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COMPARISON OF CONVENTIONAL AND TRANSGENIC TECHNOLOGIES UNDER ALTERNATIVE CULTURAL PRACTICES FOR COTTON IN GEORGIA

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Abstract

New developments in production practices and technological advances in seed genetics give cotton farmers new options to consider in their production decisions. This study was conducted to determine allocative efficiency and cost effectiveness of growing conventional and transgenic cotton varieties under alternative cultural practices in South Georgia. Conventional, Roundup Ready (*glyphosate* resistant), Bt (*Bacillus thurengiensis)*, Roundup Ready/Bt, and Buctril Resistant (*bromoxynil* resistant) cotton varieties were compared for conventional tillage and strip-till cultural practices. Data for the study was obtained from a survey of cotton producers in South Georgia conducted in the early spring of 2000. A linear programming model, specifically data envelopment analysis (DEA), was used to compare costs and returns associated with various combinations of tillage and technology. In this model, the linear program views input/output combinations of individual fields as separate data management units (dmu's).

Ninety-two percent of fields in the model's frontier of efficient dmu's utilized transgenic varieties. And 70 percent of fully efficient fields utilized strip-tillage. Cost comparisons across tillage practices revealed that strip tillage allowed considerable savings on most variable inputs. While the cost structure was similar across varieties, the use of transgenic varieties typically resulted in higher yields. Overall, transgenic fields and strip till fields were 11 percent more efficient than conventional fields. These results suggest that combining genetically modified cotton varieties with the strip till cultural practice yields a more efficient use of inputs relative to the level of output. See tables 1 and 2.

In addition to comparing DEA rank, we also averaged yield and variable input costs for all fields of each tillage practice. By comparing average yield and input costs of all strip-till fields to those reported on conventional tillage fields, we have a simple comparison of variable costs and yield for conventional tillage vs. strip-till. See table 3.

Introduction

Since the mid nineties, new developments in production practices and technological advances in seed genetics have given cotton farmers new options to consider in trying to reduce input cost. Alternative cultural practices available to farmers are conventional tillage and conservation tillage (strip-till, no-till or reduced tillage). Even though conventional tillage is still more common, conservation tillage has become an accepted cultural practice for cotton/peanut/wheat rotation in some areas of South Georgia. Strip-till seems to be the most common form of conservation tillage in South Georgia. The popularity of conventional tillage may be attributed to past experience, historical success, perceived fertilizer effectiveness, or the aesthetic quality of having no residual matter on the ground surface. Cotton growers report savings on equipment cost and labor cost as reasons for a conversion to conservation tillage. Soil and water conservation are also commonly reported reasons for converting to a conservation tillage program.

Due to technological advances, farmers have access to genetically modified cotton varieties, such as Bt (contains *Bacillus thurengiensis* gene), Roundup Ready (*glyphosate* resistant), Buctril Resistant (*bromoxynil* resistant) and stacked gene (Roundup Ready/Bt). These transgenic strains of cotton have a built-in resistance to certain pests (Bt cotton is toxic to the cotton bollworm and tobacco budworm) or tolerance to herbicides (Roundup Ready and Buctril Resistant cotton). Regardless of tillage practice, Bt cotton gives growers the advantage of improved bollworm/budworm control with a possible reduction in insecticide sprays. Roundup Ready cotton allows for effective weed control while reducing and sometimes eliminating the need for plowing weeds. Thus, one would expect herbicide resistant technology to enhance the cost effeciency of strip-till. Transgenic cotton varieties allow a reduction in the total cost of chemical application. Though genetically modified cotton comes with an added technology fee, herbicide and insect resistance reduces the amount of insecticide and herbicide placed in the environment.

In addition to Roundup Ready (*glyphosate resistant*), Bt (*Bacillus thurengiensis*) or the combination of these known as stacked gene cotton, growers may choose to plant conventional cotton. Conventional cotton, ordinarily grown under conventional tillage, can be grown under alternative tillage practices as well. However, weed management in reduced tillage without over-the-top sprays of glysphosate is very difficult. Sometimes post-emergence cultivation of conservation tillage fields is necessary. And weeds may still reduce yields, because the results of over-top roundup sprays are difficult to emulate with a cultivator and directed sprays alone. Given all these choices, it becomes increasingly difficult for farmers to evaluate all these alternatives and combinations of variable inputs in order to maximize profits.

