bt cotton. Despite the $32 per acre technology fee, Bt cotton was found to have a sizeable economic advantage over the non-Bt varieties. Producer survey data from Mississippi also showed returns above specified costs for Bt cotton to be higher than those of non-Bt cotton (Gibson et al. 1997). Total costs of production were not much different for Bt versus non-Bt varieties, but higher yields produced significantly higher net returns. Research using experimental plot data in South Carolina indicated no significant differences between Bt and non-Bt cotton yields, but did find an economic advantage for Bt cotton due to reduced pesticide costs (ReJesus et al. 1997). However, Bt cotton yields were more variable than those of non-Bt varieties. Similar results were found from a 3-year study in Arkansas where higher yields and profits were associated with Bt cotton in 1996 and 1998, but lower yields and profits resulted in 1997 (Bryant, Robertson, and Lorenz III 1998). Recommendations based on research in South Carolina (ReJesus et al. 1997) and Texas (Benedict 1996) suggest that the greatest profit opportunities from Bt cotton are for producers making 4 or more insecticide applications and spending $30 per acre or more to control the target pests, and are still not obtaining good pest control.

Data

USDA has undertaken an annual data collection effort, the Cropping Practices Survey (CPS), for information about production practices, input use, and yields on major

U.S. field crops throughout the 1990's. Data collected in the CPS has been used to estimate and publish annual input use estimates (USDA, ERS 1997). In 1996 data collected in the CPS was merged with USDA's farm financial survey program to form the Agricultural Resource Management Study (ARMS). The combined survey effort has created the opportunity to link the production practices and input use data with farm finances and cost of production. Special versions of the 1997 ARMS collected detailed information about input use and costs from a sample of soybean producers in 17 states and a sample of cotton producers in 12 states.

The target population of the ARMS soybean and cotton samples was the state acreage planted to each crop. Production practice, input use, and production costs were collected for a randomly selected field of the target commodity on each sampled farm. Acreage in each selected field represents similar acreage in the target population as indicated by an expansion factor for each field. The expansion factor, or survey weight, is determined from the selection probability of each field and expands the ARMS sample to represent the target population of each commodity. The soybean sample expands to represent 65.6 million planted soybean acres, about 93 percent of national acreage in 1997, while the cotton sample represents 13.1 million cotton acres, about 95 percent of national acreage (USDA, NASS 1998).

When survey data are collected using a complex sample design, as in the ARMS, there is no easy analytical way to produce unbiased and design-consistent estimates of variance. The variance of survey statistics using standard statistical packages, such as SAS or SPSS, are inappropriate (Brick, et al. 1997). Therefore, the replication approach using a delete-a-group jackknife method was used as the variance estimator (Kott). A major advantage of using the replication approach with the ARMS is that survey weight adjustments, such as for post-stratification and non-response, can be reflected in the variance estimates.

Methods

The ARMS data were used in this study to examine GM seed use for soybeans and cotton within geographic regions. The soybean regions were defined as: Corn Belt-IA, IL, IN, MO, and OH; Lake States-MI, MN, and WI; Southeast-KY, NC, and TN; Delta-AR, LA, and MS; and Northern Plains-KS, NE, and SD. Cotton regions were: Southeast-AL, GA, NC, and SC; Delta-AR, LA, MO, MS, and TN; Southern Plains-TX; Southwest-AZ and CA. The regions were defined to include areas with a similar soil profile, climate, and topography, and farms facing similar pest problems, but were broad enough to provide a sufficient sample from which to establish statistically reliable estimates. The extent of GM seed adoption was measured within each region and compared among regions. Practices, inputs, and costs associated with acreage planted to GM seed were compared to acreage planted to traditional seed technologies within each region. Differences in practices, and input use and costs on acreage in the various seed technologies were tested for statistical significance using a difference of means test with a t-statistic. Due to sample limitations, GM and traditional seed technologies could not be compared in all regions.

