Background

Pest Management on Major Field Crops

Corn is the largest herbicide user in U.S. agriculture, and 96 percent of the 62.2 million acres devoted to corn production in the 10 major corn-producing States were treated with more than 164 million pounds of herbicides in 1997 (USDA, 1998b). Atrazine was the top herbicide in 1997, as farmers applied more than 47 million pounds of this chemical (table 1). Metolachlor was second (nearly 44 million pounds applied), followed by acetochlor (28 million pounds) and cyanazine (16 million pounds).

Soybean production in the United States also uses a large amount of herbicides, and 97 percent of the 66.2 million acres devoted to soybean production in the 19 major soybean-producing States were treated with more than 78 million pounds of herbicides in 1997 (USDA, 1998). Pendimethalin was the top herbicide, as farmers applied more than 17 million pounds in 1997 (table 2). Glyphosate, use of which grew substantially over 1996 levels, was second (15 million pounds), followed by trifluralin (12 million pounds) and metolachlor (9 million pounds). Increased use of glyphosate has corresponded with the growth of herbicide-tolerant crop programs that use glyphosate as the primary herbicide.

Cotton production relies heavily upon herbicides to control weeds, often requiring applications of two or more herbicides at planting and postemergence herbicides later in the season (Culpepper and York, 1998). Close to 28 million pounds of herbicides were applied to 97 percent of the 13 million acres devoted to upland cotton production in the 12 major cotton-producing States in 1997 (USDA, 1998). Trifluralin was the top herbicide applied in 1997 (5.5 million pounds), followed closely by MSMA (4.9 million pounds) and fluometuron (4.9 million pounds) (see table 3).

Cotton production also uses a large amount of insecticides, and 77 percent of the 13 million acres devoted to upland cotton production in the 12 major States were treated with 18 million pounds of insecticides in

Table 1—Major herbicides used on corn, 1997[1]

Herbicide active ingredient	Area applied	Applications	Rate per crop year	Total applied
	Percent	*Number*	*Lbs./acre*	*Million lbs.*
Acetamides				78.86
Acetochlor	24	1.0	1.90	28.16
Alachlor	4	1.0	1.80	4.58
Metolachlor	35	1.0	2.00	43.77
Propachlor	<1	1.0	1.95	0.35
Triazines				64.63
Atrazine	69	1.1	1.09	47.16
Cyanazine	14	1.0	1.94	16.49
Simazine	1	1.0	1.36	0.98
Glyphosate	4	1.0	0.53	1.43
Other herbicides				21.13[2]
2, 4-D	9	1.0	0.37	2.09
Dicamba	29	1.0	0.32	5.80
Dimethenamid	6	1.0	1.21	4.73
EPTC	1	1.0	3.71	3.17
Pendimethalin	3	1.0	1.13	1.76
Bromoxynil	6	1.0	0.26	1.03
Bentazon	3	1.0	0.46	0.94
Paraquat	1	1.0	0.56	0.38
Nicosulfuron	10	1.0	0.03	0.16
Imazethapyr	1	1.0	0.02	0.01
Total				164.05

[1] 62.2 million acres were planted for the 19 States surveyed.
[2] Includes other herbicides not listed.
Source: USDA, 1998b.

Table 2—Major herbicides used on soybeans, 1997[1]

Herbicide active ingredient	Area applied	Applications	Rate per crop year	Total applied
	Percent	*Number*	*Lbs./acre*	*Million lbs.*
Acetamides				13.41
Metolachlor	7	1.1	1.87	8.91
Alachlor	3	1.0	2.36	4.50
Glyphosate	28	1.0	0.81	14.92
Other herbicides				49.88[2]
Pendimethalin	25	1.1	0.95	17.53
Trifluralin	21	1.0	0.88	12.27
Bentazon	11	1.0	0.65	4.74
Clomazone	5	1.0	0.71	2.32
2, 4-D	8	1.0	0.39	2.11
Acifluorfen	12	1.0	0.21	1.69
Metribuzin	10	1.0	0.25	1.69
Imazethapyr	38	1.0	0.05	1.24
Sethoxydim	7	1.0	0.21	1.03
Total				78.21

[1] 66.2 million acres were planted for the 19 States surveyed.
[2] Includes other herbicides not listed.
Source: USDA, 1998b.