Previous research examined different aspects of growing genetically modified cotton varieties. Speed and Ferreira (1998) analyzed implications of Roundup Ready cotton on weed control costs. Kerby and Voth (1998) evaluated gene efficacy, gene performance, agronomic performance, and weed control systems associated with Roundup Ready cotton. Brown and Bednarz (1998) examined the effects of weed control methods on Roundup cotton yields. McCloskey (1998) discussed the advantages and disadvantages of Buctril, Staple and Roundup Technologies. Wier, Mullins and Mills (1998) conducted economic analysis of Bolgard (Bt) cotton relative to conventional cotton varieties in Mississippi and concluded that it was superior to conventional cotton. However, Bachler, Mott and Morrison (1998) did not find significant economic benefits of growing Bt cotton in North Carolina and recommended it only for difficult to treat fields and environmentally sensitive areas. Limited information exists on comparing costs and benefits across genetically modified varieties. Therefore, there is a need for a more general and conclusive study of economic impacts of growing genetically modified cotton varieties.

Another aspect that needs further investigation is the effect of combining different technologies with alternative tillage practices. Bell, Harris, and Wilson (1998) evaluated the implications of conservation tillage (strip tillage in particular) on fertilizer effectiveness for conventional cotton. It has also been argued that some transgenic cotton varieties (Roundup Ready) may enhance the benefits of conservation tillage. With these tradeoffs in mind, the objective of this study is to provide an economic analysis of allocative efficiency and cost effectiveness of using different cultural practices and technologies for production of upland cotton in South Georgia.

Data

As production costs increase counter to returns, efficient allocation of inputs, relative to output, is paramount to sustaining a farming operation. This study was based on the results of a survey of cotton producers in South Georgia. A survey of cotton producers utilizing various combinations of tillage and transgenic technology was conducted in the Fall of 1999. The survey elicited data on production practices, costs and yields on a field level. Cross sectional data was generated on the cost effectiveness of variable inputs (seed, herbicide, insecticide, labor, growth regulator and operating cost of machinery) as well as variable costs associated with irrigation. The following types of cotton were compared for conventional tillage and the strip-till cultural practice: conventional, Roundup Ready, Bt, Roundup Ready/Bt, and Buctril Resistant. The data set includes 3 observations of each of the 5 types of cotton, except Buctril Resistant cotton. Only one observation for strip-till/Buctril Resistant cotton was available in the survey area.

The survey generated data on cotton yields and the cost of fertilizer, seed, and scouting. Defoliant, herbicide, insecticide and growth regulator use was reported as application rate per acre. A 1999 price list was applied to these reported rates to arrive at a cost per acre for each of these inputs. Operating hours per acre for each tractor was calculated using the reported number of acres covered per hour of operation. It was assumed that time involved in maintenance and repairs, handling seed, down time due to rain, etc. was equal to 50 percent of operating time. Therefore, the number of hours of tractor time per acre was multiplied by a factor of 1.5 to arrive at total number of hours of labor time devoted to each field.

Equipment operating cost was estimated based on information elicited in the survey in conjunction with UGA Cooperative Extension approach (Givan, 1991). This method considers 18% of purchase price to be fixed cost. The average age of equipment reported in the survey was 9 years. Therefore, 1990 retail prices were used to estimate purchase prices for each tractor (North American Equipment Dealers Association, 1995). Purchase price for implements was obtained in Doane's Agricultural Report (Estimating Machinery Operating Costs, 1997). Variable cost per hour is estimated by multiplying purchase price by a repair factor, 90% for tractors, 75% for pickers, 80% for disks, plows and cultivators, 75% for planters, and 180% for mowers and then dividing by the number of hours in the life of the machine. Interest on operating capital was assumed to be nine percent based on Extension budgets (Givan and Shurley, 1999). These calculations resulted in cost per acre estimates used in the empirical analysis.

