Gary Comstock
Philosophy, Iowa State University

Is Genetically Engineered Herbicide-resistance (GEHR) Compatible with Low-input Sustainable Agriculture (LISA)?[1]

The idea of selecting crop plants for their ability to flourish in the presence of herbicides is not new. Even before molecular biologists introduced the techniques of gene splicing, researchers used traditional techniques to create varieties of, for example, wheat. Wheat seeds were soaked in ethyl methanesulfonate and then grown in soil treated with an s-triazine herbicide, terbutryn[1]. Most of the seeds failed to come up, but those that survived produced wheat seeds tolerant of terbutryn. In the same study, tomato seeds were soaked in the ethyl methane sulfonate, producing tomato plants with increased tolerance for the herbicide diphenamid. The seed industry has recognized the importance of herbicides resistance research since at least the late 1970s when the commercial sugarcane breeding program in Hawaii began screening all new varieties for tolerance to chemical weed killers.[2]

Genetic engineering speeds up the process of producing those varieties. Researchers in Canada used molecular techniques to transfer genes from weeds resistant to the herbicide atrazine into rapeseed and rutabaga, allowing “atrazine [to] be used on crops in northern latitudes, where field conditions render other forms of weed control ineffective”.[3] Du Pont has bred tobacco plants resistant to its sulfonylurea

---

'This text is excerpted from “Genetically Engineered Herbicide-resistance,” a two-part article that appears in the Spring and Summer 1990 numbers of the Journal of Agricultural Ethics, and is reprinted by permission of the Journal Editors.

compounds, Calgene has bred tobacco and tomato plants resistant to Monsanto's herbicide glyphosate ("Roundup®"[4]), and Monsanto has produced petunias that can grow in the presence of this popular chemical.[5] Forestry and chemical lawn industries are watching with great interest as private labs and public universities apply more and more sophisticated genetic engineering techniques in herbicide- resistance research. Much of the research is funded with public tax dollars, and much of it is going on at land grant universities whose charge is, in part, to educate and help to improve the well-being of "the industrial classes."

The beneficiaries of genetically engineered herbicide-resistance (GEHR) research would include not only the companies that successfully market the seed and chemical packages but farmers and consumers as well. For example, farmers, who face tougher species of weeds every year might have more efficacious and safer chemicals available. Consumers, more and more of whom appear to be worried about pesticide residues on and in vegetables, fruit, and meat, may be able to buy produce grown with less dangerous herbicides. Despite its potential advantages, however, GEHR technology might also bear significant costs. Leaving aside for the moment agronomic questions like whether GEHR crops will actually work in the field or how long it will be before weeds resistant to the new chemicals appear, consider ethical questions that have been raised.

Some express reservations about the propriety of crossing unrelated plant species. Jeremy Rifkin, for example, has argued that it offends God to cross plants with weeds when the two species cannot be crossed by natural means of reproduction.[6] Is it right to violate species boundaries set up by "natural law"? This question may appear extreme to some plant geneticists and breeders, but it deserves the attention of moral philosophers interested in agriculture.

Others have expressed concern that new labor-saving technologies may displace farmers. Genetically engineered herbicide-resistant crops might increase the productivity and efficiency of an hour of a farmer's time, but what would that mean for farm and rural economies that are already unstable? For two hundred years, technologies have substituted for labor and farmers have been forced out of agriculture. Is this a trend that we want to continue? Is it socially desirable that the poverty rate in nonmetropolitan areas now exceeds that in cities? Do we want another farm technology that might contribute to more farm foreclosures? On the other hand, could GEHR crops help some marginal farmers become more productive, help them to compete better with foreign competitors, and thus revitalize rather than destroy our rural economies? The potential social and economic effects of GEHR crops on rural income levels and distribution is another question needing examination.

Some have worried about the medical and environmental safety of the final product. Will GEHR potatoes really be safe for humans, or will toxic residues remain in or on the vegetables? Will GEHR field corn harm pigs that eat it or adversely affect cows that graze where its residues remain? Will toxic compounds accumulate in the tissues of fish in streams collecting GEHR runoff? Given the magnitude of ecological problems we now face, problems such as soil erosion, groundwater pollution, and the destruction of rainforests in developing countries growing export crops, should we not try to imagine less environmentally taxing ways of growing food? The environmental impact of GEHR crops also needs investigation.

