Role of agriculture in air pollution and control

Shaw W.C., Hech W.W., Eggestad H.E.

L'environnement

Paris : CIHEAM
Options Méditerranéennes; n. 9

1971
pages 63-68

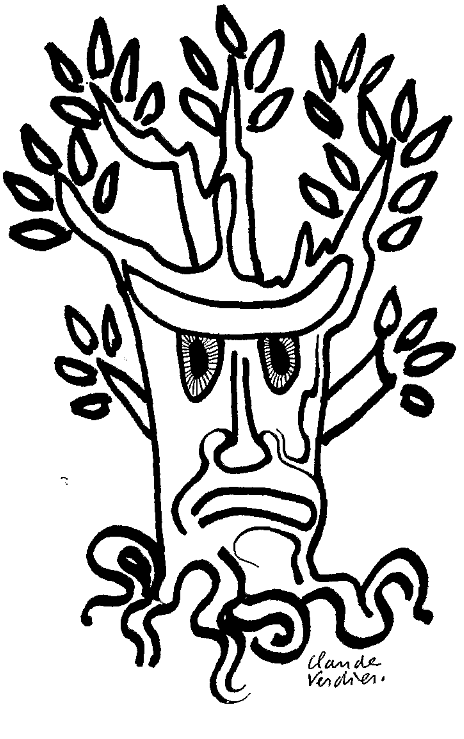
W.C. SHAW (2)
W.W. HECH (3)
and H.E. HEGGESTAD (2)

Role of agriculture in air pollution and control (1)

(1) An invitational paper presented at the 19th Annual Meeting of the Agricultural Research Institute, National Academy of Sciences, Arlington, Virginia, October 13-14, 1970.

(2) Assistant to Director, Crops Research Division, and Leader, Plan Air Pollution Laboratory, Crops Research Division, respectively, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland.

(3) Plant Physiologist, Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, and Leader of Cooperative Research and Chief, Agriculture Branch, Division of Economic Effects, Bureau of Criteria and Standards, National Air Pollution Control Administration, Department of Health, Education and Welfare, North Carolina State University, Raleigh, North Carolina.



Ten years ago, if anyone had predicted that air pollutants would make it difficult to grow healthy plants in the Washington Metropolitan area, he would have been labeled an alarmist. However, in 1970 it is a fact that many plants cannot be grown without injury during summer months in greenhouses in the Washington area unless the air is carbon-filtered. How did the air environment in the Nation's Capitol become so impaired in so short a time?

In the past decade we have witnessed an industrial revolution, an agricultural revolution and a population explosion unparalleled in the history of mankind. The first two of these significant events have provided society with many of the material things desired by man. The scientific technology that made these developments possible represents an array of unparalleled achievements. However, in reaching our goals for material things, the side effects of such technological deveopments on esthetic values, and the quality of our environment have received little or no attention.

Those raised in the Judeo-Christian tradition do not always seem to have been guilded by the teaching that man does not " live by bread alone ". This same tradition teaches that man was given dominion over the earth and all of its creatures. Too often man has acted as the master and has treated nature as his subject. In this often strange relationship, life appears to have become a struggle of man against his environment, and not a joint venture for mutual benefits. Future progress, including improvements in the quality of our environment, will require greater emphasis on the ecological consequences of technological development. A commitment, not yet made, will also be required.

The population of the world is expected to increase from 3.3 billion in 1965 to 5.0 billion in 1985 and to 7 billion by the year 2000, if fertility does not change and mortality continues to decline. However, if we where to succeed in achieving a 30 % decrease in fertility over the next 20 years, the world population would be 4.6 billion by 1985 and 6 billion by the year 2000. Short of some catastrophe, of course, neither a stable population nor a zero growth rate is very likely to be achieved.

From an environmental viewpoint, it is most important to understand that man " lives by dilution alone ". Processes of concentration that exceed acceptable tolerance limits, impair the quality of our environment and thus the quality of our lives. Familiar examples of concentration processes that impair ,our environment are: too many automobiles in too limited space; too many people per acre; too many cattle per feed lot; too much nitrogen in irrigation water; too much ozone per cubic meter of air; and chemical waste disposal. However, experience has shown that our agricultural ecosystems can be managed in such a way as to obtain high crop yields and quality livestock without impairing the quality of our soils, water and air, provided acceptable tolerance limits are established and production inputs and practices are kept within these limits.

It is probably a fallacy to assume that pollution problems can be readily solved by legislation, treaty, or high resolve. For often the spoilers of environmental quality are not always profit-hungry industralists who can be fined into submission, or lax public officials who can be replaced. More often it is the consumer who demands —or at least lets himself be cajoled into demanding— newer, faster, bigger, and cheaper things, without counting the cost in terms of a dirtier, smellier and sicklier world.