Procedures

This study sought to evaluate allocative efficiency in the use of variable inputs associated with different combinations of technology and tillage practices, relative to the level of output produced. Farrell (1957) defined allocative efficiency as the ability of a firm or industry to use inputs in optimal proportions given their respective prices. A linear programming model, specifically data envelopment analysis (DEA), was used to compare costs and returns associated with various combinations of tillage practice and transgenic technology. Data envelopment analysis ranks fields in a data set so that the most efficient fields in that data set are recognized as such. The DEA model forms weighted combinations of inputs for each field in the data set (Thompson and Thore, 1992). The linear program (DEA) then calculates a composite that represents the most efficient level of each input used relative to its output. Individual fields' weighted vectors of inputs are compared to the composite's weighted vector of inputs. Each field in the model is ranked in comparison to the fully efficient composite. A field that is considered at least as efficient as the composite receives a rank of 1.0. A field that is not as efficient as the composite receives a rank based on its efficiency relative to the composite. In other words, a field half as efficient as the composite would receive a rank of 0.50. Fields with an efficiency rank of 1.0 are said to be fully efficient and are considered to be on the "frontier" of efficient fields. Fields with efficiency rating less than 1.0 are considered inefficient because their use of inputs could be proportionally reduced by the difference between 1.0 and their efficiency ranking without a reduction in output.

It is important to point out that allocative efficiency estimated using DEA analysis is a multi-dimensional measure and is not directly comparable to two-dimensional measures such as input-output ratios and profitability. This difference occurs because within DEA analysis each input is weighted based on its own contribution to the resulting level of output and the composite is calculated based on input-output effectiveness of each particular input. Therefore, some fields with low input-output ratios and high returns above variable costs may still be considered inefficient using this approach. It implies that the profitability of these fields could have been even higher at the same overall level of input use. Some fields may be excluded from the efficiency frontier because their use of one or more of the inputs is disproportionately higher than the composite's (inefficient overuse of inputs).

GAMS software was used to construct and run the model. The results are discussed in the following manner: first the efficient frontier is described. Then the expenditures on variable inputs are compared between efficient and inefficient fields and some areas of possible inefficiencies are pointed out. Thirdly, the fields of the sample are compared based on the tillage practice used and advantages and disadvantages of alternative tillage practices are examined. Finally, fields are compared based on their use of transgenic technology, and the impact of using genetically modified varieties on efficiency and cost structure is discussed.

Results

Efficient Fields vs. Inefficient Fields

Table 1 lists the fields with efficiency coefficients of 100 percent. These fields are said to be on the efficient frontier. Forty six percent of fields in the study were ranked fully efficient, while other fields were less efficient. The combination of fields on the efficiency frontier consisted of 70 percent strip tillage and 30 percent conventional tillage. Another important result is that 12 out of 13 fields on the frontier used glyphosate resistant, Bt or stacked gene varieties. Forty percent of the frontier's 13 fields utilized Bt technology without the Roundup Ready gene. All fields that used Bt or Roundup Ready cotton and strip tillage were fully efficient. Two out of three fields that utilized Bt cotton and conventional tillage or Bt/Roundup Ready and strip tillage were on the frontier. These results demonstrate that fields utilizing genetically modified cotton varieties and the strip-till cultural practice dominate the efficient frontier.

Twenty seven percent of conventional tillage fields were on the efficient frontier, while 69% of strip-tillage fields were on the frontier. In other words, about 1 in 3 conventional tillage fields were considered fully efficient by the model, and 2 in 3 strip-till fields were considered fully efficient by the model. Eighty-three percent of Bt fields (5 of 6) were on the efficient frontier. All conventional tillage, Bt fields were on the frontier, and 2 of 3 strip-tillage Bt fields were on the frontier. While 50% of RR fields were on the frontier, it should be noted that 100% of RR/Strip-tillage fields were on the frontier. This is strong evidence that RR cotton is most efficiently produced in conservation tillage. Twenty-three percent of fields on the frontier were stack gene, 2 of these 3 were strip-till. Conventional cotton and Buctril resistant (*bromoxynil* resistant) cotton each had 1 field on the frontier (8%).