Another worry concerns the economic power of the large chemical firms investing in GEHR crops, powerful multinational companies like Monsanto and Du Pont. Will this technology allow a few chemical companies to strengthen their hold over an industry that is already oligopolistic, forcing American farmers to pay inflated prices for seeds and chemicals? Will consumers eventually pay higher food prices? The economic power of the chemical industry marketing GEHR crops deserves attention.

Finally, some are worried about who we are as a people, our communal identity. Genetically engineered herbicide-resistant crops might make American agriculture more dependent on chemical-intensive and capital-intensive practices. Is this the direction in which we want to go? If we follow this course, do we risk rendering our food supply vulnerable to attack by a single virulent organism or resistant weed? Do we want to encourage exploitive attitudes toward nature? Our cultural sense of ourselves is another matter meriting attention.

Moral questions like these cannot be answered by scientific analysis. To make ethical judgements well requires that we possess the facts, and no one who closes their eyes to the science of agricultural biotechnology will be able to make informed moral decisions about it. But science at its best gives us accurate descriptions of problems.

Ethical judgments require philosophical reflection having to do with prescriptive analysis. Where scientists ask “What is going on?” and “What can be done?” philosophers ask “What ought to go on?" and “What should be done?” Answering the ethical questions requires the use of the best available data and scientific theory, but it also requires the use of the best available humanistic reflection and philosophical theory.

An adequate discussion of the morality of agricultural biotechnological research designed to facilitate the prevention or killing of weeds must take into account a broad range of issues. Looking at weeds from a holistic perspective, one that recognizes all of the relationships necessary to establish a plant as a weed, gives rise to many intriguing questions. For example, why is it that virtually every acre of corn grown in the United States in the past decade has been sprayed with atrazine, alachlor, or a similar herbicide? Is it because farmers have been financially motivated to try to capture that extra four to twenty percent of yield? Or is it because of some unspoken aesthetic working powerfully in the rural unconscious, defining for the modern agribusiness farmer how a cornfield should appear? And this: Why are both public and private institutions so interested in genetic engineering techniques that will produce corn and bean plants able to grow in the presence of stronger doses and mixes of these chemicals? Is it because certain varieties of crabgrass have developed a resistance to atrazine and sterner measures are needed to deal with them? Or is it because giant seed and chemical conglomerates want to prolong the life of old moneymaking compounds?- Is it because new chemicals will soon replace the old suspected carcinogens and give us a safer rural environment? Or is it because molecular biologists have the single-gene replacing technology needed to give tomato plants resistance to glyphosate and, having it, want to use it? Or this: Now that atrazine has turned up in the wells of some farm families, why are land grant universities doing research to find crops that can be grown in the presence of stronger doses of it? Is it because farmers desperately need extra income for their squeezed pocketbook? Or is it because weed scientists at those universities have research projects and labs geared up for answering questions about chemical means of weed control and not for answering questions about cultural means thereof?

I do not have space here to answer all of these questions. (Interested readers may wish to have a look at the longer version of this article in the Journal of Agricultural Ethics.) I will address only the question named in my title, How compatible is genetically engineered herbicide-resistance (GEHR) technology with the goals and values of low-input sustainable agriculture (LISA)?

THE COMPATIBILITY OF GEHR AND LISA

Farmers brought low input and sustainable rotation schemes with them to the United States from Europe, often rotating wheat, oats, and barley over a five or six year period with corn or beans interspersed with years when the land would lay fallow or be used for pasture. These cultural practices have now largely disappeared from American agriculture, being replaced by monocultures or bicultures heavily dependent on purchased inputs. (It is worth noting, however, that rotation schemes have not been completely displaced. Practical Farmers of America, an Iowa based organization which claims to have many members, recommends a five year rotation in which corn, soybeans, corn, oats, and hay are grown in successive years.)

