Does planting GMO seed boost farmers' profits?

By Mike Duffy, Associate director and agricultural economist, and
Matt Ernst, Research assistant

Genetic modification of crops has taken the national and international spotlight in recent months. Depending on your perspective, crops classified as genetically modified organisms (GMOs) may be the only hope to feed a hungry world, or an inappropriate use of technology that should be halted. In Iowa, the latest wave of discussion occurred when some major United States grain trading companies, reacting to European resistance to GMOs, announced that they would only accept crops that can be certified as GMO-free.

Fueling this furor is a debate over the relative merits and safety of GMO crops-a debate that is far from being settled. Without arguing the pros and cons of genetic modification, this report describes Iowa cropping practices in 1998.

The 1998 Iowa crop survey
Information was collected by the USDA's National Agricultural Statistics Service as part of its annual Cost and Return survey. The Leopold Center funded an expansion of the USDA's cropping practices survey to provide more reliable estimates.

This information was gathered in the late fall and early winter of 1998 during personal interviews with approximately 800 Iowa farmers. They were asked what crops they grew, and whether the seed they planted had been genetically modified. The results presented here represent a random selection of 62 continuous corn fields, 315 rotated corn fields, and 365 soybean fields. These numbers and the selection methods employed provide statistically reliable estimates at the state level.

It is important to emphasize that this is only a cross-sectional survey. It does not represent a side-by-side comparison of GMO and non-GMO crops. It represents a picture of what Iowa farmers experienced, under varying conditions and situations, during the 1998 crop year.

Genetically modified soybeans
Just over 40 percent of the Iowa acres planted to soybeans last year were GMO varieties. The number of soybean acres that a producer farmed had no relationship to whether or not GMO varieties were used.

When asked why they planted GMO soybeans, 53 percent of the farmers cited increasing yields through improved pest control. Another 27 percent listed decreasing pesticide costs, 12 percent said increased flexibility in planting, and 3 percent listed adoption of a more environmentally-friendly practice. The remaining farmers listed some other reason.

Farmers who did not use GMO varieties in 1998 reported a slightly higher yield than those who used GMO varieties. The average yield for non-GMO soybeans was 51.21 bushels per acre; the average yield for GMO soybeans was 49.26.

Farmers who used GMO varieties experienced significant savings in herbicide costs, spending nearly 30 percent less than farmers who grew non-GMO soybeans. Farmers using GMOs held a cost advantage in all aspects of weed management.

Costs differed in other areas, too. The biggest difference was in seed cost. Farmers who planted GMO varieties reported an average seed cost of $26.42 per acre, compared to $18.89 per acre for non-GMO varieties. Total costs without land or labor were $115.11 for GMO soybeans, and $124.11 for the non-GMO soybeans.

To estimate returns, we used the 1998 yearly average price of $5.27 per bushel. Figure 2 shows that returns to land and labor were essentially identical for GMO and non-GMO soybeans. GMO soybeans had a return of $144.50 per acre versus a return of $145.75 for non-GMO soybeans.

Results from these 365 soybean fields indicate that 1998 yields from GMO soybeans were slightly lower than conventional varieties, but so were the costs. According to this analysis, Iowa farmers had identical returns in 1998, whether they raised GMO or non-GMO soybeans.

Bt corn

Another genetic modification that is being used is the addition of *Bacillus thuringiensis* (Bt) to corn to fight a major pest, the European corn borer. Last year almost a fourth (23 percent) of Iowa corn contained the Bt gene. The overwhelming majority of farmers (77 percent) said they planted Bt corn to increase yields. Only 7 percent said that they planted it to decrease pesticide costs, and the remaining 16 percent gave a variety of other reasons. Of the Bt corn fields, 7 percent were continuous corn while 93 percent were corn following some other crop.

Iowa farmers were right about yields. In 1998, the average yield for Bt corn was 160.4 bushels per acre. The average yield for non-Bt corn was 147.7 bushels per acre.

Use of Bt corn didn't necessarily reduce insecticide costs. Farmers applied insecticides on 12 percent of their Bt corn fields at an average cost of $17.56 per acre. They applied insecticides on 18 percent of their non-Bt corn fields at an average cost of $14.94 per acre.

The biggest cost difference between Bt and non-Bt corn was in seed. Seed for Bt corn averaged $39.62 per acre, compared to $29.96 per acre for non-Bt corn. Bt fields had slightly higher weed control costs, averaging $2.82 per acre. Fertilizer costs were $5.02 per acre higher than non-Bt corn.

When comparing gross revenue, total costs, and the return to land and labor between Bt and non-Bt corn, corn was valued at the 1998 average price of $1.90 per bushel. The total difference in return to land and labor was only $3.97 per acre.

Conclusions

Based on a cross-sectional examination of Iowa cropping practices in 1998, genetically-modified crops provided farmers with no significant difference in returns. Remember, this is not a comparison of genetically-modified crops with their conventional counterparts, but a look at the bottom line last year for Iowa farmers-both those who raised GMO crops and those who did not.

Some producers said they used GMO soybeans to increase their flexibility during planting season. The value of this feature when evaluating use of GMO and non-GMO crops cannot be determined from the data available. It is interesting to note, however, that increasing crop yields was cited by over half the farmers as the reason for planting GMO soybeans, yet yields were actually lower.

Use of genetically-modified seed didn't appear to impact a farmer's bottom line for either corn or soybean production, but the reasons were different. In soybeans, GMO yields were lower but so were costs. In corn, yields and costs were higher when GMO seed was used.

Genetic modification, and the controversy surrounding it, will likely continue for many years to come. Based on what happened in 1998, Iowa farmers will find returns per acre relatively unaffected whether or not they plant the GMO corn and soybeans currently available. Marketing may be more of a problem with GMO crops, but using GMO crops has not affected profitability. Farmers will choose to use or not use GMO corn or soybeans based on their own situation and view of the issues, but profitability does not appear to be a decisive factor.

Public acceptance of GMOs

Agri Marketing magazine reports in its July/August issue the results of a survey of consumers in the United States about genetically-modified foods or GMOs. Relatively unknown five years ago, GMOs now have a spot on the public agenda.
The survey found:

- One in five respondents saw genetically-engineered food as "something artificial, fake or unnatural." This is understandable, noted the magazine, given the media's tendency to portray GMOs as "frankenfoods."
- Slightly more than a third (37 percent) of consumers saw themselves as "supporters" of this technology, 47 percent were "opponents," and 16 percent were "fence-sitters." (In Canada, where the survey also was conducted, there were fewer "supporters" and "opponents" but more "fence-sitters.")
- "Supporters" were most likely to be men, who thought the benefits outweigh the risks.
- "Opponents" saw the technology as a moral issue, and had less trust in the technology, government and food companies.

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Study shows no economic advantage for Iowa farmers to plant GMO crops

By Michael Duffy
Associate Director

Two years ago, I reported the results of a study that showed crops in Iowa planted with genetically modified seeds provided no significant difference in economic returns to farmers based on the 1998 crop year (see Fall 1999 Leopold Letter). I repeated the study this year using information from 2000, and found the same results: use of genetically modified seed did not appear to impact a farmer's bottom line for either corn or soybean production.

The information that I analyzed was collected by the USDA's National Agricultural Statistics Service as part of its annual Cost and Return survey. It was gathered in the late fall and early winter during personal interviews with approximately 350 Iowa farmers. They were asked what crops they grew, and whether the seed they planted contained a genetically modified organism (GMO). The survey covered all aspects of crop production including yields, pesticide and fertilizer use, seeding rates and the type and nature of machinery operations performed.

My analysis used information from a random selection of 172 soybean fields and 174 corn fields from the USDA survey. These numbers and the selection methods employed provide statistically reliable estimates at the state level. Although this analysis is only a cross-sectional survey and not a side-by-side comparison of GMO and non-GMO crops, it represents a picture of what Iowa farmers experienced, under varying conditions and situations, during the 2000 crop year.

Following is a summary of my analysis. I recently presented more details at the American Seed Trade Association meeting in Chicago. My speech, and accompanying charts, are posted on the Leopold Center web site. Copies also are available by contacting the Leopold Center.

Herbicide tolerant soybeans
Approximately 63 percent of the Iowa acres planted to soybeans in 2000 were varieties that had been genetically modified to tolerate herbicides used in weed control. In 1998, just over 40 percent was grown from GMO seed. Use of herbicide-tolerant varieties resulted in lower herbicide and weed management costs. However, they also had higher seed costs and slightly lower yields.

Yield. The herbicide-tolerant soybeans averaged 43.4 bushels per acre while the non-tolerant soybeans averaged 45.0 bushels per acre. The percentage difference in yields is identical to the difference found in the 1998 crop year. In 1998, the yields were 49.2 and 51.2 bushels per acre for herbicide-tolerant and non-tolerant soybeans, respectively.

Seed costs. The seed cost for herbicide-tolerant soybeans averaged $5.69 per acre more than the non-tolerant fields. In 1998, the difference was $7.53 per acre. The expense for non-tolerant soybeans was lower in 1998 while the expense for the tolerant varieties was slightly higher.

Herbicide costs. The non-tolerant soybeans averaged $26.15 per acre for herbicides, which was $6.17 higher than the herbicide costs for the tolerant fields. This cost difference is similar to what was found in 1998 even though the herbicide costs, in general, are higher in 2000 when compared to 1998.

Bt corn
A genetic modification used in corn production is the addition of bacillus thuringiensis (Bt) to fight a major pest, the European corn borer. The study included 128 non-Bt cornfields and 46 Bt fields. Similar to herbicide-tolerant soybeans, Bt corn produced a return essentially equal to the non-Bt corn.

Yield. The average yield for Bt corn was 152 bushels per acre. The average yield for the non-BT corn was 149 bushels per acre. This yield difference is less than the difference found in the 1998 study—160.4 bushels per acre for Bt corn and 147.7 bushels per acre for non-Bt corn

Fertilizer costs. The Bt cornfields had slightly higher total fertilizer costs per acre. The Bt fertilizer cost was $53.30 versus $48.67 for the non-Bt fields, much similar to the results found in 1998. Although no production reason exists for the higher fertilizer costs, it is hypothesized that the Bt fields are managed more intensively which leads to the increased fertilizer costs.

Seed costs. The costs for seeds vary depending on number chosen. Seed costs for the Bt corn averaged $4.31 per acre higher using the conservative assumptions employed in this study.

Other considerations. If returns are not significantly different, why have we seen such an increase in the use of GMO technology? For herbicide-tolerant soybeans, farmers answer that question by saying they can cover more acres more quickly and that they do not have to worry about weed management as they did in the past. For Bt corn, farmers view use of GMO seed as an insurance policy if there's an insect infestation. There are many such non-quantifiable benefits and costs associated with using GMO seeds.

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The effects of transgenic soybeans and associated herbicide treatment upon soil-surface mesofauna

Abstract: *While the percentage of transgenic soybean varieties being planted in Iowa has increased greatly, little has been done to evaluate the ecological consequences of these new technologies. Investigators examined the possible effects of three of these transgenic varieties and their associated broad-spectrum herbicides on soil-surface mesofauna, specifically springtails.*

Principal Investigator:
Larry P. Pedigo

Co-investigator
Royce J. Bitzer
Entomology
Iowa State University

Budget:
$35,000 for year one
$35,000 for year two

Background

More than half of the 1999 Iowa soybeans were transgenic varieties. Relatively little work has been done, however, to study non-target effects of transgenic weed management systems on beneficial insects in soybean fields.

Among the most important non-target inhabitants of soybean fields are arthropods. Among them are hundreds of species, most of them beneficial. Altering this ecosystem by culturing herbicide-resistant soybeans could disrupt populations and communities of beneficial predators, parasitoids, fungal grazers, and decomposers of organic residue. Decomposers such as springtails, or Collembola, are especially important consumers of plant residues and soil fungi, and also help create humus.

Much concern has been expressed regarding effects of pesticides and pollutants on Collembola in the field. There are questions about whether herbicide activity or mechanical cultivation has the greater impact on Collembola. Another consideration is the differing potential effect of conventional pre-emergence herbicide application vs. specific broad-spectrum targeted herbicides applied several times later in the season to transgenic soybean varieties that are resistant to them. Although both chemical methods avoid the need to mechanically disturb the soil, they could have quite different impacts on Collembola populations because their application schedules, and therefore their temporal effects on weeds, differ.

There are two basic ways to assess the effects of these various weed management strategies. One is to monitor the effects on selected individual species, and the other is to examine the effects on the numbers and diversity of Collembola communities as a whole.

