Environmental and Economic Effects of Reducing Pesticide Use

A substantial reduction in pesticides might increase food costs only slightly

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Several studies suggest that it is technologically feasible to reduce pesticide use in the United States 35 to 50% without reducing crop yields (NAS 1989, OTA 1989). Denmark developed an action plan in 1985 to reduce pesticide use by 50% before 1997. Sweden also approved a program in 1988 to reduce pesticide use by 50% within 5 years (NBA 1988). The Netherlands is developing a program to reduce pesticide use 50% in 10 years. These proposals, along with the conclusion by Hof faker (1980) that the United States oversprays pesticides, prompted us to investigate the feasibility of reducing the US annual use of synthetic organic pesticides by approximately one-half.

Farmers use an estimated 320 million kg (700 million lb) of pesticides annually at an approximate cost of $4.1 billion (Table 1). Indeed, investment in pesticide controls has been shown to provide significant economic benefits. Dollar returns for the direct benefits to farmers have been estimated to range from $1 to $3 for every $1 invested in the use of pesticides (Heindly 1968, Pimentel et al. 1978). However, these cost figures do not reflect the indirect costs of pesticide use.

There are many opportunities to reduce pesticide use

There is a need for improved post-control technologies for some currently used pesticide-control practices; and assess the public health and environmental costs associated with reduced pesticide use.

Extent of pesticide use

Of the estimated 434 million kg of pesticides used annually in the United States, 69% are herbicides, 19% insecticides, and 12% fungicides (Table 1). The 320 million kg of pesticides used in agriculture are applied at an average rate of approximately 3 kg/ha to approximately 14 million ha—62% of the 185 million ha that are planted (Pimentel and Levitan 1986). Thus a significant portion (38%) of crops receives no pesticides.

The application of pesticides for pest control is not evenly distributed among crops. Overall, 93% of the hectares of row crops, such as corn, soybeans, and cabbage, is treated with some type of pesticide (Pimentel and Levitan 1986). In contrast, less than 10% of forage crop hectares are treated.

Herbicides are currently being used on approximately 90 million ha in the United States—greater than half of the nation’s cropland. Field corn alone accounts for 53% of agricultural herbicide use, and almost three-quarters of the herbicide is applied to corn and soybeans. The unequal distribution is similar in insecticide use. Of the approximately 62 million kg of insecticides applied to 5% of the total agricultural land (Table 1), approximately 25% is used on cotton and corn; some crops are treated as many as 20 times per
season (e.g., apples and cotton), whereas other crop hectares may be treated only once (e.g., corn and wheat).

Insecticide use also varies considerably among geographic regions. Warm regions of the United States often suffer intense pest problems. For example, although only 13% of the alfalfa acreage in the United States is treated with insecticides, 89% of the alfalfa acres in the Southern Plains states is treated to control insect pests (Eichers et al. 1978). In the Mountain region, where large quantities of potatoes are grown, 63% of the potato cropland receives insecticide treatment, but in the Southeast, where only early potatoes are grown, 100% of the potato cropland receives treatment (USDA 1975). Cotton insect pests such as the boll weevil are also more of a problem in the Southeast than in other regions (USDA 1983). In the Southeast and Delta states, 84% of the cotton cropland receives treatment, whereas in the Southern Plains region less than half of the crop (40%) is treated.

Fungicides are primarily used on fruit and vegetable crops (Pimentel and Levitan 1986). Approximately 95% of grapes and 97% of potato hectareage are treated with fungicides, whereas neither corn nor wheat hectareage is treated.

Crop losses and changes in agricultural technologies

Since 1945, the use of synthetic pesticides in the United States has grown 33-fold (Figure 1). The increase is largely due to changes in agricultural practices and economic standards (Pimentel et al. 1977). At the same time, some new pesticides have at least tenfold greater effectiveness than older pesticides (Pimentel et al. 1991). For example, in 1945 DDT was applied at a rate of approximately 2 kg/ha. Today, similarly effective insect control is achieved with pyrethroids and aldicarb applied at 0.1 kg/ha and 0.05 kg/ha, respectively.