Low input sustainable agriculture techniques like multi-year rotations are regaining credibility as the agricultural establishment begins to give them some attention, and yet LISA is not the norm for controlling weeds, as recent history proves. Before the Second World War with its huge governmental expenditures on chemical research and development, farmers used comparatively few synthetic chemicals on their fields. By 1949, however, they were spraying 25 different herbicides on 23 million acres of corn, wheat, and turf. By 1959, one year after the introduction of atrazine, the number of chemicals had quadrupled, and the number of acres treated had almost doubled. Still, the 100 or so herbicides and the 52 million acres receiving them represented less than 15 percent of total crop land in the U.S. in 1959. The explosion occurred in the 1960s, especially with the introduction of Alachlor® in 1969. By 1974 over half of all crop acreage was receiving herbicides, a total of more than 160 million acres. The percentage of money spent on herbicides has also constantly increased. Whereas nitrogen and insecticide costs were dominant in 1951, 58 percent of a farmer's expenditures on chemicals went to herbicides in 1974.[8] By 1978, the tonnage volume of herbicides sold by the agrichemical industry was second only to that of fertilizer.[9]

As herbicide use went up, so did total yields of crops and total values of crops lost to weeds. According to one estimate, 100 million bushels of soybeans were lost in 1970, a typical year, because of competition from weeds. This was the equivalent of what would have grown on 4 million acres.[10] As the value of crops lost to weeds went up, so did farm purchases of herbicides. By 1974, farmers were spending over one billion dollars each year on different chemicals designed to kill weeds.[11]

Why does herbicide use keep increasing? One reason is that the herbicides, while wiping out a huge percentage of some species of weeds, do not kill all of the individuals in that species. Some biotypes within the targeted species have a higher tolerance to the chemical. They survive the application, and reproduce quickly in fields where more fit competitors have been removed by the herbicide. This is known as selective pressure. Together with the fact that there are likely to be some weed species that are not killed by the herbicide, the fact of differential tolerance within species makes it necessary for the farmer to begin using more and different herbicides in succeeding years.[12] Use of the phenoxyzcetic herbicides for example, while controlling certain weeds, led to an increase in “chickweed, knotgrass, redshank, speedwells and hempnettles.”[13] Other examples are wild carrots, a weed that seems to thrive on propazine, and the birdsfoot trefoil, which grows well “after Simazine® treatment”, and finally, “of green foxtail and crabgrass after atrazine treatment.”[14] Each “new generation” of chemicals is soon met by species of chemical-resistant weeds, much as each new generation of insecticides is eventually confronted with mutant bugs that can tolerate the bug killer. For example, several years after the phenoxyacetitates were introduced in 1945, foxtails became a major problem. 2,4-D Selectively kills some broadleaf (dicot) weeds in corn, wheat and grass seed fields with little or no damage to grasses. But foxtails, a tough perennial monocot, were never controlled by 2,4-D. Understandably, Midwestern farmers jumped when CIBA-GEIGY introduced Atrazine® for use on corn in 1958.

Here was a third “new generation” of herbicides, and some corn farmers adopted it hoping that the pre-emergent would deal with their foxtails and quackgrass. By 1977, it had become the number one herbicide in the number of crop acres treated and in total dollar sales in the U.S. [15] No wonder industry officials took to calling the s-triazines “remarkable,” “a new dimension in . . .corn growing”.[16]But atrazine did not control crabgrass and foxtails, and the search for new chemicals continued.

In 1968, a triazine-resistant weed called common groundsel was discovered in western Washington.[17] But more common than the development of resistant biotypes such as these atrazine-resistant weeds, is selective pressure shifting the population of the weed species toward preexisting tolerant biotypes. So crabgrass, which was never controlled by atrazine, continued to plague monocultured corn fields, and the way was paved for a fourth "new generation", consisting of acetanilides like Monsanto's Alachlor® in 1969 and benzothiadiazines like BASF's Bentazon® in 1973.[18]

So the story goes. Contrary to what one writer claimed as recently as 1982, there is little evidence to show that resistance to herbicides has actually occurred, at least 100 herbicide-resistant weeds have been identified and weed populations tolerant of almost every herbicide known have been discovered.[19] Advertisements in farm journals now regularly recommend that farmers mix trade chemicals such as "Banvel®" with 2,4-D, MCPA, Glean®, Ally®, Finesse®, or Harmony® to "control tough broadleaves like kochia and wild buckwheat, and sulfonylurea herbicide-resistant weeds like Russian thistle and prickly lettuce."[20]

Is the recent popularity of LISA cutting into the popularity of herbicides^ There is no evidence for this claim yet. In 1976,165 herbicides were used on 200 million acres with total sales at $850 million. In 1986, total sales in the U.S. alone were worth 3.6 billion dollars.[21] By 1987, one third of all crop land in the U.S. received treatments of either atrazine or Alachlor, and these and other herbicides were applied to over 95 percent of the acres devoted to corn and soybeans, and over 60 percent of those devoted to wheat.[22] In 1982, a single company sold over a billion dollars of herbicides.[23]

But is GEHR compatible with USA's values? That may depend upon how we define LISA. There are many definitions currently being used. The state of California, for example, requires that its "organic" farmers operate for three years without applying any synthetic chemicals to their crops. Only in the fourth year can their produce be legally certified as organic. If you were to adopt this definition for LISA, GEHR crops would by their very nature be incompatible with sustainable agriculture because the seeds are designed to be used with synthetic chemical sprays.