The Bt technology for cotton production is designed as an alternative to insecticide applications for bollworm, tobacco budworm, and pink bollworm control. On acreage where these target pests are not a problem, it is not in the economic interest of the producer to consider using the technology. Therefore, it is not appropriate to compare the practices, input use, and costs on these acres with those planted with Bt seed. To examine the impact of the Bt technology, acreage planted with Bt seed was compared only to acreage in other purchased seed that was treated with insecticide applications to control for the Bt target pests. In contrast, the herbicide-resistant technology utilizes a broad spectrum herbicide, glyphosate, that can substitute for nearly all conventional herbicide applications. To examine the impact of the herbicide-resistant technology, acreage planted to herbicide-resistant seed was compared to acreage in all other purchased seed. Because of considerable differences between the yields, practices, and costs on acreage planted to purchased and homegrown seed, acreage planted with homegrown seed was not included in the analysis.

GM seed can be regarded as a part of the program to control pests in soybeans and cotton. Therefore, the relevant costs for evaluating the impact of adopting alternative seed technologies includes not only the cost of seed, but also the full costs of pest control. Pest control costs with GM seed technologies involve costs of seed, a seed technology fee, seeding, pesticide materials, pesticide applications, pest scouting, and cultivation. The ARMS data includes direct expenditures for seed, seed technology fees, pesticide materials, and custom charges for seeding, pesticide applications, pest scouting services, and cultivation. Seeding, pesticide application, and cultivation costs were estimated as the sum of custom charges, an imputed labor cost, and machinery operating costs (fuel and repairs). Pest scouting included charges for scouting services and an imputed cost for labor. Labor costs were imputed by valuing labor estimates from the ARMS data by state agricultural wage rates (USDA, NASS 1997). Operating costs for the machinery used in seeding, pesticide applications, and cultivation were estimated using ARMS data on individual field operations along with data and equations adapted from standards provided by the American Society of Agricultural Engineers (ASAE 1996).

Differences identified in this study between the practices, yields, and costs on GM seed acreage and other acreage should be interpreted with caution. Using farm survey data to compare the groups makes it impossible to control for everything that might influence the comparison. Thus differences between mean estimates of practices, yields, and costs cannot necessarily be attributed to the use of the GM seed since the results are influenced by many uncontrolled factors such as irrigation, weather, soils, nutrient and pest management practices, other cropping practices, pest pressure, management, and others. While this study attempts to control for some major factors that would affect the comparison and tests for differences in other factors, the differences between GM seed acreage and other acreage identified in this study cannot be solely attributed to the use of the GM seed.

Seed Technology Use

Acreage of various soybean and cotton seed technologies planted during 1997 are presented in Table 1. The various seed technologies range on a continuum that includes genetically modified varieties, other purchased seed varieties, and homegrown seed kept by farmers from the previous crop. About 17 percent of soybean acreage in the 17 survey states was planted with herbicide-resistant seed. Total estimated acreage of planted GM soybean seed was about 11.1 million acres, with a sampling error of plus or minus about 1.7 million acres. GM seed was planted on about 25 percent of cotton acreage in the 12 surveyed states during 1997, covering about 3.4 million acres. About 10 percent of planted cotton acreage was in herbicide-resistant varieties while 15 percent was Bt cotton. Estimated herbicide-resistant acreage was 1.4 million acres (± 376,000 acres) and Bt cotton acreage was 2.0 million acres (± 247,000 acres). The majority of soybean and cotton acreage was planted in other purchased seed varieties, while less than 20 percent was planted with homegrown seed.