The objectives for this project were to:

- Identify springtail populations to at least the generic level, and the specific level whenever possible,
- Examine how species composition of springtail communities varies over the growing season, and
- Look for correlations of springtail abundance and species composition and species richness of springtail populations with various soybean varieties and weed management treatments.

Approach and methods

Surface-active Collembola populations were studied at the Iowa State University Bruner Research Farm from 1996 through 1998. The treatments consisted of six soybean varieties and three weed management systems. The three soybean varieties resistant to Roundup® or Liberty® herbicides received each of the three weed management system treatments. The other three varieties not resistant to these herbicides received only the six conventional and mechanical treatments. (There were 15 treatments in all.)We examined how the three weed management treatments affected the total number and the numbers in each species.

The population of surface-active Collembola was sampled during the soybean-growing season. The first sample was collected one week after sampling began and samples collected in pitfall traps were taken weekly thereafter. Each treatment plot had one trap, installed during the week of planting and maintained until just before harvest. Traps were randomly placed near the center of the plot.

Samples were returned to the ISU entomology laboratory for processing. Collembola in each of a three-year total of 3,030 samples were counted and identified using both light and scanning electron microscopy. Researchers took digital photographs and scanning electron micrographs of Collembola at various magnifications.

Table 1. Weed management systems used in evaluating effects on Collembola.

Targeted System	Application Rate
Roundup Ultra® (glyphosate) 4S	1.12 kg[ai]/ha
Liberty® 1.67SL (glufosinate) + $(NH_4)_2SO_4$	0.30 kg[ai]/ha + 3.36 kg[ai]/ha
Conventional System	
Pre-emergence	
Frontier® 6EC (dimethenamid) +	1.68 kg[ai]/ha +
Sencor® 75DF (metribuzin)	0.42 kg[ai]/ha
Post-emergence	
Pursuit® 2AS (imazethapyr) + Sun-it II® + 28% N	0.07 kg[ai]/ha + 2.36 l/ha + 2.36 l/ha
Cultivations	
Mechanical System (Control)	
Hand weeding of plots	

Investigators also considered possible effects of the extent of soybean plant cover on springtail numbers, and possible correlations of any variation of weed cover with the different weed management treatments. Leaf area index (LAI) of the soybean canopy is the ratio of leaf area to soil surface area, and was measured every two weeks after soybeans reached a certain growth stage. Weed population and cover were estimated visually each week.

Results and discussion

Over three years, the project investigators counted a total of 309,056 springtails. They found approximately 50 species, a surprisingly high level of diversity in a cultivated area. Springtail populations were lowest in 1996, highest in 1997, and reached intermediate levels in 1998. Twenty-one species, ranging from rare to abundant, were analyzed in detail. They included mainly medium-to large-bodied fungus-feeders and shredders, and also several smaller humus-forming species that are probably more common deeper in the soil than at the surface.

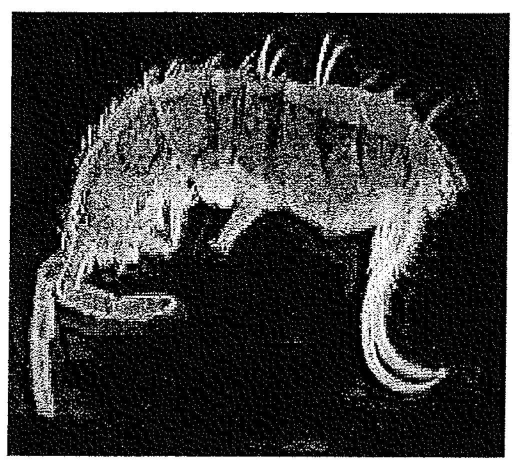
Weed management treatments affected the numbers of some common species of springtails. Overall, their numbers were highest in plots receiving targeted broad-spectrum herbicides to transgenic soybeans, intermediate in plots receiving an initial conventional herbicide application, and lowest in control plots receiving only mechanical cultivation.

However, not all these correlations were significant. The treatments strongly affected some species, mainly larger, surface-active springtails that peak in mid- to late-season, whereas early-season species, or smaller, true soil species were affected weakly or not at all. Typical patterns of abundance of particular species were:

- More individuals found in the conventional than in the mechanical plots,
- More individuals present in the targeted than in the either the conventional or mechanical plots, with the latter two not differing significantly, or
- More individuals found in the targeted and conventional than in the mechanical plots.

Targeted treatments of Liberty Link® soybeans more strongly affected springtail abundance than did targeted treatments of Roundup-Ready® soybeans. Most treatment differences, including those between Roundup-Ready® and Liberty Link®, were attributed to differences in weed cover and soil disturbance, rather than to any toxic effects of the herbicides.

Four species were chosen as the best candidates for bioindicators of the treatment effects. The timing of both weed growth and weed management was as important to springtail populations as the weed-management method itself. The more important treatment factor that induced higher populations of most spe-



The surface-active springtail, Isotoma viridis Bourlet, 1839

cies of springtails was not more weed cover per se, but likely the greater amounts of organic matter that resulted after these weeds were killed by the targeted herbicide applications. This, coupled with the lack of discernible toxic effects of the herbicides themselves, suggests a short-term benefit to springtail populations.

Conclusions

Results from this project suggest an absence of deleterious effects from transgenic herbicide-resistant soybean varieties and their associated weed management systems on total Collembola and most individual species of Collembola. There may even be a short-term benefit from targeted herbicide treatments because they kill established weeds that can provide organic matter for Collembola growth. However, this same benefit probably could be derived from any addition of organic matter to the soil.

Mechanical cultivation decreased Collembola numbers relative to the numbers in the herbicide-treated plots. This suggests that using either conventional herbicide treatments or broad-spectrum herbicides with herbicide-tolerant transgenic crops could benefit Collembola by reducing or eliminating the need for tillage. Other agricultural practices that reduce the need to disturb the soil, such as no-till cropping, could likewise benefit Collembola populations.

For more information contact Larry Pedigo, Entomology, Iowa State University, Ames, Iowa 50011; (515) 294-8694, e-mail lpedigo@iastate.edu

Impact of results

Observations during this project suggest that some springtail species are useful as general biological indicators. They respond to a relatively broad range of factors that indicate general "soil health." Thus, examining the springtail community could be useful to assess the results of a wider variety of agricultural activities, including the effects of applying organic matter or insecticides or the effects of planting vegetation in border strips near fields. Because springtails are so small and require special equipment to collect and identify, their most effective use as indicator species will be in observational or experimental research trials, rather than in field scouting efforts.

Education and outreach

Three scholarly publications recounting this research are in progress.

Who Benefits from Biotechnology?

By Michael Duffy, Iowa State University
Presented at the American Seed Trade Association meeting
December 5-7, 2001, Chicago, IL

Good morning. I appreciate the opportunity to be with you today. My talk is going to focus on an extremely important topic. Yet, too often, it also is a topic that segregates people into competing groups that rely only on rhetoric and scare tactics rather than discussing the real issues.

We all have our biases and regardless of what anyone says, our biases influence our perspectives. As scientists we strive to eliminate our biases from our research but the very fact that we look at one issue and not another reveals our biases. What we should strive for is to control our biases and acknowledge them from the beginning.

I am the Associate Director for Iowa State University's Leopold Center for Sustainable Agriculture. I also am the Professor-in-Charge of the ISU Beginning Farmer Center. Finally, I am an ISU Extension Economist.

All this means that I view the world both from an economic perspective and from the perspective of working with agriculture and farmers. I am an educator who tries to present information in as factual a way as possible and give people the tools and means to form their own opinions. I start from the basic supposition that economics is the study of allocating scarce resources and not simply the study of money. I also feel that humans are a part of the natural system and not apart from it. The impacts of our worldly actions are governed by a set of ecological principles; some of which we understand and others that we do not fully comprehend.

As an economist, I believe in the market as an efficient mechanism for allocating resources. However, just as I believe in the efficiency of the market, I also know there are market failures. These failures take several forms. Difficulty in valuing externalities is one example. Public goods, such as air and water, are other areas where the market cannot efficiently cope with all the issues. Allocating resources between generations is another problematic area for the market. Finally, I think that concentration of market power is something that will lead to the failure of markets as an efficient mechanism for allocating resources.

In this talk I will first briefly discuss biotechnology. Next, I will share the results of a study examining the farmer impact of herbicide tolerant soybeans and Bt corn. Finally, I will draw some conclusions and discuss the implications of what I have found.

Biotechnology

Biotechnology has been labeled "a misleading expression because it conveys a singularity or unity to what is actually a tremendously diverse set of activities and range of choices." (Buttel, 1985) A U.S. Department of Agriculture (USDA) publication notes, "... biotech processes and products are so diverse and have so little in common with one another that it is difficult to construct valid generalizations about them. Broader than genetic engineering and gene splicing, biotech includes tissue, cell, and embryo culture; protoplast fusion; bioregulation or hormonal control of physiological and metabolic processes; production of gene-controlled products; directed plant breeding; and fermentation processing." (USDA, 1987)

Throughout this paper I am simply going to use the term biotechnology, recognizing that there are inherent problems with using this single term. However, I do not want to further muddle an already confusing issue with what, for most of us, are technicalities.

Michael Fox provides a chronological presentation of the significant biotechnology events leading up to the present day. Fox begins with the breeding experiments by Mendel in 1869. (Fox, 1992) Others feel that the roots of biotechnology, especially as it relates to traditional plant breeding, can be traced back to the earliest days of agriculture and the domestication of plants and animals. Keeney, however, points out, "In contrast, the new agricultural biotechnologies provide the tools for molecular and cellular approaches to altering plants and animals." (Keeney, 1998)

This is a big distinction between more traditional plant and animal breeding and biotechnology. The traditional methods were limited to using only materials that were biologically similar. With today's biotechnology capabilities, scientists are able to construct animals and plants that would never have been possible using conventional breeding techniques.

Before considering who benefits from biotechnology, it is necessary to discuss one idea that I feel is erroneous. Many proponents of biotechnology say that this technology is necessary to feed the world. They argue that if we do not use biotechnology, many of the world's people will face starvation and other ills associated with malnutrition. This is certainly a concern; however, the evidence shows that it is not the hungry who are being fed but rather the affluent, i.e., those who can afford to buy the food. The earlier Green Revolution also was promoted as a means of eliminating world hunger. Food production has increased but we still have hungry people. The problem is not one of production but rather a problem of distribution and politics. Ho Zhiqian, a Chinese nutrition expert, was quoted as saying, "Can the Earth feed all its people? That, I'm afraid, is strictly a political question." (Reid, 1998) As we think about biotechnology, we must not confuse wanting the world to be fed with wanting to feed the world.

Before discussing a specific example of who benefits from biotechnology it is important to examine what agricultural examples of biotechnology have been approved. As of May 1999, there were 15 products approved for unregulated release, 13 crop, and 2 non-crop. (USDA, 2001) There were 53 different examples within the 13 crop groups. Only three of the products contained what were described as "value-enhanced traits". The rest contained "agronomic traits," primarily herbicide tolerance or insect resistance.

These are the so-called first generation biotech or genetically engineered products. A second generation now being developed or tested will greatly expand the number of available crops and applications of this technology.

Herbicide-tolerant soybeans

The case of herbicide-tolerant soybeans will be used to examine the benefits of biotechnology at the farm level. The data for this analysis come from a random sample, cross-sectional survey of Iowa soybean fields. The survey was conducted by the Iowa office of the USDA's National Agricultural Statistics Service in the fall of 2000. The data presented are for the 2000 crop year.