Currently, an estimated 37% of all crop production is lost annually to pests (13% to insects, 12% to plant pathogens, and 12% to weeds) in spite of the use of pesticides and nonchemical controls (Pimentel 1986). Although pesticide use has increased during the past four decades, crop losses have not shown a concurrent decline. According to survey data collected from 1942 to the present, losses from weeds have fluctuated with an overall slight decline, due to improved chemical, mechanical, and cultural weed-control practices, from 14% to 12% (Table 2). During that same period, US losses from plant pathogens, including nematodes, increased slightly, from 10.5% to approximately 12.0%. This increase resulted in part from reduced sanitation (because fungicides can substitute for sanitation), higher cosmetic standards, and abandonment of crop-rotation practices.

The share of crop yields lost to insects has nearly doubled during the last 40 years (Table 2), despite more than a tenfold increase in both the amount and toxicity of synthetic insecticide used (Pimentel et al. 1991). The increase in crop losses due to insects per hectare has been offset by increased crop yield obtained with higher-yielding varieties and greater use of fertilizers and other inputs, such as fertilizers, irrigation, and high-yielding crop varieties (USDA 1989).

This increase in crop losses despite intensified insecticide use is due to several major changes that have taken place in agricultural practices (Pimentel et al. 1991). These changes include:

- the planting of some crop varieties that are more susceptible to pest attacks;
- the destruction of natural enemies of certain pests, which creates the need for additional pesticide treatments;
- the increase in pests resistant to pesticides;
- the increase in monocultures and the resultant reduced crop diversity;
- the lowering of Food and Drug Administration tolerance for insect and insect-pest foods and the enforcement of more stringent cosmetic standards by fruit and vegetable processors and retailers;
- the increased use of aircraft application technology;
- the reduction in sanitation, including less attention to the destruction of infected fruit and crop residues;
- the reduction in tillage, with more crop residues left on the land surface.

Table 1. US hectares treated with pesticides (modified from Pimentel and Levitan 1986). Numbers are in millions.

<table>
<thead>
<tr>
<th>Land-use category</th>
<th>Total hectares</th>
<th>Tenanted hectares</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>472</td>
<td>114</td>
<td>520</td>
</tr>
<tr>
<td>Crop and pasture</td>
<td>150</td>
<td>24</td>
<td>55</td>
</tr>
<tr>
<td>Forest</td>
<td>290</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Household</td>
<td>35</td>
<td>4</td>
<td>35</td>
</tr>
<tr>
<td>Total</td>
<td>1016</td>
<td>148</td>
<td>454</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>All pesticides</th>
<th>Tenanted hectares</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>916</td>
<td>148</td>
</tr>
</tbody>
</table>
• the planting of crops in climatic regions in which they are more susceptible to insect attack,
• the use of herbicides that have been found to alter the physiology of crop plants, making them more vulnerable to insect attack.

**Estimated benefits/costs from reduced pesticide use**

A reduction in US pesticide use would require substituting nonchemical alter-
atives for chemical pest control and improving the efficiency of pesti-
cide application technology. Such changes in some cases increase and in other cases decrease pest control costs.

Crop losses to pests. Losses from pests for 40 major crops grown with pesticides have been estimated by examin-
ing data on current crop losses, by reviewing loss data based on experi-
mental field tests, and by consulting pest control specialists. Combina-
ting these data, however, has often been difficult. For example, data based on published experimental field tests usually emphasize the benefits of pesticides use; thus loss data associ-
ated with pesticide treatments usually emphasize benefits over costs (Pimen-
t et al. 1978).

In addition, field tests often exaggerate total crop losses because assess-
ments of insect, disease, and weed losses are carried out separately and then combined. For example, on un-
treated apples, insects were reported to cause a 50–100% crop loss, disease 30–60%, and weeds 6% (Ahres-
and Cramer 1985, Pimentel et al. 1991). This approach yields an esti-
imated total loss of approximately 140% from all pests combined! A more accurate estimate of losses in the absence of pesticides ranges from 80% to 50% based on current economic standards (Ahrens and Cramer 1985). Exactely how much overlap ex-
ists among insect, disease, and weed-loss figures for apples and for other crops is not known.

**Examples of other important limitations.** The figures for current crop losses to pests, despite pesticide use, are based on US De-
partment of Agriculture data and other estimates obtained from spe-
cialists. We emphasize that these are estimates. For certain crops, little or no experimental data are available concerning yields with pesticide use and various alternatives. In addition, in some states recent data were not available. With these crops, our esti-
mates were generally extrapolated from data on closely related crops.