A less stringent definition is found in Wendell Berry's definition of good farming. Good farming for the Kentucky poet, essayist, and farmer, is simply “farming that does not destroy either farmland or farm people,” a definition that leaves room for GEHR technology. I can imagine a judicious farmer using GEHR crops and herbicides once or twice every five or ten years while practicing the Practical Farmer's multi-year rotation.[24] On the second definition of LISA, GEHR is theoretically compatible with LISA.

The U.S. Department of Agriculture (USDA) offers another definition according to which LISA means, an economically profitable system which relies on each farmer’s interdisciplinary knowledge. A democratic and individualistic kind of farming in which decisions about chemical use are made at the local level, USDA’s idea of LISA insists that important decisions be made by farmers at the local level rather than at the national level by farm programs or experts. According to this definition, LISA farming aims at reducing, but not necessarily eliminating, synthetic chemical use.

Genetically engineered herbicide-resistance technology is theoretically compatible both with Wendell Berry’s definition of good farming and with USDA’s definition of LISA. But the real world differs from the world of theory. How compatible are GEHR and LISA likely to be in practiced Consider that modern agriculture is a highly inflexible system, not very amenable to piecemeal change. The rapid expansion in the use of herbicides after World War II went hand in hand with the use of industrially produced pesticides to control insects, synthetic anhydrous ammonia—and now ureas—to supply nitrogen, manufactured super-phosphates to provide phosphate, large amounts of capital to purchase the inputs, and large tracts of land over which to spread the costs. This produced an agriculture that exemplifies Charles Perrow's definition of a complex and tightly linked technological system.[25] As commercial nitrogen is used to stimulate the growth of high yielding varieties, it stimulates the growth of weeds as well. (In 1965, corn farmers applied 75 pounds of nitrogen per acre. In 1987, they were using over 130 pounds per acre.[26]) Herbicides are then needed to control weeds. Next, insecticides become important as pests are introduced from abroad through internationally connected markets in seeds and produce. Finally, because the technologies used are increasingly expensive (a pound of Atrazine sells for about $2.40, the newer alachlor for about $4.50, and glyphosate for approximately $22.00), farmers must have access to increasing amounts of capital for operating expenses.[27]

Despite the common wisdom that each farmer is an independent entrepreneur, the fact is that farmers have relatively few choices about their operations once they make the decision to enroll in government subsidy programs. When they make that choice, they almost invariably use high-input techniques and monoculture or bicultures. When they choose to go to a corn and soybean rotation in order to keep their acreage base, they must often choose to downplay the use of livestock while emphasizing crop production. This requires that they use purchased fertilizers, purchased herbicides, and that they use fungicides and pesticides.

It is almost impossible to play one part of the game while not playing all of the others. Choosing farm programs means choosing bicultures, large combines, large amounts of capital, large fields, and tons of purchased inputs. If you use 2,4-D to control weeds, sooner or later you will need insecticides to control corn-leaf aphids stimulated by the herbicide.[28] Sooner or later, you will also need fungicides to control smut and Southern corn-leaf blight that seem to accompany 2,4-D use. Once you start growing corn in a monocultural nonrotation, or corn and beans in a two year rotation, it is virtually impossible to change to a four or five year rotation without sacrificing your acreage base and, with it, your eligibility for essential government payments.

Contrary to popular wisdom, farmers are not autonomous businesspersons and farming is not a flexible system. You either play the whole high-input game or you are forced out of business. This is why the values of LISA will be so difficult to move from theory to practice. This is why many farmers who would like to move toward low-input systems have such difficulty figuring out what their first step should be. If they give up pesticides one year, their yields will be unable to service their debt load. If they give up large fields, their big combines will not be able to pay their way. Many farmers do not know how they could even slightly modify their game plan without jeopardizing their families' future. They are enmeshed in a tightly coupled system.