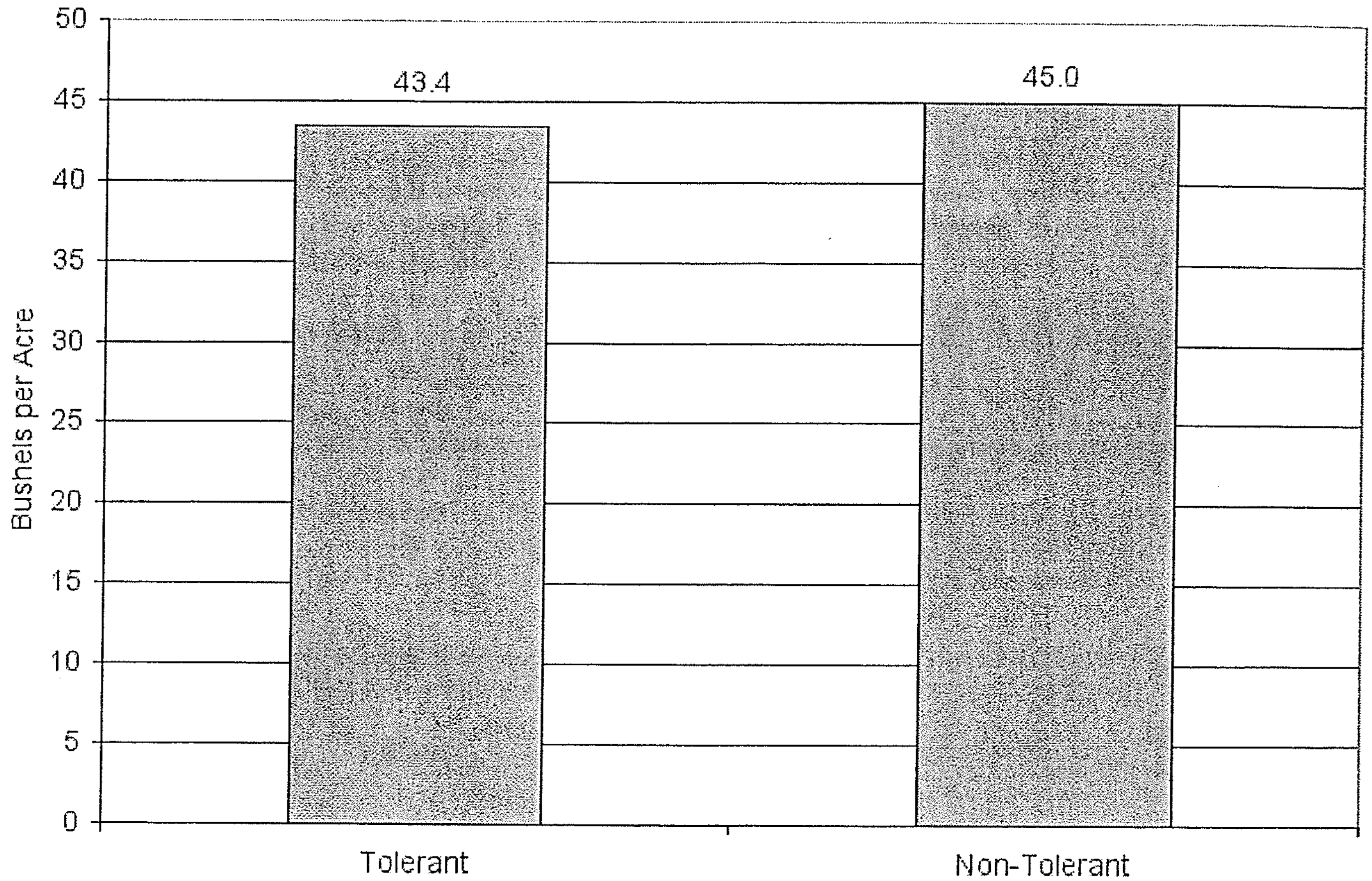
The survey covered all aspects of crop production. This included yields, pesticide and fertilizer use, seeding rates and the type and nature of machinery operations performed.

Several assumptions were necessary to compare the costs and returns for herbicide- tolerant versus non-tolerant soybeans. The price per bushel was $5.40. This price represented the average loan rate and emergency payments. The per unit cost for pesticides was obtained from various sources at Iowa State University. The per unit costs of fertilizer and seeds were the costs used in the Iowa State Extension Service cost of production estimates (Duffy and Smith, 2001). Finally, the costs for the various machinery operations represented the average custom rate charge as reported by the Iowa State University Extension Service (Edwards and Smith, 2001a).

The final data set contained observations for 172 fields. Of these fields, 63 percent (108 fields) reported using herbicide-tolerant soybeans. There were 64 fields that reported planting soybeans that were not herbicide tolerant.

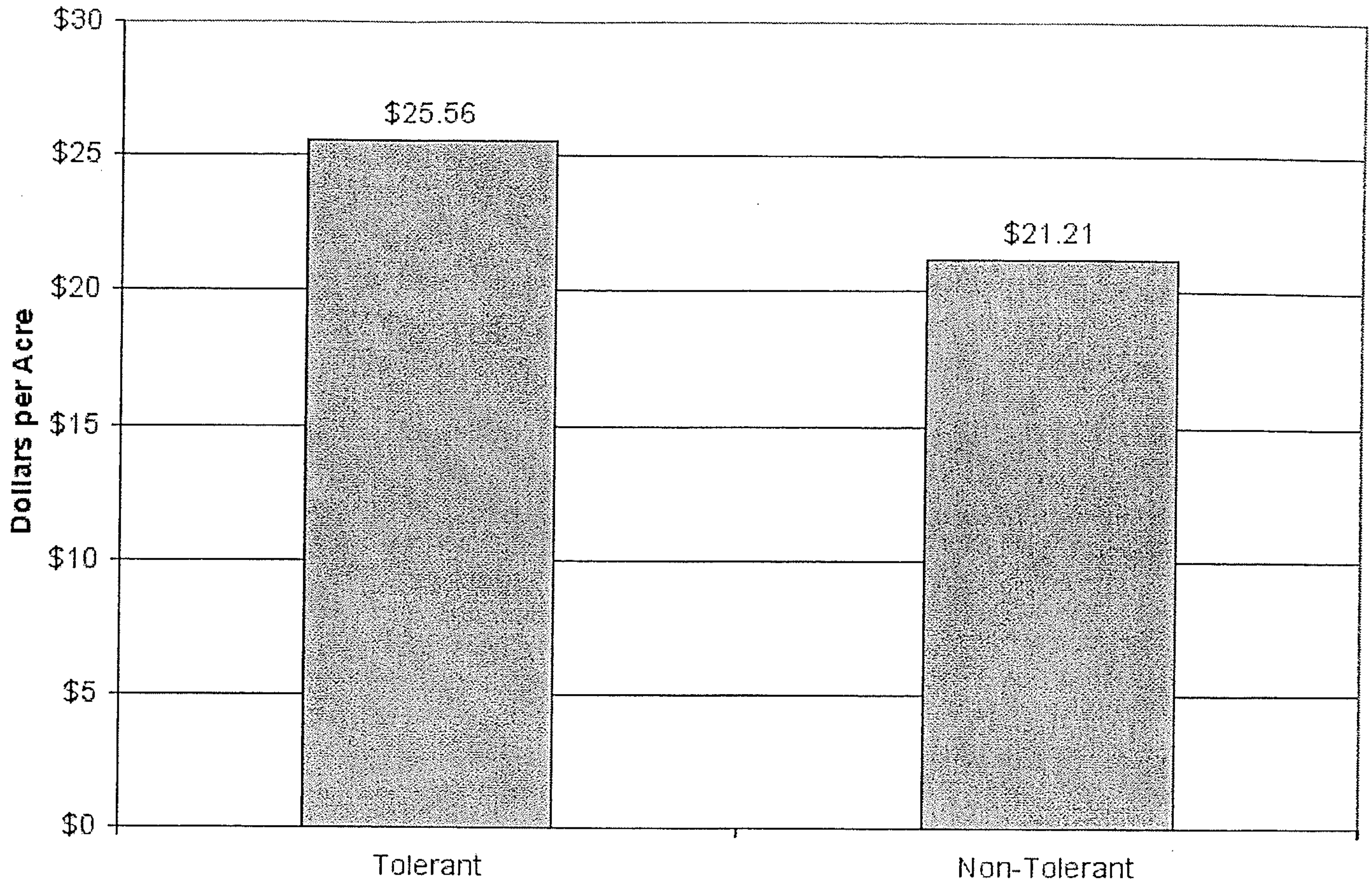
Figure 1 shows the average yields. The herbicide-tolerant soybeans averaged 43.4 bushels per acre while the non-tolerant soybeans averaged 45.0 bushels per acre. The percentage difference in yields is identical to the difference found in a similar study for the 1998 crop year (Duffy, 1999). In 1998, the yields were 49.2 and 51.2 bushels per acre for herbicide- tolerant and non-tolerant soybeans, respectively.

Figure 1: Average Yield for Herbicide Tolerant and Non-Tolerant Soybeans, 2000



The major cost differences attributed to planting herbicide-tolerant or non-tolerant soybeans are for seed and herbicide costs. Figure 2 shows the seed expenses for herbicide- tolerant and non-tolerant soybeans. The seed expenses were found by multiplying the price for seed times the seeding rate. (The seeding rate was the rate reported by the farmer.) The price for the non-tolerant seed was the price reported by Iowa State Extension (Duffy and Smith, 2001). There was a 5 percent premium added to this price to represent the price for the herbicide-tolerant seed. Five percent was a conservative estimate to reflect any price differences plus the tech fee charged.

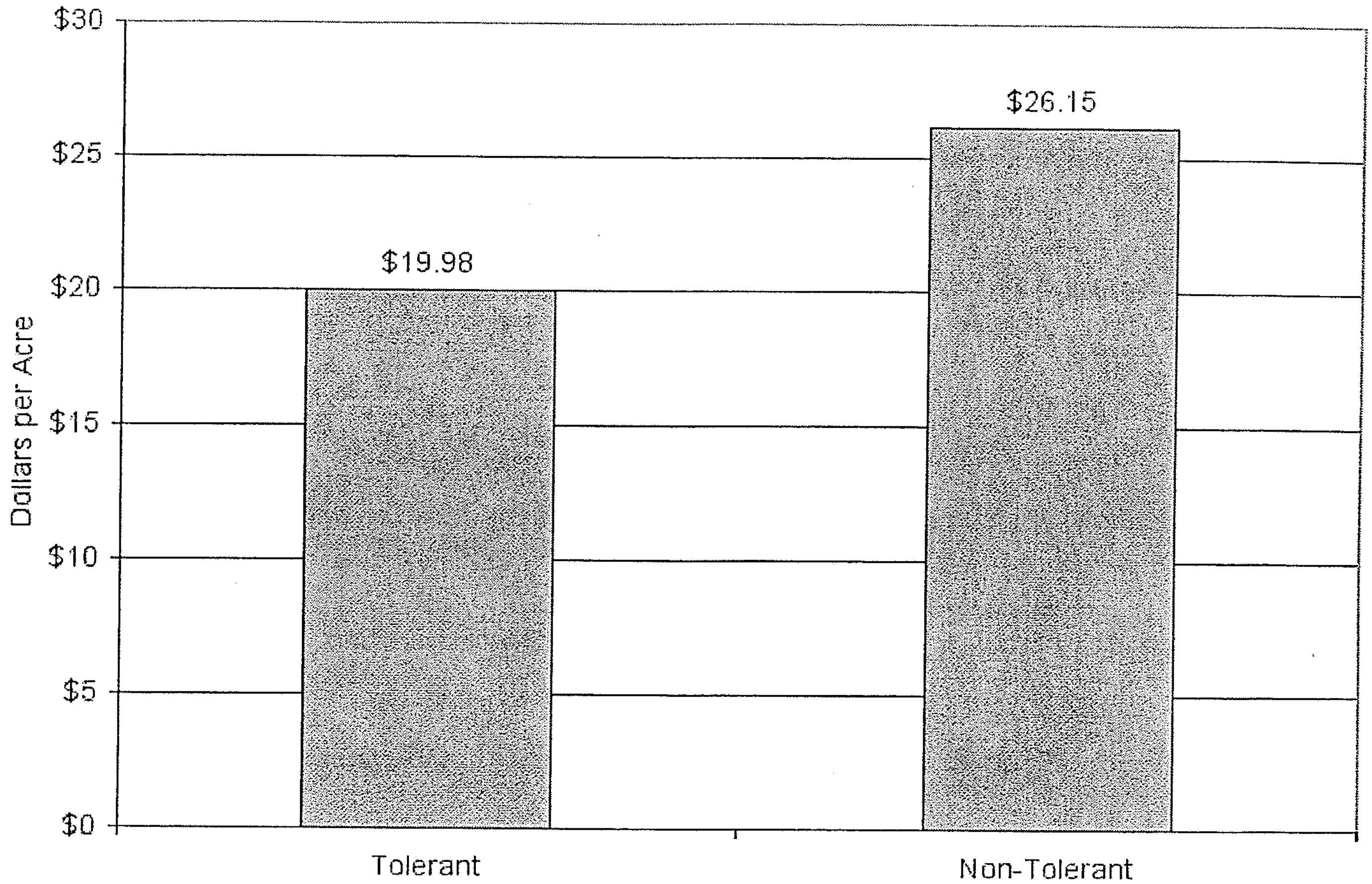
Figure 2: Average Seed Cost for Herbicide Tolerant and Non-Tolerant Soybeans, 2000



The seed cost for herbicide-tolerant soybeans averaged $5.69 per acre more than the non-tolerant fields. In 1998, the difference was $7.53 per acre. The expense for non-tolerant soybeans was lower in 1998 while the expense for the tolerant varieties was slightly higher.