Costs of inefficient fields are compared to costs of fields on the frontier in Table 2. Average seed cost is the only one not higher for inefficient fields. This can be attributed to the fact 5 of the model's 6 conventional cotton fields are not on the frontier. Fields not on the frontier spent an average of $12.18 per acre more on fertilizer ($58.67 vs. $46.49). This may be due to unnecessary fertilization or it could be indicative of lower soil fertility among fields not on the frontier. Average defoliant expenditure is $6.11 per acre greater for fields not on the frontier ($19.02 vs. $12.90). This could potentially be an over-expenditure on the part of inefficient fields. Average herbicide expenditure is $10.06 per acre greater for inefficient fields ($33.55 vs. $23.49). This may be due to improper utilization of RR technology, poor timing of application or disproportionate number of RR fields on the frontier.

Average insecticide expenditure is $10.59 per acre greater for fields not on the frontier ($28.94 vs. $18.34). This could result from excessive application, a disproportionate number of Bt fields on the frontier or poor timing of applications. Poor timing of insecticide applications would have a two-fold effect on efficiency by increasing insecticide cost as well as resulting in a higher level of insect damage. Labor cost shows little difference between fields on and off the frontier ($10.84 vs. $9.92). The fact that inefficient fields do have a higher labor cost per acre may be the result of a high proportion of fields on the frontier utilizing strip-tillage.

The average cost with the greatest difference, from frontier to inefficient fields is equipment operating cost. Fields on the frontier have an average equipment operating cost of $28.58 while fields not on the frontier have an average equipment operating cost of $49.72, a difference of $21.14. This is the widest margin of any one cost in the model, and is very likely due to the fact that 69 percent fields on the frontier utilized strip-till cultivation method. Average scouting expenditure is only $0.83 per acre greater for fields on the frontier. This may be due to the fact that 2 of the frontier's 13 fields did not utilize custom scouting, while only 1 of the 15 inefficient fields did not custom scout. Average variable cost of irrigation is $6.39 greater for fields not on the frontier. This figure is not entirely accurate however, due to insufficient irrigation data from 6 of the data set's 28 fields. Average growth regulator expenditure per acre is $7.80 greater for fields not on the frontier ($12.49 vs. $4.69). A high proportion of fields on the frontier did not apply growth regulator (62 percent) while only 7 percent of inefficient fields did not apply growth regulator. Efficient fields that did apply growth regulator spent an average of $12.19 per acre compared to $13.38 per acre for fields not on the frontier that applied growth regulator. Inefficient fields may have over applied or not properly timed their applications. In some cases growth regulator may not have been necessary.

Overall, differences in expenditure described above resulted in average total variable cost per acre being $71.19 per acre greater for fields not on the frontier. Average yield for fields on the frontier was 25.49 lbs. per acre greater than that of inefficient fields (940.69 vs. 915.20). At a price of $0.65 per pound this translates to a difference in revenue between efficient and inefficient fields of $16.57 per acre. The difference between costs and revenues resulted in higher returns above variable costs, which were $87.76 per acre higher for the fields on the frontier. The above differences in variable costs help illustrate how a slight over-expenditure on multiple inputs can lead to a significant loss in efficiency and profit.

<u>Conventional Tillage vs. Conservation Tillage</u>

The differences in costs and efficiency ratings of the fields based on the cultivation practice used are examined in Table 3. This table reveals that the use of the strip till cultural practice allows savings on most variable inputs. The only cost item that was significantly higher for strip tillage is herbicide. Strip till fields spent $11.70 per acre more on herbicide than conventional till fields (35.15 vs.23.45). One would expect herbicide cost to be higher for strip till than for conventional till. Without harrowing or cultivating, strip-till farmers are more reliant on herbicide for weed control than conventional-till farmers. However, the higher herbicide cost of strip till farmers was more than off-set by savings on most other items. The only other cost item that was higher for strip-till fields was seed cost. This difference, however, was negligible and may be considered random.