The dramatic technological achievements of our space exploration program have made interplanatary travels and communications a success. However from these explorations, we must conclude that the environments on the planets that we have visited in person or with our instruments, are totally hostile to man. Nor have we discovered any new mechanisms for creating energy. We are still dependent upon the energy of the sun interacting with green plants, and the productivity of our earth resources for adequate supplies of food, feed, and fiber. Our exploration of space has also reconfirmed that our most important role is to protect the resources of earth, and to improve their productive quality. The concern expressed by the astronauts as they observed the massive air pollution that envelopes the major populated areas in the world is now being reflected by the general public.

Agriculture has a major responsibility for research, regulatory, educational and information programs that are vital to the welfare of the general public. Those programs must be designed to assure the

production of an abundant supply of quality food, feed and fiber that will sustain the human, livestock, and wildlife populations of our Nation, and to provide assistance for underdeveloped nations. Our goal is to achieve this significant objective while improving our natural resources and the quality of our environment. Air pollution, a grave threat to this mission, cannot be ignored or underestimated.

NATURE AND MAGNITUDE OF AIR POLLUTION

Agriculture is concerned with: (*a*) air pollutants that originate from nonagricultural sources that have an impact on agriculture; and (*b*) air pollutants that result from agricultural practices that have an impact on agriculture or other aspects of our society.

Primary pollutant emissions that contaminate the air over the United States total more than 200 million tons each year. These are summarized in Table 1.

and pesticide wastes. These pollutants, generally produced in greatest abundance at point sources, usually affect agriculture in a localized region. Dilution and dispersion of effluents from such point sources are normally effective in limiting detectable injury to agricultural commodities to a radius of a few miles around the source. Ethylene and nitrogen oxides are notable exceptions since significant amounts are emitted in automobile exhaust and because they are much more widespread in origin.

Secondary pollutants such as ozone and the peroxyacyl nitrates, formed as a result of photochemical reactions in the atmosphere are generally much more widespread than the primary pollutants. Relatively uniform distribution of these pollutants over extensive areas of a state or region may cause serious injury to large acreages of forests and agricultural crops. These pollutants are believed to cause far more serious losses to agriculture than do the pollutants that originate from agricultural practices.

Air pollutants from agricultural practices that have an impact on agriculture, and

TABLE 1

Estimated Nationwide Emissions, 1968

(In millions of tons per year) (4)

Source	Carbon monoxide	Particulates	Sulfur oxides	Hydrocarbons	Nitrogen oxides	Total
Transportation . .	63.8	1.2	0.8	16.6	8.1	90.5
Fuel combustion in stationary sources	1.0	8.9	24.4	.7	10.0	45.9
Industrial processes	9.7	7.5	7.3	4.6	.2	29.3
Solid waste disposal	7.8	1.1	.1	1.6	.6	11.2
Miscellaneous (5) .	16.9	9.6	.6	8.5	1.7	37.3
Total	100.1	28.3	33.2	32.0	20.6	214.2

(4) Note this Table does not include secondary, photochemically formed pollutants such as ozone and peroxyactyl nitrates (PAN). These cause serious damage to plants and other organisms and objects.

(5) Primarily forest fires, agricultural burning, coal waste fires. Source: N.A.P.C.A. Inventory of Air Pollutant Emissions 1970.

The most important toxic air pollutants that originate primarily from nonagricultural sources, that affect agriculture include ozone, sulfur dioxide, the peroxyacyl nitrates (PANs) and other oxidants, ethylene and other hydrocarbons, fluoride, chlorine and hydrogen chloride, nitrogen oxides, heavy metals, particulates, acid aerosols, ammonia, aldehydes, hydrogen sulfide, carbon monoxide, pesticide and other chemical wastes, and radioactive chemicals. Although relatively little is known about the importance of various mixtures of these pollutants, there is evidence that interactions, including synergistic effects, do exist. Experimental evidence suggests that toxicity may be enhanced by combinations of two or more pollutants.

Contaminants in the atmosphere may be grouped into two categories: (1) primary pollutants emitted by combustion or industrial processes; and (2) secondary pollutants produced by chemical reactions in the atmosphere. Primary pollutants of major concern to agriculture are sulfur dioxide, ethylene, fluoride, nitrogen oxides,

on other aspects of our society, include chemical air pollutants that result from burning forest and crop residues, infectious agents and allergens, and pesticides and other agricultural chemicals. Agricultural burning produces some nitrogen oxides and hydrocarbons from which a small amount of photochemical air pollutants are produced. In 1970, crop residues on 1,117,900 acres equivalent to 3,625,075 tons were burned as a means to reduce losses caused by plant diseases and other soil-borne pests, and also as a means for the disposal of crop residues.