Although we recognize the limita-
tions of the data used in this analysis, we believe there is a need to assemble available information to provide a first approximation of the potential for reducing pesticide use by one-half. We hope that better data will be available in the future, so that a more complete analysis of pesticide costs and benefits can be made.

**Reduction of the risks associated with pesticides is in itself a compli-
cated issue, particularly because environ-
mental and health trade-offs are often associated with changes in tech-
ology. Because of the complexity of these trade-offs, they could not be included in the analysis. One exam-
ple, however, involves the conflict be-

tween reducing pesticide use and pro-

tecting soil conservation through the use of no-till culture as well as re-
duced tillage. Although no-till and reduced-tillage culture significantly re-
duce soil erosion (Van Doren et al. 1977), they also significantly increase the need for herbicides, insecticides, and fungicides (Taylor et al. 1984).

However, although reducing pesti-
cide use may require reducing the use of some no-till systems, highly cost-
effective soil conservation alternatives to no-till do in fact exist. These in-
clude ridge-till, crop rotations, strip

cropping, contour plowing, terracing, windbreaks, mulching, cover crops, and green mulches (Mohlenbauer and Hudson 1988). Ridge-tilling, for example, makes the crop on perma-
nent ridges 20 cm high along the contour, is rapidly growing in popu-
larlasy as an alternative replacement for no-till practices for most row crops. It is a form of reduced-till that has many advantages over no-till (Forcella and Lindstrom 1988). For example, ridge-
till can be employed without the use of herbicides, and it controls soil ero-
sion more effectively than no-till (Rouse and Smith 1983).

Techniques to reduce pesticide use. The increase in crop losses associated with recent changes in agricultural practices suggests that some alterna-
tive strategies exist that might reduce pesticide use. Two important prac-
tices that apply to all agricultural crops include widespread use of moni-
toring and improved application equipment. Currently, a significant number of pesticide treatments are applied unnecessarily and at im-
appropriate times due to a lack of treat-
ment when necessary program. Further-
more, pesticide is unnecessarily lost during application (e.g., only 25–
50% of the pesticide applied by air-
plane actually reaches the target area: Akesson and Yates 1984, Mazzaraios1985). By increasing monitoring and improving application equipment, more efficient pest control can be achieved.

**Insecticides**

Corn and cotton account for approxi-

mately 25% of the total insecticide use in agriculture. Thus reducing in-
secticide use in these two crops by substituting nonchemical alternatives would contribute significantly to a reduction in insecticide use.

Corn. During the early 1940s, little or no insecticide was applied to corn, and losses to insects were only 3.5%.

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Table 2. Comparison of annual pest losses* in the United States. (After Pimentel et al. 1990).

<table>
<thead>
<tr>
<th>Period</th>
<th>Insects</th>
<th>Diseases</th>
<th>Weeds</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>13.0</td>
<td>12.0</td>
<td>12.0</td>
<td>37</td>
</tr>
<tr>
<td>1978</td>
<td>13.0</td>
<td>12.0</td>
<td>12.0</td>
<td>37</td>
</tr>
<tr>
<td>1951-1960</td>
<td>12.9</td>
<td>12.2</td>
<td>12.0</td>
<td>37</td>
</tr>
<tr>
<td>1942-1951</td>
<td>7.1</td>
<td>10.4</td>
<td>11.8</td>
<td>27</td>
</tr>
<tr>
<td>1942-1951</td>
<td>10.7</td>
<td>NA</td>
<td>NA</td>
<td>4</td>
</tr>
</tbody>
</table>

*Not adjusted for inflation. NA = Not available.
management, rotations, clean weed, and changed tillage practices (Keng et al. 1986, OTA 1979).

Currently, a total of 29 million kg of insecticide is applied to cotton, and it is estimated that this amount could be reduced by approximately 40% through the use of readily available technologies (Pimentel et al. 1991). By effectively using a monitoring program, one might reduce insecticide use by approximately 20%. Through the use of pest-resistant cotton varieties and the alteration of planting dates in zones growing regions, insecticide use could be reduced by another 3% (Fram 1983, Friske 1985).