The greatest savings from the use of strip tillage were in equipment operating costs. Strip-till fields spent $21.29 per acre less on operating equipment than conventional-till fields (28.50 vs.49.79). Another cost item associated with equipment is labor. Strip-till fields spent $4.34 per acre less on labor than conventional-till fields (8.09 vs.12.43). Thus, combined savings from labor and equipment for strip-till fields consisted of $25.63 per acre. These savings are associated with lower cultivation requirements for strip-till fields. The cost structure of strip-till fields is also characterized by $9.06 per acre savings on fertilizer. This difference may be explained by the fact that some strip till fields used a low cost fertilizer (chicken litter), while all conventional tillage fields applied a commercial fertilizer. Some savings were also associated with the use of defoliant on strip till fields ($1.21 per acre). Strip-till fields exhibited $6.33 per acre savings on insecticide. This may be attributed to added ground cover in conservation tillage, which potentially could harbor more beneficial insects (particularly fireants). Lower irrigation costs associated with strip tillage ($10.91 per acre savings) and $7.63 per acre savings on growth regulator may be associated with specific management practices on certain fields.

The combined effect of the cost reductions associated with strip tillage discussed above resulted in total variable cost $49.46 per acre lower for strip-till fields than for conventional-till fields. However, strip-till fields were characterized by yield 6.24 lbs/acre lower than on the conventional-till fields. This difference in yield resulted in revenues of $4.06 lower for strip till fields than for conventional-till fields. Lower revenues were more than offset by cost savings and resulted in returns above variable costs $45.40 higher for strip-till fields than for conventional-till fields. A similar pattern was observed in efficiency ratings. An average efficiency rating of strip-till fields was 0.90 (70 percent of fields fully efficient) compared to 0.80 for conventional-tillage fields (27 percent of fields fully efficient). Thus, on average, fields utilizing strip-tillage cultural practice appear more efficient and more profitable than fields utilizing conventional tillage practices.

<u>Conventional vs. Transgenic Varieties</u>

Table 4 compares fields that utilized conventional seed to fields that used genetically modified varieties. This table reveals the "price of technology" that these fields had to pay, which was $16.07 per acre ($23.41 for transgenic seed vs. $7.34 for conventional seed). The utilization of genetically modified varieties was expected to reduce the cost of insecticide and herbicide as well as labor and operating equipment associated with their application. In fact, all these cost items were lower for the fields that utilized transgenic technology: insecticide cost was $8.76 per acre lower, herbicide cost was $0.28 per acre lower, equipment cost was $11.51 per acre lower, and labor cost was $2.61 per acre lower for transgenic fields. Surprisingly, transgenic fields spent more on scouting: $7.23 compared to $5.92 for conventional fields.

The differences in costs between conventional and transgenic fields pretty much offset each other with total variable cost differing very little ($7.02 per acre less for transgenic fields). However, the effect of better pest control using transgenic varieties is demonstrated by much higher yields. The yields of transgenic fields were 107.80lbs/acre higher than the yields of conventional fields. This difference resulted in revenues of $70.07 per acre higher for transgenic fields relative to non-transgenic fields, which translated into higher average returns above variable costs of $77.09 for transgenic fields. Efficiency ratings demonstrate the same relationships with average efficiency rating for transgenic fields 0.11 higher than for non-transgenic fields (0.87 for transgenic fields vs. 0.76 for non-transgenic fields). 55 percent of transgenic fields were fully efficient, while only 17 percent of non-transgenic fields were fully efficient.

Comparison of Specific Combinations of Tillage and Technology

Table 5 describes average costs and returns of fields utilizing similar combinations of tillage and technology. This table reveals that within our sample all combinations of Bt and Roundup Ready technology with strip tillage were fully efficient. Combinations of Bt-Roundup Ready cotton with conventional or strip tillage, and Bt cotton with conventional tillage resulted in average efficiency ratings of 90 percent or better, which implies that two out of three fields were fully efficient. Other combinations of tillage and technology were less efficient.