TABLE 1 Acreage Planted to Various Seed Technology in U.S. Soybean and Cotton Production, 1997

	Percent of acreage		1,000's of acres	
Seed technology	Mean	Interval[a]	Mean	Interval[a]
Soybeans:				
Herbicide-resistant seed	17.0	14.4-19.6	11,124	9,449-12,862
Other purchased seed	68.1	64.9-71.3	44,686	42,587-46,787
Homegrown seed	14.9	13.3-16.5	9,810	8,727-10,827
Cotton:				
Herbicide-resistant seed	10.4	7.6-13.2	1,388	1,012-1,757
Bt seed	15.0	13.1-16.9	1,992	1,745-2,251
Other purchased seed	56.8	51.8-61.8	7,566	6,900-8,232
Homegrown seed	17.8	12.5-23.1	2,375	1,665-3,077

[a]95 percent confidence interval.

[b]The total is for the 17 States surveyed in the 1997 ARMS for soybeans including: Corn Belt-IA, IL, IN, MO, and OH; Lake States-MI, MN, and WI; Southeast-KY, NC, and TN; Delta-AR, LA, and MS; Northern Plains-KS, NE, and SD.

[c]The total is for the 12 States surveyed in the 1997 ARMS for cotton including: Southeast-AL, GA, NC, and SC; Delta-AR, LA, MO, MS, and TN; Southern Plains-TX; Southwest-AZ and CA.

The extent and rate of adoption of GM seed for soybean and cotton production by region is presented in Table 2. Herbicide-resistant soybean seed was planted on more acreage in Corn Belt states, about 6 million acres, than in all other regions combined.

However, the rate of adoption was highest in the Delta where about one-third of soybean acreage was planted with herbicide-resistant seed, significantly higher than in all other regions. About 17-18 percent of Southeast and Corn Belt soybean acreage was in GM seed during 1997, compared to significantly less acreage in the Lake States (9 percent). In general, the adoption rate of herbicide-resistant soybeans was highest in the southern regions and lowest in northern regions. Greater weed pressure, as indicated by historically higher rates of herbicide use, likely makes herbicide-resistant varieties attractive to southern soybean growers.

TABLE 2 The Extent and Rate of Adoption of Genetically Modified Seed for Soybean and Cotton Production in Major U.S. Production Regions, 1997

Technology/Region	Adoption extent (1,000 acres)	Adoption rate (percent)	Regions different in adoption rate[a]
Herbicide-resistant soybean seed:			
Corn Belt (CB)	5,960	16.9	(LS, DE)
Lake States (LS)	846	8.7	(CB, SE, DE)
Southeast (SE)	737	18.3	(LS, DE)
Delta (DE)	2,369	33.4	(CB, LS, SE, NP)
Northern Plains (NP)	1,213	12.8	(DE)
Herbicide-resistant cotton seed:			
Southeast (SE)	424	14.4	(SP, SW)
Delta (DE)	576	16.7	(SP, SW)
Southern Plains (SP)	299	5.4	(SE, DE)
Southwest (SW)	89	6.3	(SE, DE)
Bt cotton seed:			
Southeast (SE)	781	26.6	(SP, SW)
Delta (DE)	713	20.7	(SP)
Southern Plains (SP)	253	4.6	(SE, DE, SW)
Southwest (SW)	245	17.4	(SE, SP)

[a]Regions with an estimated rate of adoption that is significantly different at the 5 percent level.

GM cotton seed was used much more extensively during 1997 in the Southeast and Delta regions than in regions to the west. About 40 percent of Southeast and 37 percent of Delta cotton acreage was planted with GM seed, compared to 24 percent in the Southwest and only 10 percent in the Southern Plains. Herbicide-resistant cotton was planted on more than a half-million acres in the Delta. The adoption rate for herbicide-resistant cotton, 14 in the Southeast and 17 percent in the Delta, was significantly higher than in the other regions. Only 6 percent or less of the cotton acreage in regions to the west was in herbicide-resistant seed. Almost 800,000 acres in the Southeast were planted with Bt seed in 1997 including more than a quarter of cotton acreage. Bt seed was used on about 21 percent of acreage in the Delta and 17 percent of acreage in the Southwest, but on only 5 percent of acreage in the Southern Plains, significantly less than in all other regions.