The cost for herbicides is shown in Figure 3. The farmers reported the rate of each chemical they applied. The non-tolerant soybeans averaged $26.15 per acre for herbicides, which was $6.17 higher than the herbicide costs for the tolerant fields. This cost difference is similar to what was found in 1998 even though the herbicide costs, in general, are higher in 2000 when compared to 1998.

Figure 3: Average Herbicide Cost for Herbicide Tolerant and Non-Tolerant Soybeans, 2000

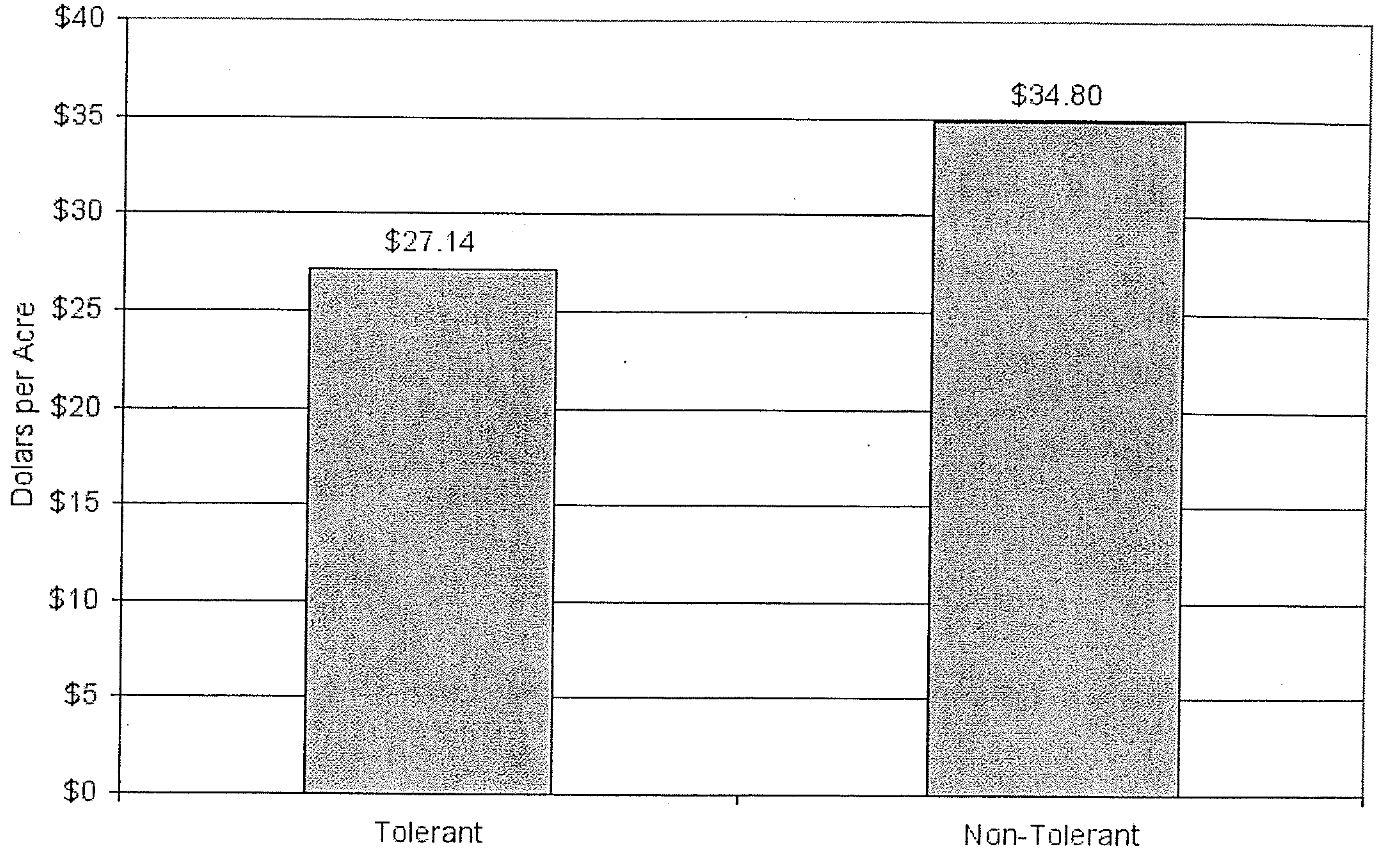


The herbicide-tolerant soybean fields had an average of 1.55 sprayer trips in 2000, compared to 2.45 trips for the non-tolerant fields. Sprayer trips ranged from 1 to 4 for the tolerant fields while 6 was the maximum number of sprayer trips reported for the non-tolerant fields.

Cultivation is another technique used to manage weeds. In 2000, 48 percent of the tolerant fields reported at least one cultivation. This compares to 63 percent of the non-tolerant fields that reported at least one cultivation. The number of cultivations ranged from 0 to 2 but the average number of cultivations reported for the tolerant fields was .59 versus an average of .85 cultivations for the non-tolerant fields.

Figure 4 presents the total weed management costs for both the tolerant and non-tolerant soybeans. This figure includes herbicide material and application costs as well as the cost for cultivations. The total weed management cost for tolerant fields was $27.14 versus $34.80 per acre for the non-tolerant fields. Again, these costs and the differences were very similar to the 1998 totals.

Figure 4: Total Weed Management Costs for Herbicide Tolerant and Non-Tolerant Soybeans, 2000

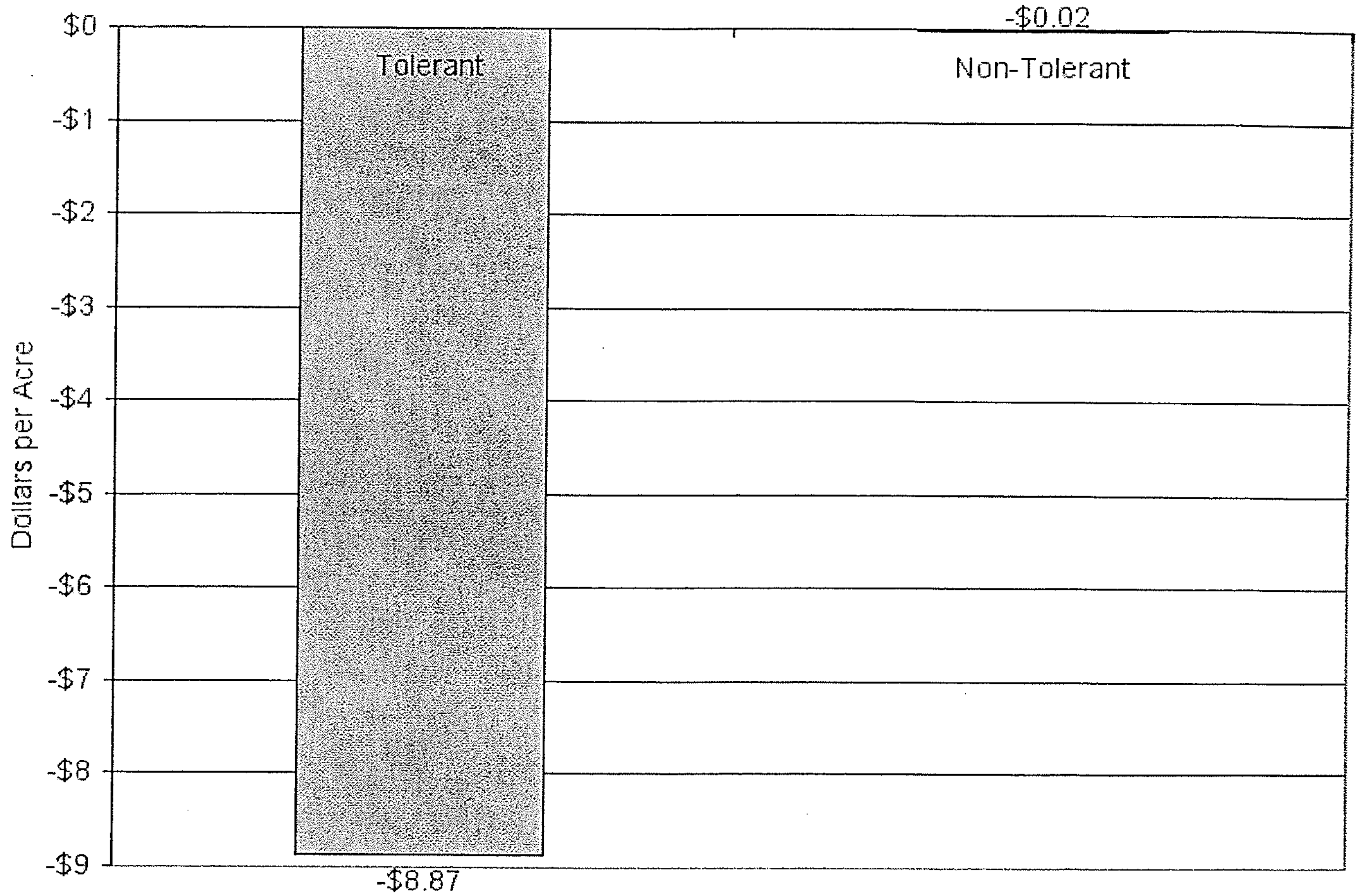


When all of the costs, including those mentioned, plus fertilizer, lime, all machinery operations, insurance, and a land charge are considered, there is essentially no difference in costs between the tolerant and non-tolerant fields.

The land charge used was calculated in three steps. First, the average statewide yield for soybeans was divided by the average rent per acre. (Edwards and Smith, 2001b) The result was $2.85 per bushel. This amount was multiplied by the average yield in the survey and the result was $125.08 per acre. This was the land charge used for all fields.

Figure 5 shows the return to labor and management for the tolerant and the non-tolerant fields. In 2000 both seed types lost money. The return to the herbicide-tolerant fields was an $8.87 per acre loss while the non-tolerant varieties essentially broke even with a calculated $.02 per acre loss.

Figure 5: Return to Labor & Management for Herbicide Tolerant and Non-Tolerant Soybeans, 2000



Two major considerations could not be included in this analysis. First, the price per bushel for either the type of soybeans was assumed to be the same. Recently there have been some considerations for price differentials based on whether or not the soybeans were herbicide tolerant. The second major consideration omitted from this analysis was the difference in time for combining. Farmers report that they are able to combine tolerant fields faster because there is less clogging of the combine. Many also report producing cleaner beans. These considerations are beyond the scope of this analysis.

These considerations notwithstanding, based on this analysis it appears that there is essentially no difference in the return to using herbicide-tolerant versus non-tolerant soybeans. This is the same conclusion that was reached in the similar 1998 study.

Use of herbicide-tolerant varieties results in lower herbicide and weed management costs. However, they also have higher seed costs and slightly lower yields.

If the returns to the herbicide tolerant and non-tolerant varieties are similar, why have the tolerant crops been adopted so readily? The acreage planted to herbicide-tolerant varieties has gone from nothing a few years ago to more than half the acres planted or higher depending on the estimate. There are several reasons for this phenomenon. First, the ease of harvest is an overriding consideration for many producers. Being able to harvest easier and faster makes farmers more willing to adopt a new technology even if it does not produce clearly superior returns.

Farmers also may be using the herbicide-tolerant varieties on fields with particularly heavy weed problems. If the average returns are comparable. then it is simpler to use the same varieties so that commingled soybeans are not an issue.

Advertising and landlord pressure could also be part of the explanation for the phenomenal rise in the use of herbicide-tolerant soybeans. Some landlords insist on clean fields and the herbicide-tolerant varieties offer that option.

There are other reasons that have been mentioned such as greater flexibility, less time in the field at harvest, and so forth. Many of these become individually compelling reasons. But, given the analyses in 1998 and again in 2000, there does not appear to be any difference in the per acre profitability between the two varieties.