1997 (USDA, 1998). Malathion was the top insecticide, as farmers applied more than 7 million pounds of this chemical in 1997 (table 4). Aldicarb was second (2.4 million pounds), followed by methyl parathion (2 million pounds) and acephate (0.9 million pounds).

Previous Studies on the Farm Effects of Genetically Engineered Crops

Many field-test and enterprise studies have analyzed the agronomic, environmental, and budget effects of adopting genetically engineered crops (for example, Arnold et al., 1998; Culpepper and York, 1998; Delannay et al., 1995; Goldman et al., 1996; Keeling et al., 1996; ReJesus et al., 1997; Roberts et al., 1998; Vencill, 1996). However, only a few studies have investigated the actual yield, pesticide use, and economic effects of using farm-level adoption data (Fernandez-Cornejo and Klotz-Ingram, 1998; Gibson et al., 1997; Marra et al., 1998; Stark, 1997). Some of the findings of these studies are summarized below.

Herbicide-Tolerant Soybeans

♦ Prior to commercial release of the technology, yields from plots with a glyphosate-tolerant soybean line treated with glyphosate were compared with non-treated control plots at numerous sites in both northern and southern soybean-producing areas—17 locations in 1992, 23 locations in 1993, and 18 locations in 1994 (Delannay et al., 1995). No significant yield reductions resulted from the glyphosate 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, with no negative impact on yields.

♦ Data from field trials in west Tennessee were used in an economic analysis of glyphosate-tolerant soybeans (Roberts et al., 1998). Comparing per acre net returns from 14 trials, the returns from the glyphosate system were 13 percent higher than the returns from the second most profitable system. The higher returns from the glyphosate system resulted from both higher yields and lower herbicide costs.

♦ Research results from trials in Mississippi (Arnold et al., 1998) have also shown higher yields and net returns from glyphosate-tolerant soybeans versus conventional varieties.

♦ Using farm-level data, Marra et al. (1998) estimated that the net farm returns from using glyphosate-tolerant soybeans were about $6.00 per acre higher than

Table 3—Major herbicides used on cotton, 1997[1]

Herbicide active ingredient	Area applied	Applications	Rate per crop year	Total applied
	Percent	*Number*	*Lbs./acre*	*Mil. lbs.*
Triazines				3.87
Cyanazine	18	1.3	0.95	2.20
Prometryn	19	1.2	0.66	1.67
Other herbicides				22.20[2]
Trifluralin	55	1.1	0.76	5.46
MSMA	29	1.4	1.30	4.90
Fluometuron	44	1.3	0.84	4.85
Pendimethalin	28	1.1	0.69	2.49
Norflurazon	13	1.0	0.63	1.04
Diuron	12	1.1	0.55	0.88
Metolachlor	5	1.1	1.17	0.74
Glyphosate	14	1.3	0.81	1.54
Total				27.61

[1] 13.1 million acres were planted for the 12 States surveyed.
[2] Includes other herbicides not listed.
Source: USDA, 1998b.

Table 4—Major insecticides used on cotton, 1997[1]

Insecticide active ingredient	Area applied	Applications	Rate per crop year	Total applied
	Percent	*Number*	*Lbs./acre*	*Mil. lbs*
Organophosphates				11.76
Malathion	11	5.9	4.97	7.25
Methyl parathion	13	2.7	1.22	2.00
Acephate	10	1.7	0.72	0.90
Phorate	7	1.0	0.73	0.67
Profenofos	4	1.6	0.98	0.56
Dicrotophos	8	1.7	0.35	0.38
Pyrethroids				0.41
Cypermethrin	8	1.7	0.14	0.14
Lambdacyhalothrin	18	1.9	0.05	0.13
Cyfluthrin	13	1.7	0.05	0.09
Zeta-cypermethrin	5	1.4	0.05	0.03
Tralomethrin	2	2.1	0.04	0.01
Fenpropathrin	1	1.1	0.19	0.01
Other insecticides				6.11[2]
Aldicarb	27	1.0	0.68	2.43
Chlorpyrifos	4	1.9	1.45	0.81
Oxamyl	15	1.6	0.33	0.65
Endosulfan	2	2.3	0.88	0.27
Dicofol	2	1.0	1.13	0.26
Total				18.28

[1] 13.1 million acres were planted for the 12 States surveyed.
[2] Includes other insecticides not listed.
Source: USDA, 1998b.

those of traditional varieties. The lower herbicide costs alone were enough to outweigh the higher seed costs and technology fee.