Herbicide-resistant Soybeans

Soybean yields during 1997 were significantly higher in the Corn Belt, Southeast, and Northern Plains on herbicide-resistant seed acreage, all at 6 bushels per acre above acreage planted with other purchased seed (Table 3). Among cultural practices, tillage use was most different between the production systems using each seed technology. The use of herbicide-resistant seed was associated with reduced tillage use in 3 of 4 regions, and used at a significantly higher rate with no-till systems in the Southeast and Northern Plains. Neither mean seeding rate nor seeding method were significantly different. Differences in acreage irrigated and in various cropping systems were also not significant between the seed technologies. Acreage in herbicide-resistant seed was planted about 1 to 2 weeks earlier than acreage planted to other purchased seed in 3 of the 4 regions, possibly due to improved timeliness with fewer tillage operations.

Significantly fewer herbicide treatments were used on acreage with herbicide-resistant seed than with other purchased seed acres, averaging about 1 less treatment in each of the 4 regions (Table 4). Significantly more of the acreage planted with herbicide-resistant seed was treated with post-emergent applications in 3 of 4 regions, and significantly less with pre-emergent herbicides in all regions. Cultivating for weeds was less common with herbicide-resistant seed than for other purchased seed, covering significantly fewer acres in 3 regions. It was thought that seed programs using herbicide-resistant seed might reduce the need for weed scouting because of the broad-spectrum nature of glyphosate. However, no difference in acres scouted was observed, and only in the Corn Belt was less acreage commercially scouted.

Seed costs on acreage in the herbicide-resistant varieties averaged around $10 per acre higher than for other varieties and included a charge for the technology (Table 4). Pesticide costs were significantly lower on acreage in herbicide-resistant seed for all regions, saving producers $7-$11 per acre. Cultivation costs were also significantly less in 3 of 4 regions, saving producers about another $1 per acre. However, the higher seed costs offset the reduced pesticide and cultivation costs so that total seed and pest control costs per acre were not significantly different between acreage in the seed technologies. Despite higher yields on acreage with herbicide-resistant seed, per bushel costs were also not significantly different from those on acreage in other purchased seed.

Herbicide-resistant Cotton

Yields of herbicide-resistant cotton were not significantly different from yields of other purchased seed in the Southeast, but were significantly less, more than 80 pounds per acre, in the Delta (Table 5). As for cultural practices, no-till cotton acreage was significantly greater with herbicide-resistant seed in the Southeast, but still only 12 percent of acreage was in no-till. Other cultural practices used on herbicide-resistant

TABLE 3 Soybean Yields and Cultural Practices Used on Acreage Planted to Herbicide-resistant and Other Purchased Soybean Seed[a], by Region, 1997

Technology[b]	Corn Belt	Southeast	Delta	Northern Plains
Herbicide-resistant seed:				
Yield (bu/acre)	52**	39**	29	45**
Seeding rate (pounds)	66	64	55	60
Seeding method (percent)				
Drill	43	67	22	31
Row	56	33	77	69
Planting date (Julian)	127*	145**	140*	141
Irrigation (percent)	1	0	18	17
Previous crop (percent)				
Corn	62	37	4	65
Soybeans	26	11	43	6
Wheat double crop	2	38	8	2
Rice	0	0	18	0
Tillage system (percent)				
Conventional	3**	27	42	2**
Reduced	12**	1*	26	13*
Mulch-till	37	3**	1	23
No-till	48	69**	31	62**
Other purchased seed[c]:				
Yield (bu/acre)	46	33	34	39
Seeding rate (pounds)	68	63	57	63
Seeding method (percent)				
Drill	55	54	30	44
Row	44	39	69	55
Planting date (Julian)	139	160	147	142
Irrigation (percent)	2	0	25	14
Previous crop (percent)				
Corn	85	25	7	64
Soybeans	9	30	30	14
Wheat double crop	2	35	25	0
Rice	1	0	28	0
Tillage system (percent)				
Conventional	14	36	60	14
Reduced	28	12	14	30
Mulch-till	27	13	8	37
No-till	30	40	18	17

**Significantly different from other purchased seed at the 5 percent level.
*Significantly different from other purchased seed at the 10 percent level.