An additional 10% reduction in insecticide use could be achieved through the replacement of the price-support program with a free-market system (without commodity and price-support programs) and no price-support program for cotton production (NAS 1969). This change would allow cotton to be grown in regions with fewer insect pests, thus reducing the need for insecticide use. However, changing the current price-support program to allow society to take advantage of these benefits is politically unattractive.

The amount of insecticide reaching target areas could be increased by changing the type of application equipment employed, especially reducing the use of aircraft ultra-low-volume application equipment, which wastes 75% of pesticide applied. The amount of insecticide waste could be reduced by 25% if ground-application instead of air-application equipment were used (Mattos and McFate 1985, Pimentel and Levitan 1986). In addition, covering the spray boom with a plastic shroud can further decrease drift 85% (Ford 1986), thereby allowing for an additional reduction in pesticide use.

Insecticide use on cotton might be reduced by another 6% through the implementation of other pest-control techniques, including cultivation of short-season cotton, fertilizer and water management, improved sanitation, crop rotations, the use of crop seed cleaned of weed seeds during culture and processing, and altered tillage practices (Gittens 1985, OTA 1979). Depending on the particular environment, insecticide use on cotton might even be reduced much more. For example, Shanholtz et al. (1982) reported that insecticide use in the Lower Rio Grande Valley of Texas could be reduced 97% by planting short-season cotton under dryland conditions. This practice also resulted in a twofold increase in net profits over conventional methods.

Thus, by implementing combina- tions of monitoring, application technology, short-season cotton, fertilizer and water management, improved sanitation, crop rotations, and tillage practices in cotton, insecticide use might be reduced 40%. These alternative controls should pay for themselves through reduced insecticide and application costs.

Herbicides

Corn and soybeans account for approximately 70% of the total herbicide applied in agriculture (Pimentel and Levitan 1986). We use these crops to illustrate the potential of decreasing herbicide use.

Table 3. Current and potential reduced use of pesticides in US crops. Total current pesticide costs plus total added alternative control costs (Pimentel et al. 1991).

<table>
<thead>
<tr>
<th>Pesticide use (million kg)</th>
<th>Cost (million dollars)</th>
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<tbody>
<tr>
<td>Current</td>
<td>Potential reduced</td>
</tr>
<tr>
<td>Insecticides</td>
<td>6.21</td>
</tr>
<tr>
<td>Herbicides</td>
<td>219.6</td>
</tr>
<tr>
<td>Fungicides</td>
<td>37.4</td>
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<tr>
<td>Total</td>
<td>219.3</td>
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* * *

<table>
<thead>
<tr>
<th>Environmental factor</th>
<th>Cost ($ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human pesticide poisoning</td>
<td>21.6</td>
</tr>
<tr>
<td>Animal pesticide poisonings and contaminated livestock products</td>
<td>35</td>
</tr>
<tr>
<td>Reduced natural enemies</td>
<td>150</td>
</tr>
<tr>
<td>Pesticide residues</td>
<td>150</td>
</tr>
<tr>
<td>Home environment and reduced pollution</td>
<td>150</td>
</tr>
<tr>
<td>Losses of crops and trees</td>
<td>75</td>
</tr>
<tr>
<td>Fishery and wildlife losses</td>
<td>15</td>
</tr>
<tr>
<td>Government pesticide pollution regulation</td>
<td>150</td>
</tr>
<tr>
<td>Monitoring wells and groundwater</td>
<td>1200</td>
</tr>
<tr>
<td>Total</td>
<td>2155</td>
</tr>
</tbody>
</table>

vated to help control weeds (Duffy 1982).

The average costs and returns per hectare to no-till, reduced-till, and conventional-till agriculture have been found to be quite similar (Duffy and Hanthorn 1984). For example, added labor, fuel, and machinery costs for conventional-till practices for corn were approximately $42/ha higher than those for no-till. However, the costs for the added fertilizers, pesticides, and seeds in the no-till system were $52/ha higher than conventional-till (Duffy and Hanthorn 1984).