Herbicide-Tolerant Cotton

♦ Field tests from Arkansas and Missouri (Goldman et al., 1996), Georgia (Vencill, 1996), and Texas (Keeling et al., 1996) indicated little difference 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). While yields and net returns of the glyphosate systems (including the technology fee) were similar to, but no greater than, those with the most effective traditional systems, fewer herbicide applications were required and less total herbicide was used with the glyphosate systems.

Herbicide-Tolerant Corn

♦ Using USDA field-level survey data on herbicide-tolerant corn adoption in 1996, Fernandez-Cornejo and Klotz-Ingram (1998) estimated the effects of herbicide-tolerant corn adoption on yields, profits (including the technology fees), and herbicide use. They concluded that lower herbicide use (especially for the acetamide herbicide family) was significantly related to the adoption of these corn varieties. Adoption of those corn varieties had a small effect on yields. The effect on profits was not statistically significant.

Bt Cotton

♦ 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 to control insect and plant growth were reduced by 2.5 applications per acre on 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 between Bt and non-Bt varieties, but higher yields for Bt cotton produced significantly higher net returns, despite the technology fee.

♦ 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 yields of non-Bt varieties.

♦ In a 3-year study in Arkansas, Bt cotton produced higher yields and profits (despite the technology fees) in 1996 and 1998, but lower yields and profits in 1997 (Bryant, Robertson, and Lorenz III, 1998).

♦ Marra et al. (1998) in a survey of 300 farmers in North and South Carolina, Georgia, and Alabama, found that yields were significantly greater for Bt cotton in the lower southern States (Georgia and Alabama) and for the entire sample, but not for the upper southern States. They also found that farmers growing Bt cotton made fewer insecticide applications, especially of pyrethroid insecticides. The rate of return was less in the upper South than the lower South. The additional crop revenues and insecticide savings outweighed the higher seed and technology costs in the lower South.

Bt Corn

♦ Marra et al. (1998) determined that use of Bt corn resulted in better control of the European corn borer, boosting yields by 4 to 8 percent, depending on location and year. On the other hand, Bt corn use resulted in only modest savings from reduced insecticide applications. However, returns from increased corn yields were greater than the seed premiums and technology fees. This translated into net gains of about $3-$16 per acre.

In sum, several field test and enterprise studies have analyzed the effects of adopting genetically engineered crops, but few studies have investigated the yield, pesticide use, and profit effects from farm-level data. The main results for these studies are summarized in table 5.

Table 5—Summary of the effects of genetically engineered crops on yields, pesticide use, and returns, as reported in previous studies

Crop/ researchers	Data source	Yield	Effects on pesticide use	Returns
Herbicide-tolerant soybeans				
Delannay et al., 1995	Experiments	Same	na	na
Roberts at al., 1998	Experiments	Increase	Decrease	Increase
Arnold et al., 1998	Experiments	Increase	na	Increase
Marra et al., 1998	Survey	Increase	Decrease	Increase
Herbicide-tolerant cotton				
Vencill, 1996	Experiments	Same	na	na
Keeling et al., 1996	Experiments	Same	na	na
Goldman et al., 1998	Experiments	Same	na	na
Culpepper and York, 1998	Experiments	Same	Decrease	Same
Herbicide-tolerant corn				
Fernandez-Cornejo and Klotz-Ingram, 1998	Survey	Increase	Decrease	Same
Bt cotton				
Stark, 1997	Survey	Increase	Decrease	Increase
Gibson et al., 1997	Survey	Increase	na	Increase
ReJesus et al., 1997	Experiments	Same	na	Increase
Bryant et al., 1998[1]	Experiments	Increase	na	Increase
Marra et al., 1998[2]	Survey	Increase	Decrease	Increase
Bt corn				
Marra et al., 1998	Survey	Increase	Decrease	Increase

na = not available
[1] Results are for 1996 and 1998. Results were different in 1997 when pest pressure was low.
[2] Result is for the lower South (Alabama and Georgia).