[a]Means are statistically compared using a difference of means test. Differences between the mean estimates cannot necessarily be attributed to use of the GM seed since they are influenced by several other factors not controlled for in the analysis.

[b]Units are in parentheses. Percent refers to the percent of planted acreage.

[c]Excludes acreage planted with homegrown seed.

TABLE 4 Pesticide Use, Pest Management Practices, and Seed and Pest Control Costs on Acreage Planted to Herbicide-resistant and Other Purchased Soybean Seed[a], by Region, 1997

Technology[b]	Corn Belt	Southeast	Delta	Northern Plains
Herbicide-resistant seed:				
Herbicide treatments	1.86**	1.33**	1.75**	1.92**
Pre-emergent (percent)	32**	22**	44**	41**
Post-emergent (percent)	96**	88	94**	91*
Cultivator times over	0.10**	0.05	0.25*	0.15**
Weed scouting (percent)				
All scouts	83	71	71	86
Commercial scouts	2**	6	25	10
Costs ($/acre):				
Seed[c]	30.04**	31.74**	26.44**	27.87**
Seeding	3.93	3.77	2.75**	3.71
Pesticides	19.04**	16.04**	20.99**	19.16**
Pesticide application	2.94	2.56*	3.63	3.85
Pest scouting	0.29	0.67	0.22**	0.88
Cultivation	0.30**	0.17	0.50**	0.32**
Seed & pest control ($/acre)	56.55	54.95	54.52	55.79
Seed & pest control ($/bu.)	1.09	1.40	1.87	1.25
Other purchased seed[d]:				
Herbicide treatments	2.99	3.01	3.24	2.65
Pre-emergent (percent)	76	67	84	71
Post-emergent (percent)	76	84	65	75
Cultivator times over	0.31	0.17	0.59	0.39
Weed scouting (percent)				
All scouts	86	80	70	82
Commercial scouts	14	7	12	7
Costs (dollars per acre)				
Seed	19.15	16.02	16.28	19.04
Seeding	3.88	3.70	3.56	3.77
Pesticides	28.42	27.36	27.47	26.54
Pesticide application	3.56	3.53	4.27	2.64
Pest scouting	0.27	0.50	0.72	0.38
Cultivation	1.09	0.43	1.76	1.12
Seed & pest control ($/acre)	56.36	51.53	54.06	53.49
Seed & pest control ($/bu.)	1.22	1.58	1.61	1.37

**Significantly different from other purchased seed at the 5 percent level.
*Significantly different from other purchased seed at the 10 percent level.

[a]Means are statistically compared using a difference of means test. Differences between the mean estimates cannot necessarily be attributed to use of the GM seed since they are influenced by several other factors not controlled for in the analysis.
[b]Units are in parentheses. Percent refers to the percent of planted acreage.
[c]Includes the seed technology fee.
[d]Excludes acreage planted with homegrown seed.

TABLE 5 Cotton Yields and Cultural Practices Used on Acreage Planted to Herbicide-resistant and Other Purchased Cotton Seed[a], by Region, 1997

Technologyb	Southeast	Delta
Herbicide-resistant seed:		
Yield (lbs/acre)	672	731**
Seeding rate (pounds)	10	12
Seeding method (percent)		
Drill	13	7
Row	87	93
Planting date (Julian)	120	128
Irrigation (percent)	11	48
Previous crop (percent)		
Cotton	72	90
Corn	10	8
Soybeans	7	2
Peanuts	0**	0
Tillage system (percent)		
Conventional	85	92
No-till	12*	4
Other purchased seed[c]:		
Yield (lbs/acre)	700	816
Seeding rate (pounds)	10	12
Seeding method (percent)		
Drill	13	3
Row	87	97
Planting date (Julian)	122	125
Irrigation (percent)	8	35
Previous crop (percent)		
Cotton	57	89
Corn	5	5
Soybeans	8	2
Peanuts	20	0
Tillage system (percent)		
Conventional	94	97
No-till	3	1

**significantly different from other purchased seed at the 5 percent level.
*significantly different from other purchased seed at the 10 percent level.