It might be possible to reduce herbicide use on corn by approximately 60% if the use of mechanical cultivation and rotations is increased (Ferracchi and Lindstrom 1981). Corn and soybean rotations have been found to provide substantially higher returns than either crop grown separately and continuously (Helmers et al. 1986). However, we estimate that weed control costs will increase by approximately 30%, because not all alternative practices and rotations are profitable.

Soybeans. The second-largest amount of herbicides is applied to soybeans, with approximately 96% of soybean hectare receiving treatment for weed control; 96% of the hectarage also receives some tillage and mechanical cultivation for weed control (Duffy 1982). Several techniques have been developed that increase the efficiency of chemical applications. The rope-wick applicator has been used in soybeans to reduce herbicide use approximately 90%, and this applicator was found to increase soybean yields 4% over conventional treatments (Dake 1981). Also, a new model of recirculating spray equipment saves 70-90% of the spray emitted that is not trapped by the weeds (Matthews 1985). Spot treatments are a third method of decreasing unnecessary pesticide applications.

In addition, alternative techniques are available to reduce the need for herbicide use on weeds. These include ridge-till, illusion, mechanical cultivation, row spraying, planting date, tolerant varieties, crop rotations, spot treatments, and reduced dosages (Ferracchi and Lindstrom 1982, Helmers et al. 1986, Rousseling and Smith 1988, Tew et al. 1982). Employing several of these alternative techniques in combination might reduce herbicide use in soybeans by approximately 60%. Despite the results of Tew et al. (1982) that indicate no added control costs for the alternatives, we estimate that the costs of weed control would increase $10/ha (Pimentel et al. 1991).

Fungicides

In considering the possible reduction of fungicide use, apples and potatoes were selected as examples. These two crops account for 26% of all the fungicides used in agriculture (Pimentel et al. 1993).

Apples. Most fungicides are applied to apples, peaches, citrus, and other fruit crops (Pimentel and Levinson 1986). Integrated pest management data from apples in New York State suggest that fungicide use on apples could be reduced approximately 10% by monitoring and better forecasting of disease based on weather data (Koch and Tette 1988). In addition, a recent design in spray nozzles and application equipment demonstrated that the amount of fungicide applied for apple scab control could be reduced by 50% (Van der Scheer 1984). Thus, by employing better weather forecasting and improved application technology combined with scouting, fungicide use on apples could be reduced an estimated 20% (Pimentel et al. 1991).

Potatoes. Approximately 96% of potato hectarage is treated with fungicides (Pimentel et al. 1991). Without fungicide treatments, losses from diseases ranged from 5% to 25% depending on the year, weather, and pathogen spread, whereas losses with fungicide treatments were reported to be approximately 20% in a controlled experiment (Teng and Basonnette 1985). Sheldrake et al. (1984) reported that approximately 50% of the late blight on potatoes in Wisconsin reduced the number of required fungicide applications to one or two in 1983.

Correct storage, handling, and planting of seed tubers and proper management of soil structure and fertility minimize losses to most diseases (Rich 1991). Forecasting and monitoring may also be employed to reduce fungicide use 15-35% (Roisyle and Shaw 1985). Monitoring should concentrate on disease incidence and forecasting weather conditions so fungicides can be applied before disease outbreaks. Employing a combination of these controls, it might be possible to reduce fungicide use on potatoes approximately one-third, at an estimated cost of $50/ha (Pimentel et al. 1991).

Overall pesticide-reduction assessment

By substituting nonchemical alternatives for some pesticides used on 40 major crops, we estimate that total agricultural pesticide cost can be reduced by approximately 50% (Pimentel et al. 1991). The added costs for implementing these alternatives are estimated to be approximately $1 billion (Table 3). These alternatives would increase total pest-control costs approximately 25% and would increase total food production costs at the farm 0.6%.

Alternative technologies that result in reduced crop yields become acceptable, the assessment of benefit and cost relationships would be quite different. For example, each 1.0% decrease in crop yield in agriculture results in a corresponding 4.5% increase in the farm price of goods. It is also important to note that over...
production is the prime reason that the United States spends $26 billion annually on price supports (USOMB 1989). Thus, if changes in pest control did in fact reduce yields, it might both increase farm income and decrease government subsidy expenses.

Environmental and health aspects

Society now pays a high price for its use of pesticides. Pesticide-control measures cost approximately $4.1 billion annually, not including the indirect environmental and public health costs, which total more than $2.2 billion annually (Pimentel et al. 1991).