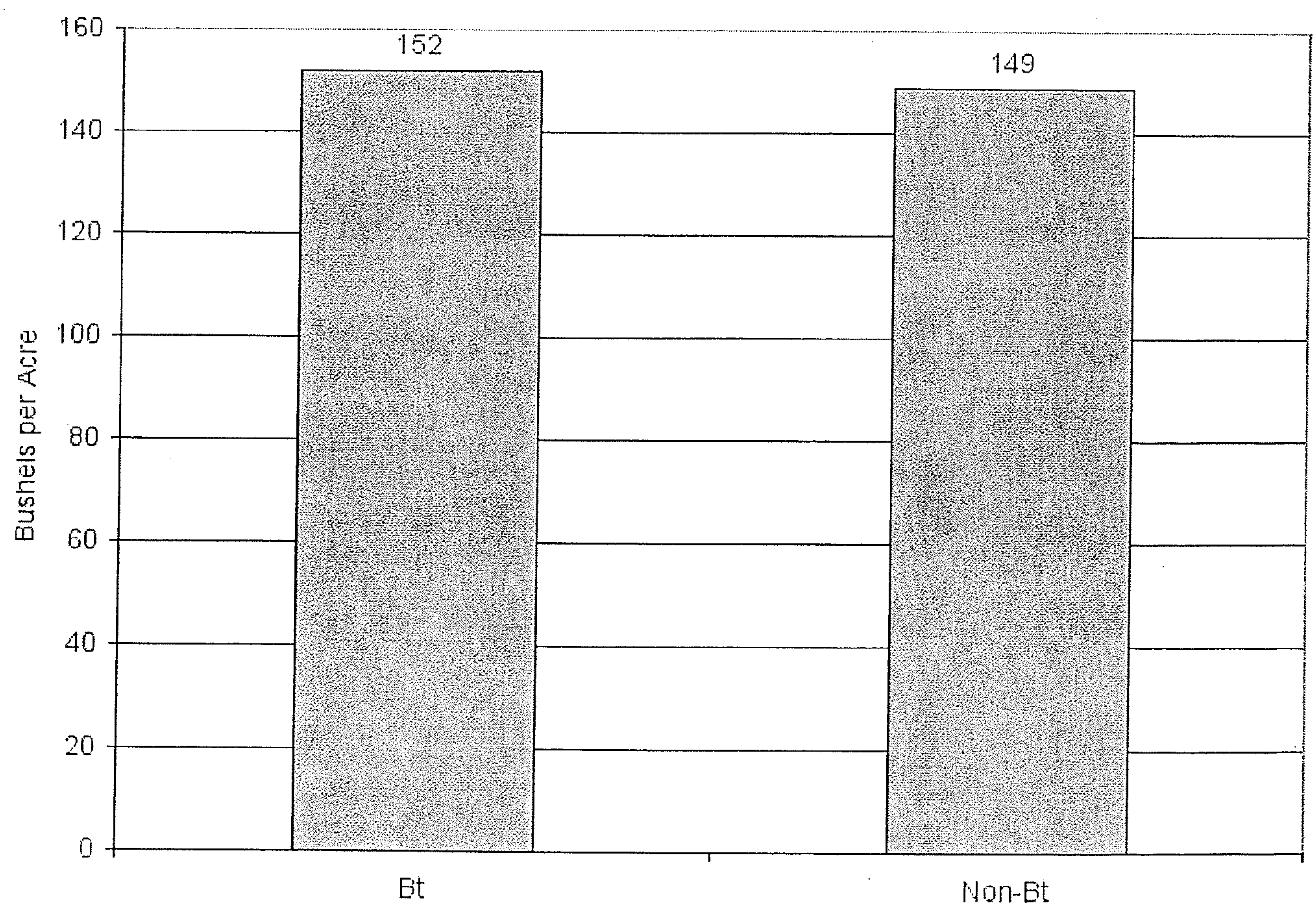
Bt Corn

The second example used to evaluate who benefits from biotechnology is Bt corn. The data used for this study come from the same data set used for the soybean example just reported. For corn, there were 128 non-Bt fields and 46 Bt fields.

The costs and returns were calculated in the same way as for the soybeans. The price used for corn was $2.06 per bushel. This price reflects the $1.76 loan rate of regular government payments plus emergency payments.

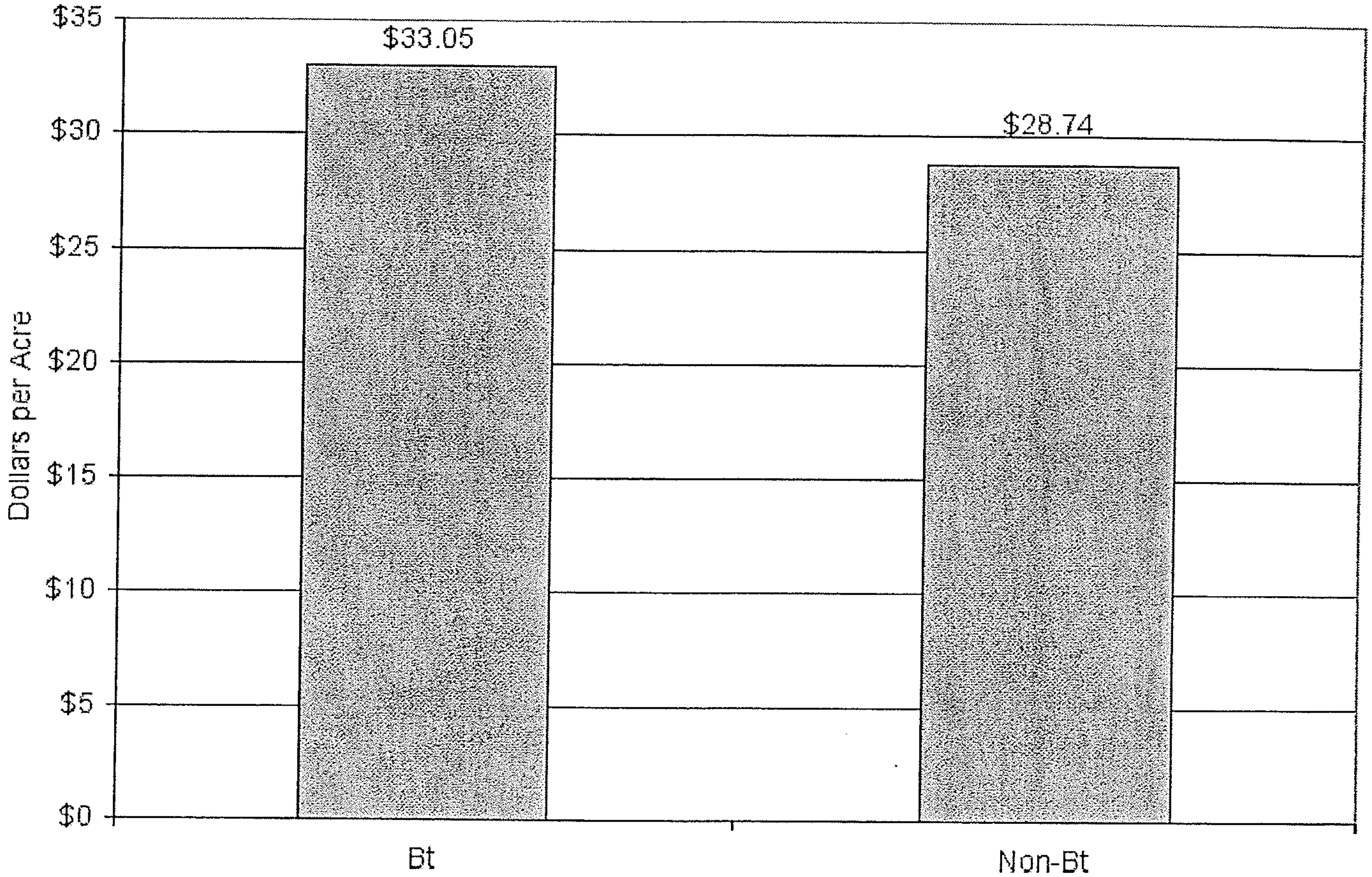
The average yield for Bt corn was 152 bushels per acre (Figure 6). The average yield for the non-BT corn was 149 bushels per acre. This yield difference is less than the difference found in the 1998 study.

Figure 6: Average Yield for Bt and Non-Bt Corn, 2000



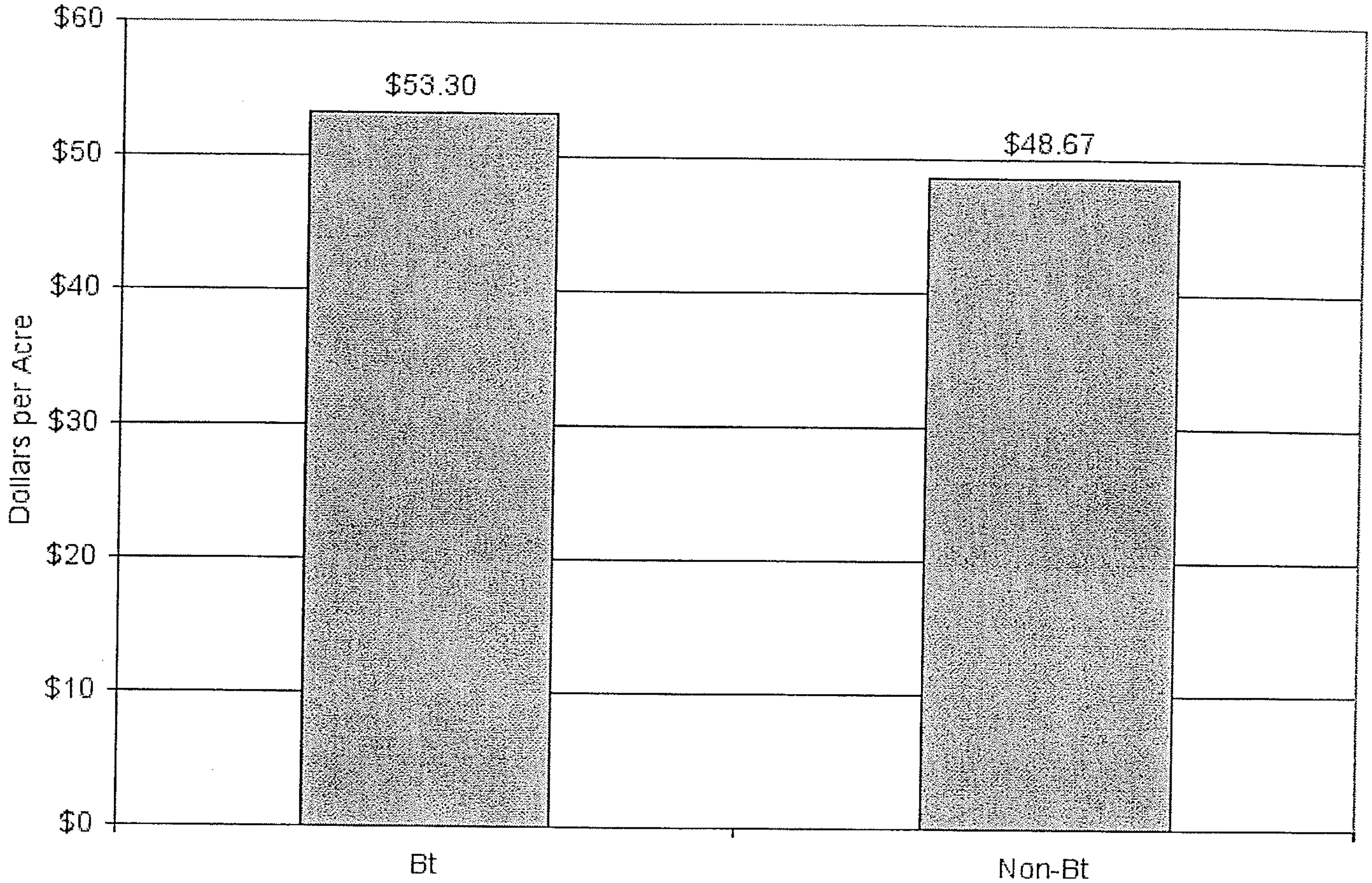
The planting rate was reported by the farmers, while the cost for seed was reported by Iowa State Extension with a 15 percent premium added for Bt seeds. This reflects the cost differences plus the tech fee. Figure 7 shows the seed cost comparisons.

Figure 7: Average Seed Costs for Bt and Non-Bt Corn, 2000



The Bt cornfields had slightly higher total fertilizer costs per acre (Figure 8). The Bt fertilizer cost was $53.30 versus $48.67 for the non-Bt fields, much similar to the results found in 1998. Although no production reason exists for the higher fertilizer costs, it is hypothesized that the Bt fields are managed more intensively which leads to the increased fertilizer costs.