[a]Means are statistically compared using a difference of means test. Differences between the mean estimates cannot necessarily be attributed to use of the GM seed since they are influenced by several other factors not controlled for in the analysis.

[b]Units are in parentheses. Percent refers to the percent of planted acreage.

[c]Excludes acreage planted with homegrown and Bt cotton seed.

cotton acreage were not significantly different from those on acreage with other purchased seed, except that in the Southeast the herbicide-resistant seed was not used on acreage planted to peanuts in the previous year.

Herbicide treatments were significantly less on herbicide-resistant acreage in the Delta, nearly 3 fewer treatments (Table 6). In the Southeast, herbicide treatments were not significantly less, but much less of the herbicide-resistant acreage was cultivated for weeds.

Significantly less acreage was treated with pre-emergent herbicide applications in both regions when compared to the acreage of other purchased seed. Despite significantly fewer herbicide treatments in the Delta, pesticide costs were not different in either the Delta or Southeast. Costs on herbicide-resistant acreage were about $3 per acre less for cultivation in the Southeast, but significantly higher for seed in the Delta. Differences in the total costs of seed and pest control per acre were not significant between acreage in each seed technology. Likewise, unit-costs were not significantly different despite lower yields on herbicide-resistant acreage in the Delta.

Bt Cotton

Yields, practices, and input use and costs for Bt cotton acreage were compared to those on acreage of other purchased seed where the Bt target pests were treated with insecticides. Differences in yields on Bt and other purchased seed acreage were not significant in either the Southeast or Delta (Table 7). Bt cotton was seeded at a lower rate in the Delta and significantly less of the Bt cotton acreage was irrigated. Other differences in cultural practices were not significant.

Total insecticide treatments were significantly fewer on Bt cotton acreage in the Southeast with a major difference in applications to control the Bt target pests (Table 8). Nearly 1.2 fewer applications were used with the Bt technology for bollworm and budworm control. Total insecticide treatments were not significantly different on Bt and other purchased seed acreage in the Delta, but applications for the Bt target pests included about 1.4 less treatments on Bt acreage. Bt acreage in the Delta was infested more heavily with beetles, weevils, and/or wireworms than acreage in other purchased seed. Almost 1.5 more applications were made for these pests on Bt acreage than on acreage in other purchased seed.

Despite the differences in insecticide use, no significant differences were measured in pesticide costs on acreage in either region. Average seed and pest control costs per acre were significantly greater on aggregates of Bt cotton acreage, about $20 higher in the Southeast and $34 per acre higher in the Delta, compared to costs on acreage in other purchased seed. The cost differences are similar in magnitude to the additional technology charge associated with the Bt technology. Unit-costs were also significantly greater on Bt cotton acreage in the Delta, about 5 cents per pound.[2]

TABLE 6 Pesticide Use, Pest Management Practices, and Seed and Pest Control Costs on Acreage Planted to Herbicide-resistant and Other Purchased Cotton Seed[a], by Region, 1997