Will GEHR chemicals and crops help those farmers to make the transition out of modern chemical agriculture? The answer depends on whether the companies investing in GEHR technology want to market the product to low-input sustainable farmers. In this context, remember that research and development of GEHR technology is very expensive, and is being pursued at present primarily by large multinational corporations. When GEHR seed and chemical packages are ready to be marketed, they will be promoted by the advertising wings of these conglomerates. Will giants like Monsanto, CIBA-GEIGY and Dow Chemical try to recuperate their research and development costs by selling GEHR technology to smaller, quasi-organic farmers who will buy their seeds and herbicides only once every five or ten years? Or will they do as they have done in the past, direct their marketing departments to target sales toward big farmers and big cooperatives that can buy seeds and chemicals in bulk? In my judgement, the latter scenario seems most likely. If I am right, GEHR technology, far from reversing the trend of the last century toward fewer and larger farms, will add impetus to the trend as new comparative advantages are introduced for larger, chemical-and capital-intensive, farmers.

Genetically engineered herbicide-resistant crops promise to make American agriculture an even more tightly knit system, not a more flexible one. It makes little difference whether you adopt a rigid or loose definition of LISA. Even if GEHR and LISA are compatible in theory, they are not likely to be compatible in fact.

NOTES

1 Moshe J. Pinthus, Yaacov Eshel, and Yalon Shehori, “Field and Vegetable Crop Mutants with Increased Resistance to Herbicides”, Science 177 (25 August 1972): 715-716.

2 Webster H. Sill, Jr. Plant Protection: An Integrated Interdisciplinary Approach (Ames: Iowa State University Press, 1982), pp. 201, 286. Sill cites M. Pinthus, V. Eshel, and Y. Shehori, “Field and Vegetable Crop Mutants with Increased Resistance to Herbicides”, Science 177 (4050): 715-716.

3 Charles M. Benbrook and Phyllis B. Moses, “Engineering Crops to Resist Herbicides,” Technology Review (November-December 1986): 57.

4 Cf. JoAnne J. Fillatti, John Kiser, Ronald Rose, and Luca Comai, “Efficient Transfer of a Glyphosate Tolerance Gene into Tomato Using a Binary Agrobacterium Tumefaciens Vector" Bio/Technology 5 (July 1987): 726-730.

5 Cr. unpublished draft of a paper by Loren W. Tauer and John Love, "The Potential Economic Impact of Herbicide-Resistance Corn in the United States," (Cornell University: Department of Agricultural Economics, November 1988): 1; Anonymous, WSSA Newsletter [Weed Science Society of America] 16 (1988): 8; Charles M. Benbrookand Phyllis B. Moses, (1986), p. 57; Charles M. Benbrook and Phyllis B. Moses, "Herbicide Resistance: Environmental and Economic Issues," staff paper, Board on Agriculture, National Research Council, Washgton, D.C., n.d., pp. 8, 9; and John P. Quinn, Joseph M. M. Peden, and R. Elaine Dick, "Glyphosate Tolerance and Utilization by the Microflora of SoilsTrested with the Herbicide," Applied Microbiology and Biotechnology 29 (November 1988): 511-516.

6 Jeremy Rifkin, Algeny: A New Word—A New World (Harmondsworth: Penguin, 1983).

7 Tauer and Love (p. 1) cite two studies: W. F. Lagrone and R.D. Krenz, "Corn Production Practices in Selected States" (University of Nebraska, Lincoln: Department of Agricultural Economics Report No. 108, 1980); Michael Hanthorne, Craig Osteen, Robert McDowell, and Larry Roberson, "1980 Pesticide Use on Field Corn in the Major Producing States," (U.S. Department of Agriculture: ERS Staff Report No. AGES820202, February, 1982).

8 E.F. Adler, W.L. Wright, and G.C. Klingman, "Development of the American Herbicide Industry," in Jack R. Plimmer, ed., Pesticide Chemistry in the Twentieth Century (Washngton, D.C.: American Chemical Society, 1977), p. 37.

9. Furtick, in Pimentel (1978), p. 60.

10 Adler et. al., p. 42.

11 Adler, et. al., p. 49.

12. Richard Levins and Richard Lewontin, The Dialectical Biologist (Cambridge: Harvard University Press, 1985), p. 236.

13. Trevor J. Martin, "Broad versus Narrow-Spectrum Herbicides and the Future of Mixtures," Pesticides Science 20 (1987): 290. Martin identifies himself with Bayer, UK.