Figure 8: Total Fertilizer Costs for Bt and Non-Bt Corn, 2000

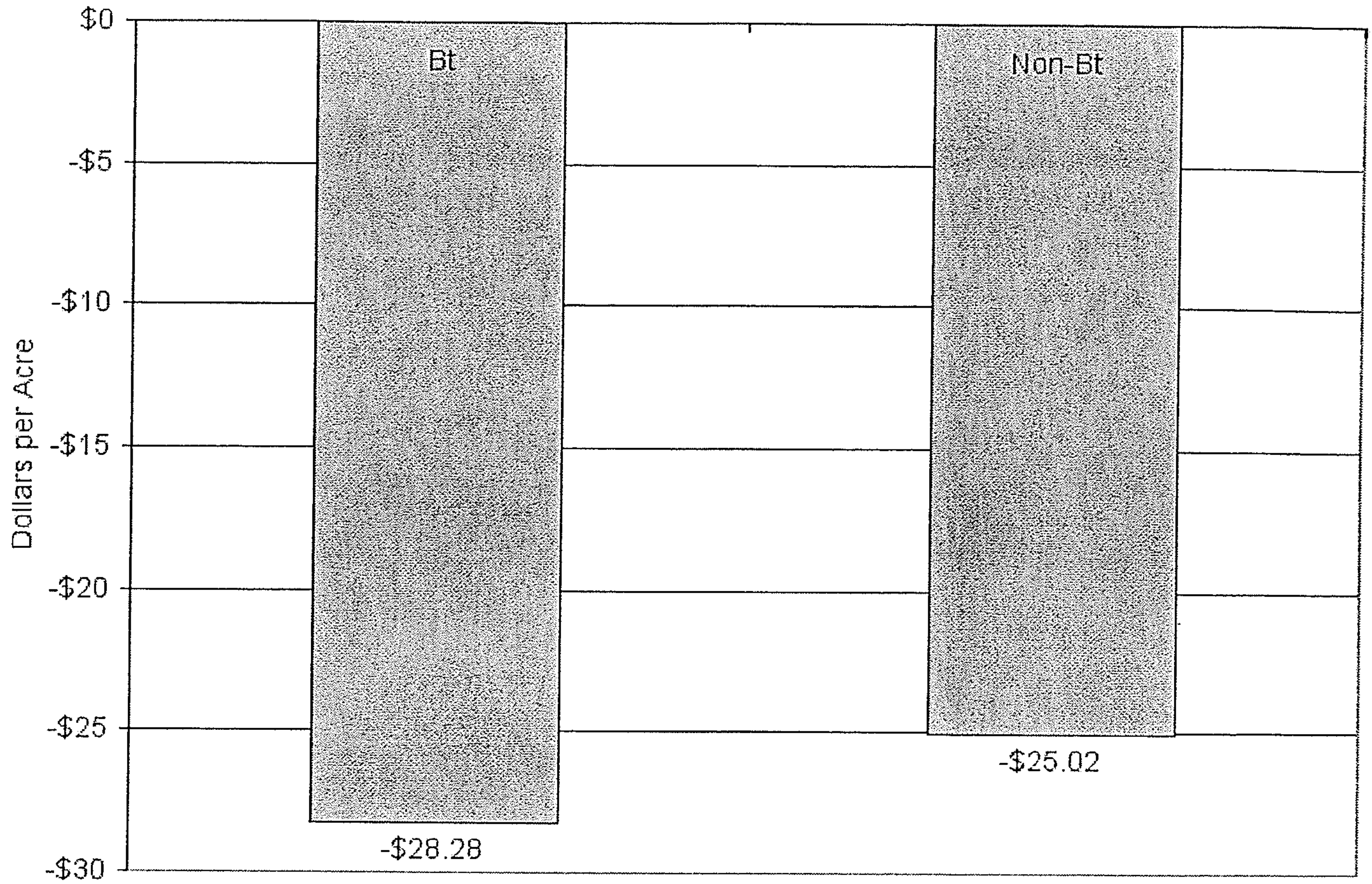


Total, non-land, costs for Bt corn averaged $207.25 per acre as opposed to the non-Bt corn that averaged $197.00 per acre. This difference is lower than the cost difference found in 1998. At that time the Bt corn was $20 per acre more costly than the non-Bt varieties.

The land charge used here was calculated similarly to the land charge for the soybeans. The average rental rate used was $130 per acre. This is higher than the Iowa average rate of $120 reported by the Iowa State Extension (Edwards and Smith, 2001b).

Both Bt and non-Bt corn showed a negative return to labor and management. The Bt corn lost an average of $28.28 per acre while the non-Bt corn posted an average loss of $25.02 (Figure 9).

Figure 9: Return to Labor and Management for Bt and Non-Bt Corn, 2000



Similar to herbicide-tolerant soybeans, Bt corn produced a return essentially equal to the non-Bt corn. Even though Bt corn has not increased in acreage as the herbicide-tolerant soybeans have, this again raises the question of why people would adopt an equal technology at all, especially given the potential marketing problems associated with Bt corn.

Many farmers plant Bt corn as a sort of insurance policy. Pest populations are unknown at the beginning of the season. There are certain fields and conditions where a pest outbreak is more likely. For these fields, the use of Bt corn could produce dramatically different results than those presented here. Remember that this is a cross-sectional study and not a side-by-side comparison.

Some farmers claim the Bt corn has more brittle stalks and that it is not as appealing to cattle as a feed. In spite of these observations, the yields for Bt corn found here are higher than the non-Bt and this was similar to the cross-sectional study in 1998.

Who Benefits from Biotechnology?

The preceding analysis shows that the primary beneficiaries of the first generation biotechnology products are most likely the seed companies that created the products. Additionally, in the case of herbicide tolerance the companies that supply the tolerant herbicides also are the benefactors from the development of the biotech crops.

It also appears that farmers have benefited from biotechnology. Their gains, however, appear to more related to greater ease of production and the ability to cover more acres as opposed to an increase in the profits per acre. The farmer benefits are evidenced by the rapid adoption of this new technology. As noted, in Iowa soybean acres planted to herbicide-tolerant varieties went from zero to more than half the total acreage in just a few years. Farmers definitely perceive a benefit even if their profits are not increasing.

It has been argued that consumers also are the beneficiaries of the first generation biotech products because the increased production leads to lower prices. Whether or not production increases depends upon the crop under consideration. For soybeans, the yields actually are slightly less, while for corn they are slightly higher.

Regardless of the crop under consideration, it is hard to determine whether consumers actually benefit from the first generation biotech products. The prices for the basic commodities covered are already low due to abundant supplies. In addition, government programs that support prices will cost the taxpayers more if the prices continue to drop.

Consumers actually spend only a fraction of their food dollar on these basic commodities. Changes in the price of the basic commodities will have little impact on the prices charged to the consumers. Additionally, a consumer backlash against biotech indicates that, for at least some consumers, the addition of biotech crops is not seen as a benefit but an added risk.

Today's biotech crops and applications are merely the first generation of products. It appears from these examples that the primary beneficiaries are the seed and chemical companies and, to a lesser extent, the farmers. What will happen with the proposed second-generation products remains to be seen.

Conclusion

The results presented here are from a cross-sectional study. Replicated, randomized plot studies by Pecinovsky also reached the same conclusions. (Iowa State University, 2001) Similar to this study, he found the Bt corn had higher yields whereas the herbicide tolerant soybeans had lower yields.

Today the primary benefactors of biotechnology are the seed companies and chemical companies. Farmers appear to be receiving some non-pecuniary benefits. And, in spite of arguments to the contrary, there is only mixed evidence with respect to consumer benefits.

The primary reason for the first generation biotech applications was to focus on input traits. Given this approach it is not surprising that the input companies are the primary beneficiaries. Biotech applications that focus on output traits, as opposed to the input traits, may produce more widely dispersed benefits.

One of the issues that I have not addressed but that is a concern to many people pertains to the externalities associated with the use of biotechnology, especially as it has been applied to date. There is a question of unknown health effects from the genetically modified products. Health officials have assured the public that this should not a concern, but this is not an entirely satisfactory reassurance to many.

Several other externality issues surround the use of biotech crops. Insect and weed resistance will develop faster with the widespread use of these products. There also is the issue of pollen drift that affects people trying to grow either organic commodities or some other type of crop requiring segregation from biotech varieties.

Biotechnology is an extremely powerful tool. It has the potential to create many useful products as well as many unforeseen problems. As with any new technology, it must be evaluated carefully. It is not prudent to expect private companies to develop products for the public good. Companies are in the business of making money and the products they pursue are designed for that end. To expect any other result from private research is not appropriate or realistic.

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"As spectacular and exciting as biotechnology is, its breakthroughs have tended to delay our shift to long-term, ecologically-based pest management because the rapid array of new products provides a sense of security just as did synthetic pesticides at the time of their discovery in the 1940s . . . the crops engineered to express toxins of pathogens are simply targeted as replacements for synthetic pesticides and will become ineffective in the same way that pesticides have."

– Joe Lewis, USDA-ARS researcher

COMMODITIES & AGRICULTURE

Concern in Canada over biotech wheat

Growers fear loss of exports to countries that have banned GM food

By Scott Morrison in Toronto and Nikki Tait in Chicago

North American wheat producers are expressing concern that the introduction of genetically-modified wheat varieties could result in a loss of exports.

Nowhere is this concern greater than in Canada, which exports about 85 per cent of its wheat production, making it the second largest player in the global market.

The Canadian Wheat Board, the marketing organisation that controls about 95 per cent of Canada's production, advocates a "better safe than sorry" approach.

The CWB is worried that once GM wheat was commercialised, it would be virtually impossible to prevent it from contaminating conventional wheat stocks.

Also, since several overseas customers have already rejected GM food products, the board fears they might stop buying Canadian wheat if Ottawa allowed GM varieties to be produced.

Crunch-time is approaching fast: GM wheat varieties that are pesticide-resistant are currently being trialled by Monsanto, the US life sciences group, and could be ready for commercialisation between 2003 and 2005.

But already, says Earle Geddes, CWB vice-president for farmer relations, some customers in Europe and Asia have said they will go elsewhere if Canadian farmers start planting genetically modified wheat.

Algeria, which buys more than 40 per cent of Canada's durum wheat production, recently banned all GM foods. Meanwhile, Thailand is concerned that food it produces using US and Canadian wheat, such as biscuits, could be denied export access to European markets.

'Nobody can guarantee zero tolerance. If that's what people want, then nobody can deliver it'

"The mere fact that Canada would grow it would mean we wouldn't be shipping it [to certain customers]," says Mr Geddes.

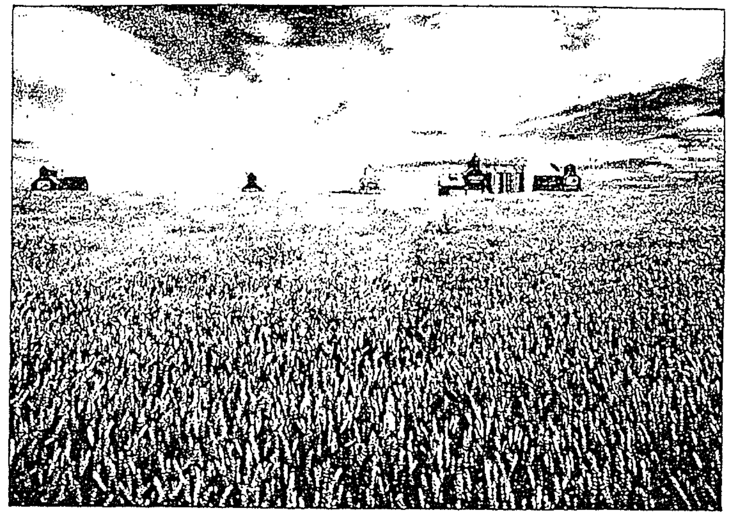
Concern over how GM wheat might be received has also surfaced in the US. US wheat acreage has declined in recent years, but export markets remain important for the diminished number of US growers. Almost half the US crop is exported and in some states, such as Idaho, the proportion is around 80 per cent.

US Wheat Associates, the industry's export market development arm, says several Asian and Middle Eastern countries have already requested assurances that produce is GM-free – a demand that currently can be met by a US Department of Agriculture letter stating that biotech wheat is not grown in the US. That would no longer suffice once GM wheat was commercialised.

So wheat producers and exporters are scrambling to come up with solutions. The Canadian wheat board is lobbying Ottawa to make market acceptance a factor when deciding whether a GM product should receive regulatory approval. Mr Geddes says that would prevent the commercialisation of a crop that has no "customer pull".

Meanwhile, the US wheat industry's big trade associations have drawn up six principles that they believe should govern the introduction of GM wheat.

These include support for customer choice; an insistence that a viable identity-preservation system (a production and transport structure that separated GM wheat from conventional crops) and testing programme be in place before any biotechnology products are commercialised; as well as a general agreement on a "reasonable threshold" for accidental inclusion of biotechnology traits in supposedly non-GM supplies.