Technology[b]	Southeast	Delta
Herbicide-resistant seed:		
Herbicide treatments	3.77	2.38**
Pre-emergent (percent)	67**	41**
Post-emergent (percent)	86	63
Cultivator times over	0.44**	1.45
Weed scouting (percent)		
All scouts	78	69
Commercial scouts	49	27
Costs ($/acre):		
Seed	8.88	14.17**
Seed technology fee	8.45**	7.30**
Seeding	5.39*	5.17*
Pesticides	55.32	71.93
Pesticide application	10.58	7.50**
Pest scouting	5.42	3.81
Cultivation	0.83*	3.94
Seed & pest control ($/acre)	94.88	113.82
Seed & pest control ($/lb.)	0.14	0.16
Other purchased seed[c]:		
Herbicide treatments	3.99	5.13
Pre-emergent (percent)	99	98
Post-emergent (percent)	88	97
Cultivator times over	1.80	1.78
Weed scouting (percent)		
All scouts	74	67
Commercial scouts	39	33
Costs ($/acre):		
Seed	7.73	9.85
Seeding	4.70	3.73
Pesticides	71.42	82.51
Pesticide application	8.93	11.49
Pest scouting	5.54	5.00
Cultivation	3.93	4.35
Seed & pest control ($/acre)	102.25	116.92
Seed & pest control ($/lb.)	0.15	0.14

**significantly different from other purchased seed at the 5 percent level.
*significantly different from other purchased seed at the 10 percent level.
[a]Means are statistically compared using a difference of means test. Differences between the mean estimates cannot necessarily be attributed to use of the GM seed since they are influenced by several other factors not controlled for in the analysis.
[b]Units are in parentheses. Percent refers to the percent of planted acreage.
[c]Excludes acreage planted with homegrown and Bt cotton seed.

TABLE 7 Cotton Yields and Cultural Practices Used on Acreage Planted to Bt and Other Purchased Cotton Seed[a], by Region, 1997

Technology[b]	Southeast	Delta
Bt seed:		
Yield (lbs/acre)	764	805
Seeding rate (pounds)	9	10**
Seeding method (percent)		
Drill	20	1
Row	80	99
Planting date (Julian)	124	126*
Irrigation (percent)	15	14**
Previous crop (percent)		
Cotton	67	96
Corn	6	3
Soybeans	4	0
Peanuts	16	0
Other purchased seed[c]:		
Yield (lbs/acre)	720	874
Seeding rate (pounds)	10	11
Seeding method (percent)		
Drill	17	3
Row	83	97
Planting date (Julian)	122	122
Irrigation (percent)	8	32
Previous crop (percent)		
Cotton	61	89
Corn	4	4
Soybeans	10	2
Peanuts	21	0

**significantly different from other purchased seed at the 5 percent level.
*significantly different from other purchased seed at the 10 percent level.

[a]Means are statistically compared using a difference of means test. Differences between the mean estimates cannot necessarily be attributed to use of the GM seed since they are influenced by several other factors not controlled for in the analysis.

[b]Units are in parentheses. Percent refers to the percent of planted acreage.

[c]Excludes acreage planted with homegrown and herbicide-resistant cotton seed, and acreage where the Bt target pests, bollworms and budworms, were not treated.

TABLE 8 Pesticide Use, Pest Management Practices, and Seed and Pest Control Costs on Acreage Planted to Bt and Other Purchased Cotton Seed[a], by Region, 1997

Technology[b]	Southeast	Delta
Bt seed:		
Insecticide treatments	1.61*	5.38
For Bt targets-bollworms, budworms	0.28**	0.45**
For beetles, weevils, wireworms	0.03	2.56**
Insect scouting (percent)		
All scouts	100	98
Commercial scouts	72	92
Costs ($/acre):		
Seed	8.27	9.81
Seed technology fee	32.09**	32.02**
Seeding	5.08	3.90
Pesticides	67.05	85.02
Pesticide application	8.72	14.52
Pest scouting	4.99	6.23
Cultivation	3.55	3.95
Seed & pest control ($/acre)	129.75**	155.45**
Seed & pest control ($/lb.)	0.17	0.19**
Other purchased seed[c]:		
Insecticide treatments	2.22	4.11
For Bt targets-bollworms, budworms	1.45	1.86
For beetles, weevils, wireworms	0.06	1.09
Insect scouting (percent)		
All scouts	100	100
Commercial scouts	73	95
Costs ($/acre):		
Seed	7.63	9.22
Seeding	4.73	3.77
Pesticides	78.44	84.55
Pesticide application	9.91	12.54
Pest scouting	5.52	6.36
Cultivation	3.80	4.75
Seed & pest control ($/acre)	110.03	121.20
Seed & pest control ($/lb.)	0.15	0.14

**significantly different from other purchased seed at the 5 percent level.
*significantly different from other purchased seed at the 10 percent level.

