HERBICIDE TOLERANCE IN PLANTS Homer M. LeBaron President, Weed Science Society of America Senior Research Fellow, New Technology and Basic Research, CIBA-GEIGY Corporation Herbicide Resistance in Plants1 The first discovery of a triazine-resistant weed (common ground- sel) was in western Washington in the late 1960s.I hasten to add that there will be very useful tools and technology developed to help us do better in se- lecting the more acceptable herbicides, using lower rates, reduce the leaching and environmental impact of those used, getting more of them to their sites of action, improve the integration of other control methods for best management practices, use of biologicals for control of major or nixous weeds which cannot be adequately controlled with herbicides, and other improvements for the protection of both crops and the environment.The Environmental Protection Biotechnology and Sustainable Agriculture: Policy Alternatives Agency (EPA) and the public are increasingly concerned about pesti- cides in groundwater since analytical advances have allowed us to mea- sure very low and often meaningless levels of synthetic chemicals in water, mostly traceable to point-source contamination.In the U S. the total area of land or crops infested with triazine-resistant weeds is still rela- tively limited (estimated to be about 3,000,000 acres) and does not seem to be expanding rapidly, except in a few states where continuous corn or no-tillage farming is being practiced or good alternative herbi- cides are not used.Some scientists need to study the effects of herbicides versus tillage practices on the movement of natu- ral toxins (e.g., organics, inorganics, and microorganisms) into our water and air, including their potential mutagenic or health effects, identification, characterization, and quantification.Conservation tillage not only protects 50 to 90 percent of essential topsoil that would otherwise be permanently lost by water and wind erosion, but it prevents much more than just inert soil moving into streams, rivers, lakes and air.Although weeds have taken longer to evolve herbicide-resistance compared to insect pests and pathogens, biotypes of 40 broadleaves and 15 grass weed species are known to have developed resistance to triazine herbicides somewhere in the world.There are many ways that herbicides can and are being used to protect and enhance the environ- ment for use by humans, birds and animals, and in most cases, they will be safer and have less environmental impact than other weed con- trol tools such as mechanical tillage, biological (live organism) con- trols, etc.In summary, nothing will come out of biotechnology, biocontrol organisms, or other presently perceived and much talked about techno- logy that will substantially replace chemicals for weed control in the foreseeable future (20 to 40 years).Much more soil will be preserved if the pro- jected 40 million acres (11 percent of total cropland) is set aside over the next two years and better herbicide programs could be developed to make farmers more confident that the weeds can be controlled with- out tillage.A total of 45 weed bio- types (29 broadleaves and 16 grasses) have evolved resistance to 14 other types of classes of herbicides, making a grand total of 100 herbicide-resistant weed biotypes to date.In most areas of the U.S. where triazine-resitant weeds have evolved it has not even been necessary or desirable to cease using the triazine herbicide of choice, due to the many susceptible weeds that are still usually prevalent.The subsequent widespread and frequent occurrence of other triazine-resistant weeds over the past 20 years have made triazine herbicide-resistance the best known and most studied case of herbicide-resistance.The Low Input Sustainable Agriculture (LISA) philosophy promotes conservation tillage, as do all weed scientists.Soil conservation

programs, agricultural sustain- ability and production efficiency are, and will continue to be, abso- lutely dependent upon herbicides.The switch from the moldboard plow and cultivator to conserva- tion tillage systems makes us more dependent on herbicides, but the benefits more than compensate for the risks.This reduced ero- sion, combined with the erodable cropland that has been planted to grasslands or woodlands have already saved more than half a billion tons per year of top soil.We will depend more and more on imported foods, our surpluses will disappear, we will have less control on the quality of our food, and the greatest agricultural technology in the world that is responsible for providing by far the highest quality and variety of food at the lowest prices that this country or any other has ever known, will be in jeopardy.If other single target site residu- al herbicides (e.g., diuron) were used as extensively and continuously as the triazines, they would have almost certainly led to resistant bio- types.Only 21 of the triazine-re- sistant biotypes and 16 biotypes resistant to other herbicides have been