Combination of Roundup Ready cotton and strip tillage resulted in the lowest average total variable cost of $178.46 per acre. However, the yields for this combination of tillage and technology were also comparatively low (912.33 lbs/acre). Combination of Bt-Roundup Ready and conventional tillage resulted in the highest yield, and thus highest revenue of $694.42 per acre. The highest returns above variable costs were available from the combination of Bt-Roundup Ready cotton and strip tillage. It is important to keep in mind that efficiency ratings are better measures of allocative efficiency than returns above variable costs, therefore these ratings should be preferred in the decision-making process.

Summary and Conclusions

This study sought to evaluate allocative efficiency of various combinations of tillage practice and technology for cotton production in South Georgia. Data envelopment analysis demonstrates that the frontier of efficient fields is dominated by fields combining genetically modified cotton varieties with the strip-till cultural practice. In particular, all combinations of Bt and Roundup Ready cotton with strip tillage were fully efficient in the current sample. Most combinations of Bt-Roundup Ready cotton with strip and conventional tillage and Bt cotton with conventional tillage were also fully efficient. Comparison of tillage practices revealed that conservation (strip) tillage allows savings on most of the variable inputs. Our analysis also demonstrates that the use of transgenic varieties typically resulted in higher yields. Overall, transgenic fields were 11 percent more efficient than conventional fields. Similarly, fields that utilized strip tillage were 11 percent more efficient than fields that utilized conventional tillage.

The results of this analysis may help cotton farmers decide what combinations of tillage and technology to use in their production process. The study was based on data from South Georgia for the 1999 crop year. Although the weather conditions that year were typical for this production region, different weather combinations could have resulted in different efficiency rankings, therefore, a similar study that would combine several years of data may be needed to confirm these results. Additionally, this study utilized field data, rather than experimental data. Various fields in this study came from several counties in the same production region, however, these fields were not necessarily homogeneous. The differences in soil types that were not taken into account in this analysis may have affected efficiency rankings. Therefore, a more general study of economic efficiency of various combinations of tillage and technology on a larger scale may be recommended for future research.

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Table 1**.** Summary of the Efficiency Frontier.

I.D.	**Tech.**	**Tillage**	**Eff. Rank**	**Yield**	**Total VC**	**Rev@ 0.65**	**Return above VC**
						$/acre	
25	BtRR	strip	1.00	950	160.37	617.50	457.13
12	conv	strip	1.00	850	174.94	552.50	377.56
23	RR	strip	1.00	1100	192.98	715.00	522.02
2	BXN	conv	1.00	834	173.43	542.10	368.67
40	BtRR	strip	1.00	1185	224.00	770.25	546.25
29	RR	strip	1.00	975	186.52	633.75	447.23
34	Bt	strip	1.00	1290	251.33	838.50	587.17
16	Bt	strip	1.00	985	236.86	640.25	403.39
21	Bt	strip	1.00	856	198.16	556.40	358.24
9	BtRR	conv	1.00	1100	281.92	715.00	433.08
20	RR	strip	1.00	662	155.89	430.30	274.41
4	Bt	conv	1.00	656	202.63	426.40	223.77
26	Bt	conv	1.00	786	240.91	510.90	269.99
Averages				940.69	206.15	611.45	405.30

Table 2. Average Costs of Efficient Fields Compared to Fields Ranked Inefficient.

Inputs\Fields	Efficient	Inefficient	Difference
		$/acre	
Fertilizer	46.49	58.67	-12.18
Seed	23.48	16.92	6.57
Defoliant	12.90	19.02	-6.11
Herbicide	23.49	33.55	-10.06
Insecticide	18.34	28.94	-10.59
Labor	9.92	10.84	-0.92
Equipment	28.58	49.72	-21.14
Scouting	6.51	7.33	-0.83
Irrigation	23.31	29.70	-6.39
Growth reg.	4.69	12.49	-7.80
Interest	8.43	12.02	-3.59
Total VC	206.15	277.34	-71.19
Yield	940.69	915.20	25.49
Revenue @.0.65$/lb	611.45	594.88	16.57
Returns above VC	405.30	317.54	87.76
Efficiency	1.00	0.71	0.29

Table 3. Conventional Tillage vs. Strip Tillage.