Bitter harvest: some customers have said they will go elsewhere if Canadian farmers plant GM wheat

Some growers have also pushed for more stringent restrictions. Motions to declare a moratorium on biotech wheat have been introduced in the Montana and North Dakota state legislatures, for example, although both have failed to make much headway.

Monsanto acknowledges wheat producers have legitimate concerns, but argues that they are "pure conjecture" at this point. Still, in an effort to address the worries, it has outlined a process under which it would move to commercialise pesticide-resistant wheat.

First, it would not commercialise the product until it had demonstrated agronomic benefits to farmers and received regulatory approval in Canada, the US and Japan. Second, it would ensure there was a guaranteed market for limited GM wheat production. Finally, it would wait until there was an adequate "identity preservation system".

However, Monsanto rejects the Canadian Wheat Board's idea that market acceptance should be a criterion in determining whether a crop variety receives regulatory approval. "That would give everyone outside Canada a say in how Canada runs its business," says spokeswoman Trish Jordan.

The CWB counters that it would not be cost-effective to segregate GM wheat. Based on current technology, the board says testing Canada's entire production would cost its wheat farmers hundreds of millions of dollars.

A bigger concern to the wheat board is that it would not be able to provide an iron-clad guarantee that Canada's conventional crops were not contaminated by GM varieties.

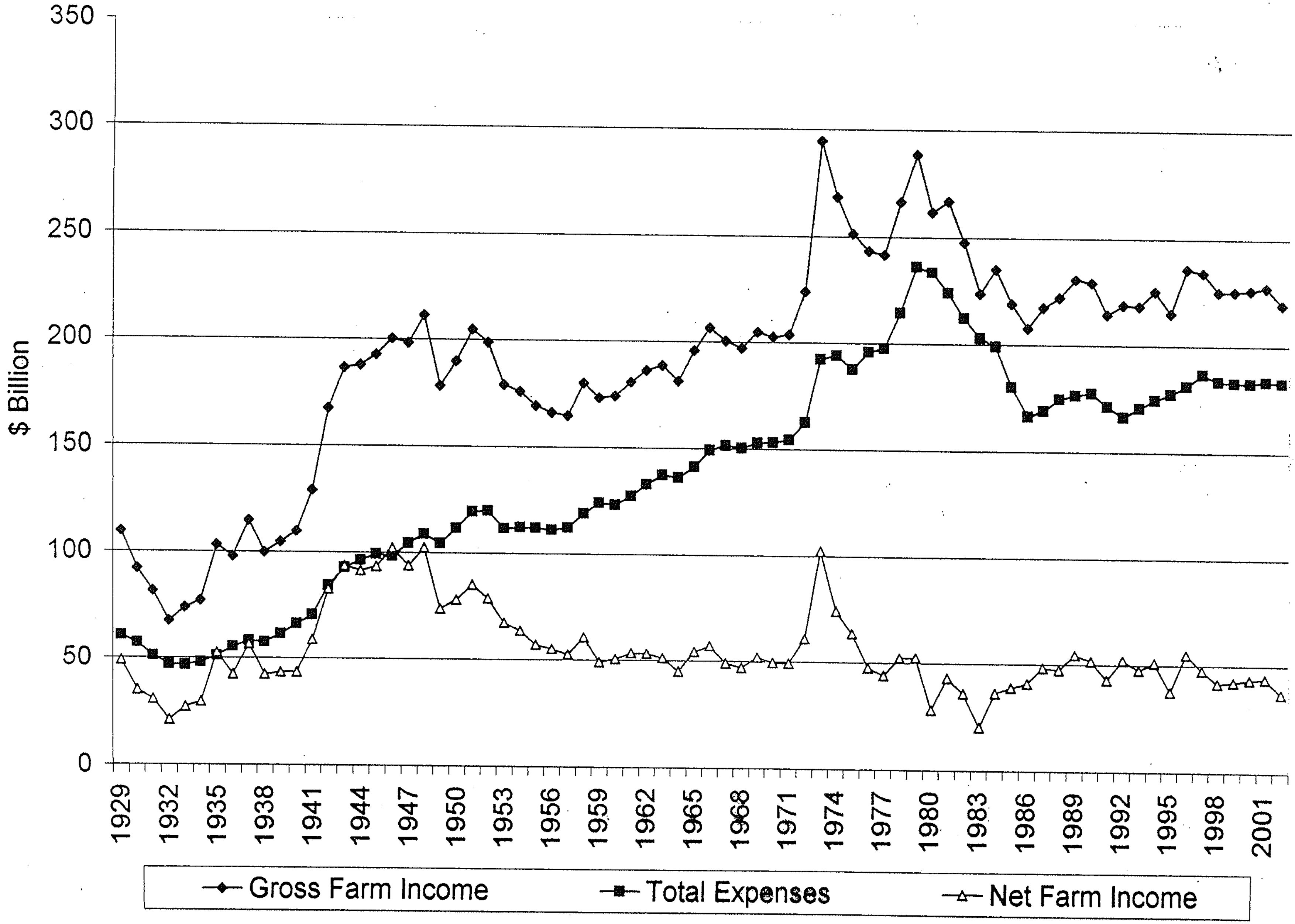
Concerns over the adequacy of segregation arrangements have mounted since last year's Starlink debacle in the US, when GM corn approved only for animal consumption reached the human food chain.

Monsanto acknowledges it would be impossible completely to segregate GM and conventional wheat if both were transported on the same vehicles or were stored in the same facilities.

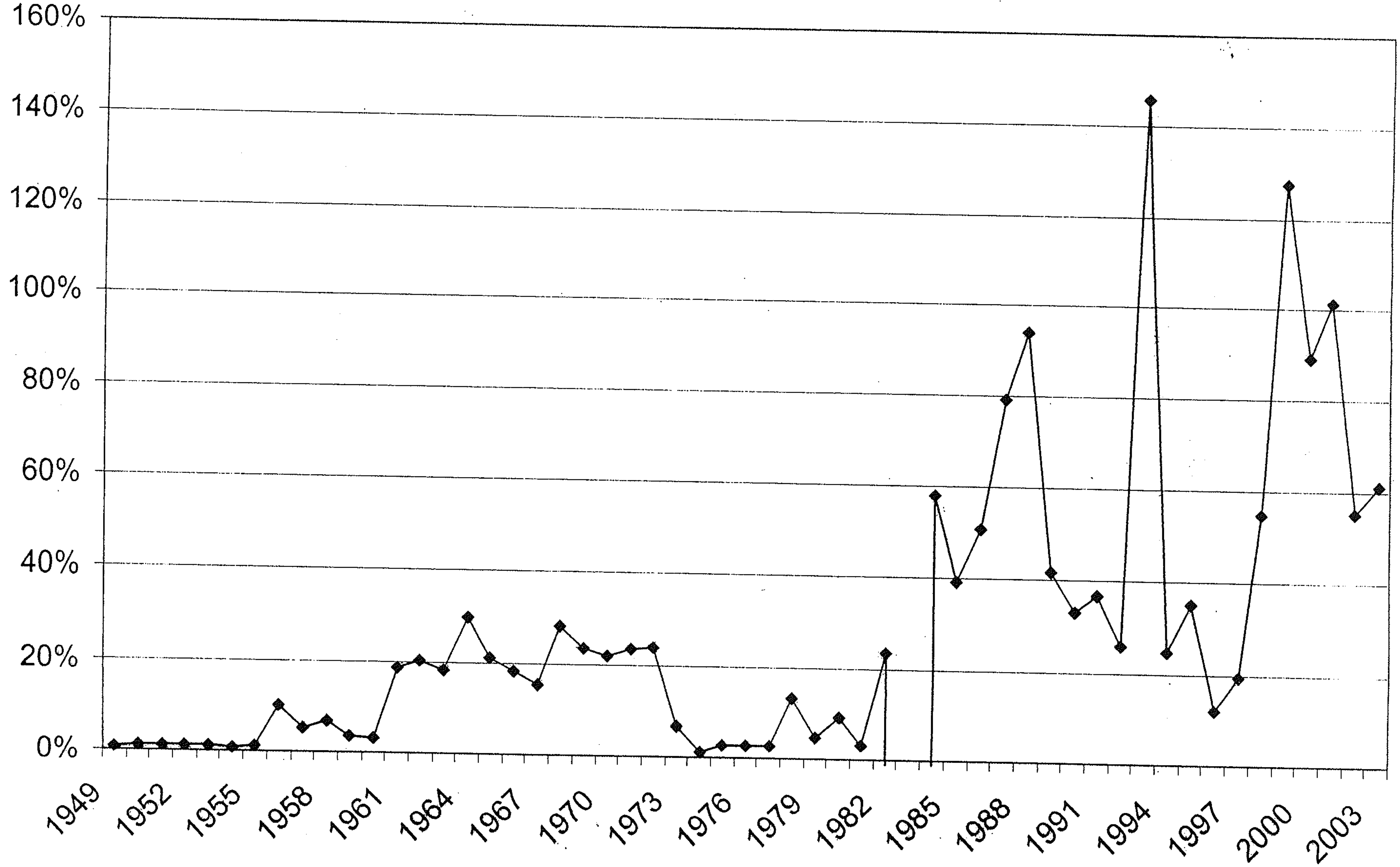
"Nobody can guarantee zero tolerance. If that's what people want, then nobody can deliver it," says Monsanto's Ms Jordan.

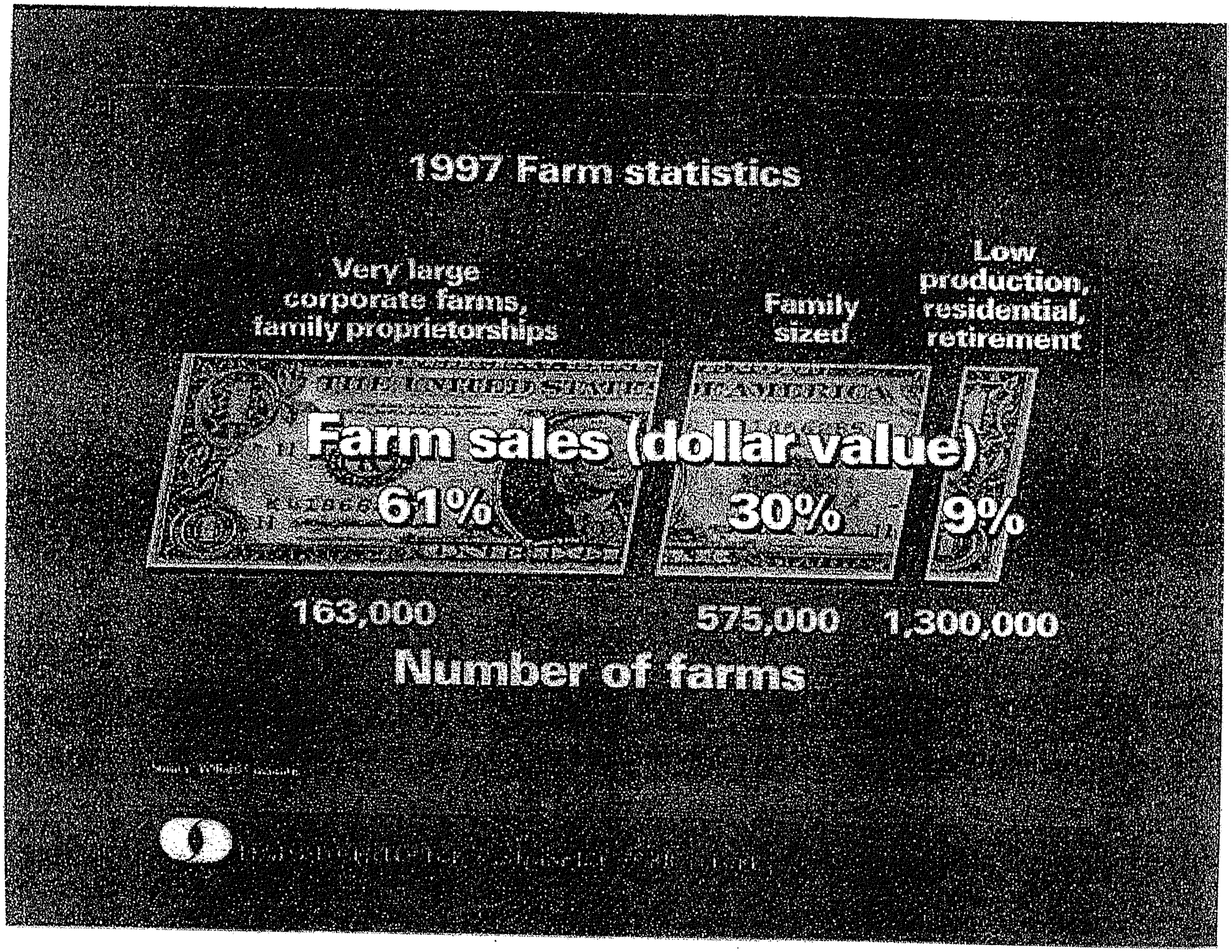
Processors under pressure from surging prices