found in the U.S., but one or more of these resistant biotypes have invaded 39 states, six provinces of Canada and 27 other countries.'LeBaron noted that this paper was represented as the President of the Weed Science Society of American and as a weed scientist, rather than a representative of CIBA-GEIGY Corporation.It is only because of our surplus and efficient production without farmers always being the economic benefactors that we have such vocal opponents to herbicides.Where herbicides have been extensively used, some species have almost disappeared and the weed seed density in the soil is often much reduced.Herbicide Resistance in Plants PUBLIC AND POLITICAL PERCEPTIONS The main problem in agriculture today is not the technology, but pub- lic perceptions.There is the option of dropping herbicide use and purchas- ing only food produced without them, but we will not remain competi- tive in world agriculture.Triazine-resis- tance has also been of great interest because of the importance and ex- tensive use of this group of herbicides.It is very important for nonbiologists to understand that an essen- tial requirement of herbicides is that they control all weeds through- out the season.Furthermore, it must not be assumed that LISA or alternate farming methods have no environmental impacts.They may, in fact, cause exposure to more toxic or objectional contaminants than do herbi- cides.We do not know everything that manure contains, and it may be that very little of it reaches groundwater, but there could be contaminants in runoff water.With only two percent of our population on the farm, our graneries and supermarkets full, and people who do not have an appreciation for how sensitive the balance is between feast and famine, some difficult choices lie ahead.But just do not try to do it without chemical herbicides or agriculture will fail to be competitive, profitable, sustain- able, or environmentally sound.HERBICIDES AND LISA Herbicides have already made great contributions to low input and sustainable agriculture.This does not mean that mechanical (e.g., tillage, moving), biological (e.g., mycoherbicides, allelopathy, cover crops), and other tools are of no value.This trend should be con- tinued and increased where it can be advantageous to agriculture, as well as the environment.Some watershed studies in recent years have shown a rever- sal from major losses to net gain in soil.This is not obvious or easy to measure, especially to nonbiologists, because there are still many weed seedlings that ger- minate each spring.Nature will adapt and take advantage of any nitch available, and the weed infestations and species will likely get worse with time.There is no significant exposure or risk to human health or the environment from herbicides in food or groundwater; we are at serious risk of solving the wrong

problem.Past experience has shown that weeds resistant to triazines can be managed or restrained within a reasonable limit.This may be from 5 to 25 species, not just the one or two pests that insecticides and fungicides usually try to control.However, without herbicides, there would be little or no conservation tillage in most crops.However, these methods will continue over the next 20 to 30 years, at least, to be very limited in application, even though their development and use needs encour- agement wherever they fit the problem.Herbicides have had beneficial effects on water quality through conservation tillage; the whole picture needs to be seen.For example, I would prefer to drink water coming off of or from under a field treated with herbicides and commercial fertilizers rather than a field treated with 10 to 20 tons per acre of cow manure.We need to know what the effects and comparative risks are, and not assume that LISA is a safer way to farm than using syn- thetic chemicals.Another concern about LISA, or any arbitrary reduction in the use of herbicides, is the phenomenon of biological changes with time.This phenomenon is even contributing to some of the short-term successes from cutting back on herbicides.With considerable misgivings, I am prompted to say that what we most likely need in this country and some others in the developed world is to experience a little famine.Biotechnology and Sustainable Agriculture: Policy AlternativesVirtually no- thing is known about natural pollutants or mutagens that have been and may still be in drinking water.But, the full effect of reducing or eliminating herbicides will not be seen the first year.Ignorance, fear and emotions must be replaced by education, reason and rational thought and action.In a few cases, the resistant bio- types have even disappeared.If all but one species is controlled, little has been accomplished because that species will take over.In many situations, the weed populations and pressure are not the same as 30 years ago.There is not, never has been, and never will be zero- risk agriculture or life.We need to learn to live with herbicides and solve the right problems.