14. Enrico Kneusli, "The s-Triazine Herbicides, " in Plimmer, ed., p. 87. Knuesli identifies himself with CIBA-GEIGY, Switzerland.

15. Adler, et. al., p. 54.

16. Knuesli, p. 87.

17. Homer M. LeBaron, “Management of Herbicides to Avoid, Delay and Control Resistant Weeds—A Concept Whose Time Has Come,” unpublished paper presented at the 42nd Meeting, Western Society of Weed Science, March 14, 1989, p.l. Cf. LeBaron and Janis McFarland, “Overview and Prognosis of Herbicde Resistance in Weeds and Crops,” unpublished paper, CIBA-GEIGY Corporation, n.d., p. 3 and Table VIII; and Steven R. Radosevich, “Herbicide Resistance in Higher Plants,” in George P. Georghius, ed., Pest Resistance to Pesticides (New York: Plenum, 1983), pp. 453-479. Radosevich notes that “there are few examples of formerly susceptible weed species that have developed resistance....” Further, as he explains, “in every case [of herbicide resistance to atrazine] resistance has occurred in the field after approximately ten years of successive atrazine.. .or other s-triazine treatment” (pp. 453,460). The problem appears to be related as much to cultural practices (such as monoculture) as it does to the chemicals involved.

18. Adler, et. al., p. 51. Cf. Knuesli, in Plimmer, ed., p. 87. For explaining the relationship of atrazine and crabgrass, I am indebted to my colleague at Iowa State, Richard S. Fawcett.

19. Sill (1982) writes that “Resistance to atrazine herbicides has been reported in a few localities in North America on a few annual weeds.. .but in most situations.. .no weed resistance has been reported” (p. 79). Cf. LeBaron (1989), who lists the weeds and the herbicides they tolerate.

20. Advertisement forBanvel®, Oregon Farmer-Stockman 112 (April 1989): 11. Banvel® is a registered trademark of Sandoz, Ltd. and Glean®, Ally®, Finesse® and Harmony® of E.I. du Pont de Nemours & Co.

21. According to the Economic Analysis Branch, Office of Pesticide Programs, EPA, cited in Table 1 of LeBaron and McFarland, p. 11. Total sales wordlwide of all pesticides were estimated to be 16 billion dollars in 1986.

22. Stan G. Daberkow and Katherine H. Reichelderfer, “Low-input Agriculture: Trends, Goals, and Prospects fo Input Use,” Ameri-

can Journal of Agricultural Economics (December 1989): 1159. Two thirds figure from Benbrook and Moses, p. 55.

23. The company was Monsanto. According to Jack Doyle, Altered Harvest: Agriculture, Genetics, and teh Fate of the World's Food Supply (New York: Viking, 1985), pp. 214-215, half of Monsanto's total sales are from Roundup®. See also Philip C. Kearny, "Introduction," Plimmer, ed., p. 37.

24. Wendell Berry, "A Defense of the Family Farm," in Gary Comstock, ed. Is There a Moral Obligation to Save the Family Farm?(Ames: Iowa State University Press, 1987), p. 348.

25. Charles Perrow, Normal Accidents (New York: Basic Books, 1984), Cited by Joseph Rouse, Knowledge and Power: Toward a Political Philosophy of Science (Ithaca: Cornell University Press, 1987): 230. Perrow Introduced these terms, Rouse explains, "to illuminate the occurrence of what he calls 'normal accidents' in certain high-risk technological systems. These are accidents that are due 123 not so much to the malfunction of a single component of a system as to multiple failues whose combination was not anticipated. He claims that such accidents are to be expected in systems that are complex and tightly coupled" (p. 230).

26. Daberkowand Reichelderfer, p. 1160.

27. For relative prices of herbicides, see Benbrook and Moses, p. 58.

28. "2,4-D increases insect and pathogen pests on corn.. .In 1974 field tests.. .corn leaf aphid populations numbered 3116 per tassel compared with only 1420 per tassel in an untreated corn field.. .European corn borer attackes on 2,3-D exposed plants were significantly greater (70 percent) than on untreated plants (63 percent)...2,4-D corn had more southern corn leaf blight lesions and significantly larger corn smut galls. David Pimentel, (1978): 180. Cf. David Pimentel, "Down on the Farm: Genetic Engineering Meets Ecology," Technology Review (January 1987): 28.