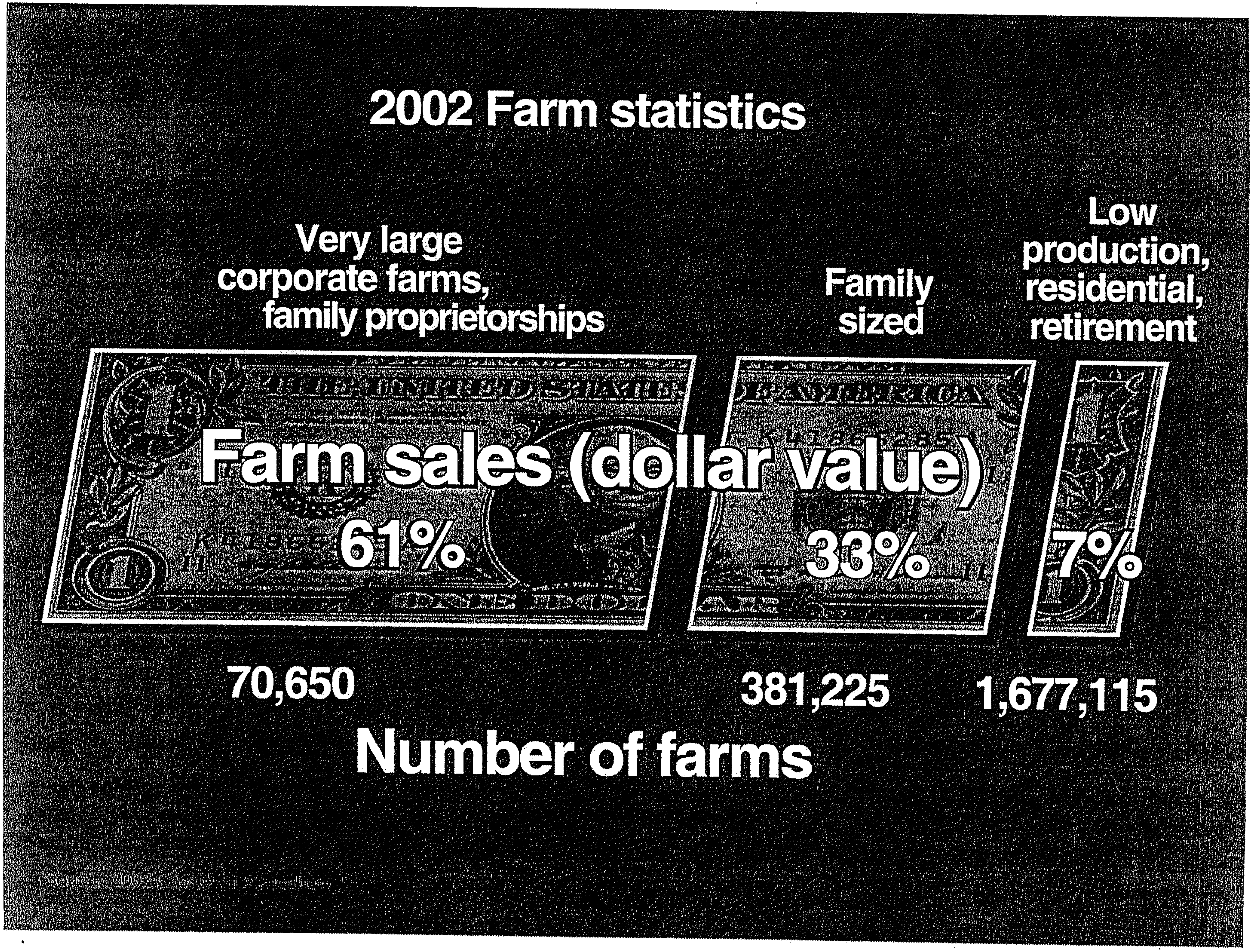
U.S. Farm Income and Total Expenses in Constant Dollars



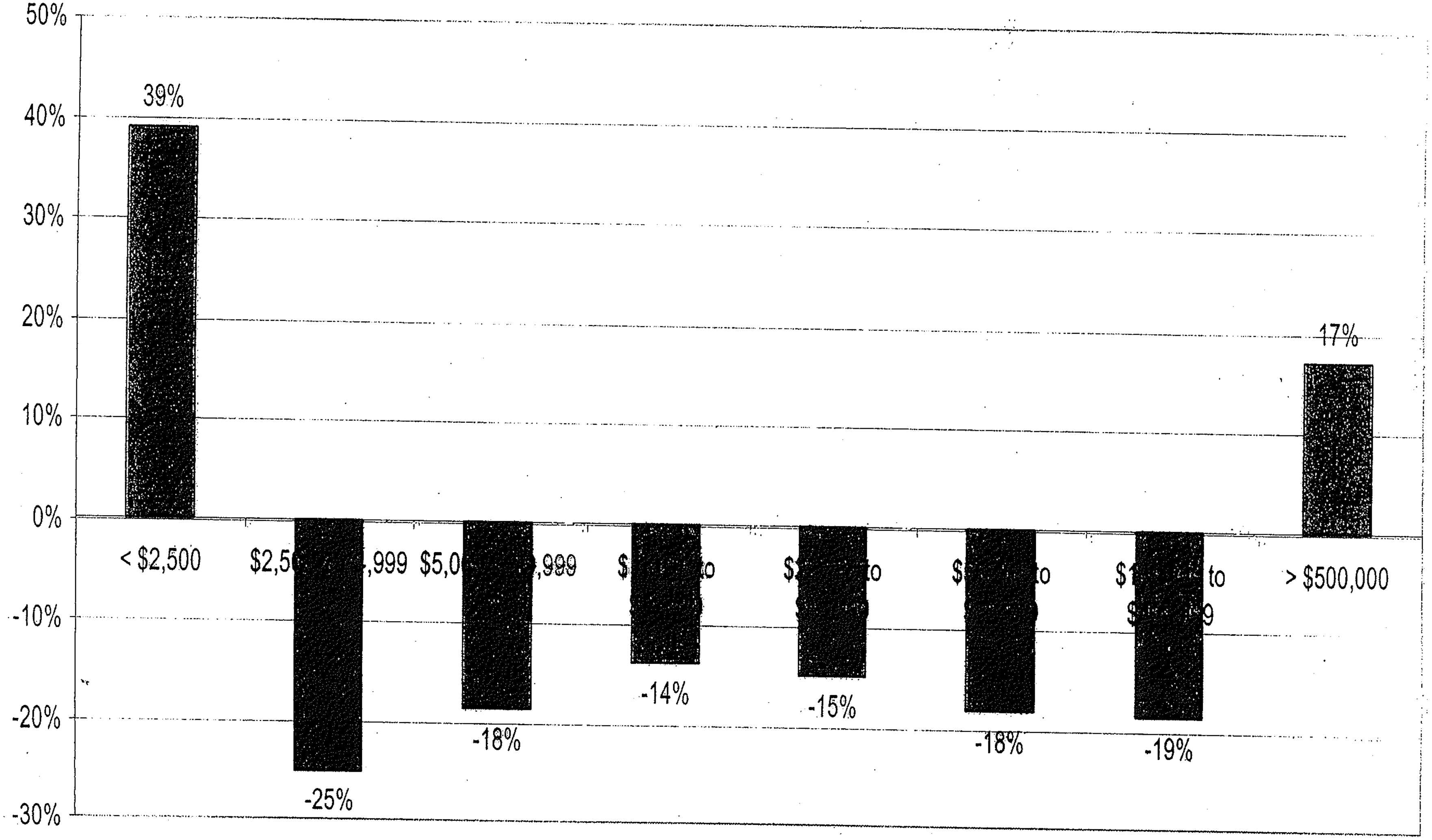
Government Payments as a Percent of Net Farm Income



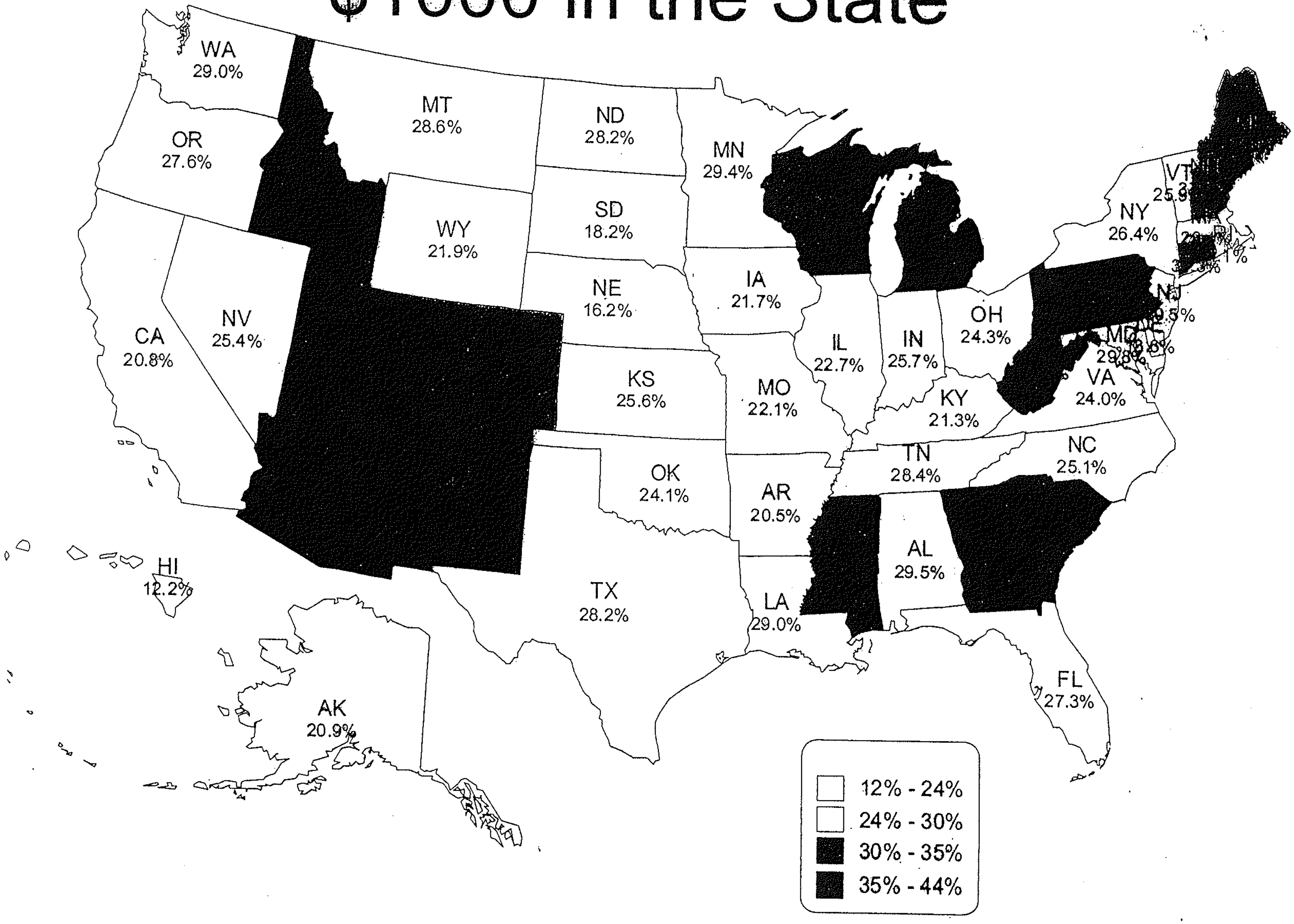

1997 Farm statistics
Very large corporate farms, family proprietorships
Family sized
Low production, residential, retirement
Farm sales (dollar value)
61%
30%
9%
163,000
575,000
1,300,000
Number of farms


2002 Farm statistics
Very large corporate farms, family proprietorships
Family sized
Low production, residential, retirement
Farm sales (dollar value)
61%
33%
7%
70,650
381,225
1,677,115
Number of farms

Percent Change in Iowa Farms by Sales Category, 1997 to 2002



Percent of Farms with Sales Under $1000 in the State



Percent of U.S. Farmers Under 35 and over 65