Inputs\Tillage	Strip	Conventional	Difference
		$/acre	
Fertilizer	48.16	57.22	-9.06
Seed	20.05	19.89	0.16
Defoliant	15.53	16.74	-1.21
Herbicide	35.15	23.45	11.70
Insecticide	20.63	26.96	-6.33
Labor	8.09	12.43	-4.34
Equipment	28.50	49.79	-21.29
Scouting	6.82	7.07	-0.25
Irrigation	20.89	31.79	-10.91
Growth reg.	4.78	12.41	-7.63
Interest	9.20	11.36	-2.16
Total VC	217.79	267.25	-49.46
Yield	923.69	929.93	-6.24
Revenue @..65	600.40	604.46	-4.06
Returns above VC	382.61	337.21	45.40
Efficiency	0.90	0.80	0.11

Table 4. Conventional Seed vs. Genetically Modified Varieties.

Inputs\Technology	Transgenic	Conventional	Difference
		$/acre	
Fertilizer	52.68	54.25	-1.58
Seed	23.41	7.34	16.07
Defoliant	15.66	18.07	-2.41
Herbicide	28.82	29.11	-0.28
Insecticide	22.14	30.90	-8.76
Labor	9.85	12.46	-2.61
Equipment	37.44	48.95	-11.51
Scouting	7.23	5.92	1.32
Irrigation	27.36	24.41	2.95
Growth reg.	9.15	7.81	1.34
Interest	10.30	10.57	-0.26
Total VC	242.78	249.80	-7.02
Yield	950.14	842.33	107.80
Revenue @.0.65$/lb	617.59	547.52	70.07
Returns above VC	374.81	297.72	77.09
Efficiency	0.87	0.76	0.11

Table 5. Comparison of Average Costs and Returns Across Various Combinations of Tillage and Technology.

Technology Tillage	Bt strip	RR strip	BtRR conv	BtRR strip	Bt conv	BXN conv	conv strip	conv conv	RR conv	BXN* strip
					$/acre					
Fertilizer	58.08	38.22	62.57	43.77	43.36	62.15	49.15	59.35	58.67	58.42
Seed	31.60	11.59	32.57	33.09	30.23	11.44	7.24	7.43	17.79	10.07
Defoliant	8.42	19.02	20.61	16.96	13.29	13.68	14.70	21.45	14.68	24.63
Herbicide	29.12	25.25	12.39	34.88	18.88	30.78	35.24	22.97	32.22	83.50
Insecticide	22.90	18.85	23.04	19.29	11.37	18.33	22.00	39.80	42.23	19.05
Labor	6.99	6.78	11.49	10.02	14.52	10.31	8.02	16.90	8.92	9.72
Equipment	26.28	22.20	45.10	29.92	40.21	43.85	35.64	62.26	57.53	28.43
Scouting	8.33	7.03	5.33	6.67	7.83	5.50	4.17	7.67	9.00	10.00
Irrigation	22.38	17.13	26.04	12.92	35.99	32.28	20.57	28.25	36.42	52.50
Growth reg.	5.21	4.69	14.90	6.64	8.17	10.42	1.56	14.06	14.50	7.81
Interest	9.47	7.68	11.03	9.64	9.67	10.34	8.52	12.61	13.14	13.69
Total VC	228.78	178.46	265.07	223.78	224.22	249.07	206.81	292.79	305.09	317.81
Yield	1043.67	912.33	1068.33	1042.67	754.00	951.33	730.67	954.00	922.00	820
Revenue @ 0.65 $/lb	678.38	593.02	694.42	677.73	490.10	618.37	474.93	620.10	599.30	533.00
Returns above VC	449.60	414.56	429.35	453.95	265.88	369.29	268.12	327.31	294.21	215.19
Efficiency	1.00	1.00	0.91	0.90	0.90	0.83	0.82	0.71	0.64	0.59

*Based on one observation, therefore not an average.