Perhaps the most serious social and environmental costs related to pesticide use are the human pesticide poisonings. Annually approximately 20,000 accidental poisonings occur, mostly from agricultural pesticides, with 2000 cases requiring hospitalization. These poisonings result in approximately 50 fatalities per year. Pesticides are also implicated in numerous other human diseases, including cancer and sterility. An estimated 60,000 human cases of pesticide-induced cancer occur each year (EPA 1987).

The costs of human poisonings and other detrimental environmental effects of pesticide use are delineated in Table 4:

- A large number of domestic animals are poisoned each year by pesticides. Significant amounts of meat and milk are contaminated with pesticides and must be destroyed.
- When pesticides are applied to crops, natural enemies important for controlling some pests are frequently destroyed (OTA 1979). This destruction causes pest outbreaks that must be controlled with additional pesticide applications.
- The development of pesticide resistance in pest populations is another major environmental problem. This resistance requires additional pesticide treatments and more costly controls.
- Large numbers of honeybees and wild bees are poisoned by pesticides, resulting in honey losses and reduced crop pollination.
- Some pesticides, especially when applied by aircraft, drift onto adjacent agricultural lands and damage or destroy crops and forest resources.
- Significant numbers of fish and other wildlife are killed by pesticides each year.
- The government program that attempts to regulate and limit pesticide pollution also incurs major administrative costs (Pimentel et al. 1991).
- Monitoring wells and groundwater for pesticide contamination is costly (Nielsen and Lee 1987).

This analysis is an incomplete assessment of the existing environmental problems caused by pesticide use. There is no completely satisfactory way to summarize all of the environmental and social costs or benefits in terms of dollars. For example, it is impossible to place a monetary value on human death; disease, or disability. The nearly $1 billion attributed to environmental and social costs (Pimentel et al. 1989) represents only a small portion of the actual costs. A more complete accounting of the indirect costs would also include unrecovered losses of fish, wildlife, crops, and trees; losses resulting from the destruction of soil invertebrates, microflora, and microfauna; even higher costs of human poisonings; chronic health problems such as cancer; groundwater contamination; and contamination of human food other than livestock products (Blume 1987). If the full environmental and social costs could be estimated, the total cost could rise to as much as $4 billion annually.

Although the nonchemical alternative controls proposed as substitutes for pesticides in this study are significantly safer than pesticides, the alternatives themselves may cause some social and environmental problems (Pimentel et al. 1984). However, if one assumes that reducing pesticide use by 50% might also eventually reduce the environmental and public health risks from pesticides by approximately one-half, then the added costs for the nonchemical alternatives ($1 billion) might be offset by the reduced environmental and public health risks.

Conclusions

Pesticides cause serious public health problems and considerable damage to agricultural and natural ecosystems. A conservative estimate suggests that the environmental and social costs of pesticide use in the United States are at least $2.2 billion annually, and the actual cost is probably double this amount. In addition to these costs, the nation spends $4.1 billion annually to treat crops with 3.2 million kg of pesticides.

This article confirms previous reports that it is feasible to reduce pesticide use by one-half. The cost is estimated at $1 billion. Such a finding supports the projections of the Office of Technology Assessment (1979) and the National Academy of Sciences (1989); as well as the policies adopted by the Danish and Swedish governments intended to reduce pesticide use 30%.

The 50% pesticide reduction in our current assessment would help satisfy the concerns of the majority of the public, who worry about pesticide levels in their food as well as damage to the environment (Sachs et al. 1987). If pesticide use were reduced by one-half without any decline in crop yield, the total price increase in purchased food, due to increased costs of alternative controls, is calculated to be only 0.6%. If assured that pesticides in food and the environment were greatly reduced, it is likely that the public would be willing to pay this slight increase in food costs.

Higher cosmetic standards have resulted in greater quantities of pesticides being applied to food crops. The rapidly growing use of pesticides for cosmetic purposes is detrimental to both public health and the environment, and it is also contrary to public demand (Pimentel et al. 1977). The public would accept some reduction in cosmetic standards if it would result in a reduction in pesticide contamination of food (Healy 1989).

This acceptance is indicated by the growing popularity of organic food.