[a]Means are statistically compared using a difference of means test. Differences between the mean estimates cannot necessarily be attributed to use of the GM seed since they are influenced by several other factors not controlled for in the analysis.

[b]Units are in parentheses. Percent refers to the percent of planted acreage.

[c]Excludes acreage planted with homegrown and herbicide-resistant cotton seed, and acreage where the Bt target pests, bollworms and budworms, were not treated.

Conclusions

Substantial acreage of soybeans and cotton were planted with genetically modified seed technologies in 1997. About 17 percent of soybean acreage and 25 percent of cotton acreage was planted with GM seed in 1997. Regional differences in adoption rates were also significant. Significantly more of the soybean acreage in southern states had been planted with herbicide-resistant seed than had soybean acreage in northern states. Herbicide-resistant and Bt cotton had also been adopted at higher rates on acreage in eastern compared to western cotton producing states. Regional adoption rates for GM seed in 1997 appear to be tied to the pest pressure that characterizes each area, with the highest adoption rates in the relatively humid Southeast and Delta.

Results of the analysis regarding input use and practices associated with herbicide-resistant seed tend to concur with much of the scientific and industry claims about the environmental qualities of the technology. Herbicide treatments on acreage planted to herbicide-resistant soybeans and cotton were reduced in 1997. Significantly more of the treatments on the herbicide-resistant acreage were post-emergent applications in response to observed weed conditions, while significantly less were pre-emergent preventative treatments. Post-emergence weed control can be regarded as more environmentally friendly because it treats actual weed problems rather than potential problems and thus limits pesticide applications to only those needed. The relationship between herbicide-resistant seed and a reduction in tillage use in soybeans, and to a more limited extent in cotton, is also evidence that this technology can be part of production systems that are more friendly towards the environment.

The comparison of mean costs and mean yields over highly aggregated regions did not show a clear cost advantage on acreage planted with the herbicide-resistant technology for soybeans or cotton in 1997. Pesticide costs were significantly lower on soybean acreage planted with the herbicide-resistant seed, but costs of seed including a seed technology fee were higher. Greater soybean yields on herbicide-resistant acreage were also not sufficient to significantly lower unit-costs relative to those on acreage of other purchased seed. Similar results were found for the herbicide-resistant cotton.

The same general implications can be drawn about the Bt technology for cotton. Insecticide treatments for target pests on Bt cotton acreage were low relative to other acreage with these pest problems. The comparison of yields and costs did not suggest either a cost advantage or cost disadvantage on cotton acreage utilizing the Bt technology in 1997. Bt cotton yields were not significantly greater than for traditional technologies when means were compared, but this could be misleading since other, uncontrolled variables are influencing yields within each region. The Bt seed technology fee was greater than observed average reductions in seed and pest control costs.

Evidence from the body of literature about GM seed does suggest that the relative costs and yields from GM seed compared to traditional varieties likely vary from year-to-year and area-to-area according to annual growing conditions. A more definitive evaluation of the impacts of GM seed will require more information about how these technologies perform under a variety of growing conditions.

Endnotes

[1]The authors are Agricultural Economists with the Economic Research Service, U.S. Department of Agriculture.

[2]These comparisons of mean values give implications that differ somewhat from those of Fernandez-Cornejo, Klotz-Ingram, and Jans who used ARMS data in an econometric analysis that found a positive effect on cotton yields and profits from the adoption of the Bt and herbicide-resistant technologies. A contributing reason for this difference is that their non-adopter group included all farms not using a specific GM seed technology, while in this study acreage in each GM seed technology was compared to acreage in other non-GM purchased seed.

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