Natural dust is emitted into the atmosphere of the United States at the rate of about 30 million tons each year. This is equivalent to the top soil from 30,000 acres of land. Much of this dust arises from excavations involving the building of homes, industrial sites, highways, and from other industrial practices that involve soil movement. Agriculture also contributes to this dust problem, created by wind-blown soil, the result of improper agricultural practices, and unprotected fields. Agricultural dusts also arise from processing operations. such as cotton gins and alfalfa mills. Some of the adverse effects of airborne dust are illness; irritation; morbidity; and the accummulation of silt in homes and on mechanical equipment.

Airborne infectious agents and allergens are known to cause plant, animal and human diseases. Weeds produce pollens and toxins that cause serious human allergies in most of our heavily populated areas. Such allergies reduce working efficiency, impair health, and increase medical costs. Allergies from weed pollens caused an estimated 12 1/2 million or more cases of asthma, hay fever or both. Of these, about 5 million are asthma sufferers and about 75 % became ill because of the weed pollens in the air they breathe. About 10 1/2 million work days are lost each year, for a total annual cost of $ 125 million in services. Odors from agricultural practices also contribute to this growing problem.

Agricultural chemicals including pesticides, when used properly, have resulted in great benefits to man and his environment. Conversely, when they are misused or used carelessly, they cause harm. The adverse effects have been relatively minor in relation to the great benefits that have resulted from safe and effective pest control and improved crop management. Crop damage, resulting from the drift and volatilization of herbicides, plant growth regulators, desiccants and defoliants, has been steadily reduced through effective research and educational programs. However, some losses are still caused each year by faulty application techniques, and by the drift and volatilization of chemicals to susceptible crops and ornamental plantings. While there has been considerable discussion of the harmful effects caused by pesticides on non-target organisms, few if any reliable data exist to document the annual losses caused by airborne agricultural chemicals.

LOSSES CAUSED BY AIR POLLUTION AND THE COST OF CONTROL

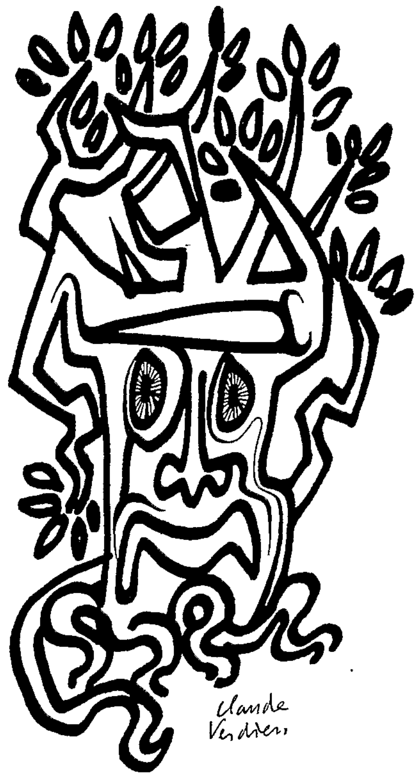
Air pollution adversely affects man and his environment in many ways. It interferes with the growth of food, fiber, ornamental plants, and forests. It diminishes the value of agricultural products, obscures man's view, adds unpleasant smells to his environment, soils his home, and endangers his health.

Air pollution inflicts widespread and costly damage to plant life, buildings, and materials. Some experiences of the past warned us of extensive damage from air pollutants. Sulfur dioxide fumes from a large copper smelting plant in Copper Basin, Tennessee, destroyed 30,000 acres of timberland. Most of this once forested mountain land is still barren. Today injury to plants from air pollutants is less dramatic. However, chronic and physiological types of injury inflicted on agricultural crops, forests, and ornamentals by increasing quantities and varieties of air pollutants has now spread to all parts of the country. Total damage to vegetation from reduced photosynthetic effectiveness and yield and quality reductions are unknown. However, annual agricultural losses during the period 1951-60, due to air pollution were estimated at $ 500 million, and losses have continued to increase at an accelerated rate. Most of these losses were due to growth suppression and chronic injury. In research, this is demonstrated by the relative growth and quality of plants in ambient polluted air, as compared to plants grown in carbon filtered air from which most oxidants and some of the other pollutants have been removed.

Assessment of the contribution of particular pollutants to chronic human and livestock diseases is complicated by the infinite variety of pollutants to which man and animals are exposed from the day of birth. It is also difficult to separate pollution from the other biological and physical stresses to which people and animals are subjected. Nonetheless, it is well established that air pollution contributes to the incidence of such chronic diseases as emphysema, bronchitis and other respiratory ailments. Polluted air is also linked to higher mortality rates from other causes, including cancer and certain forms of heart disease. Smokers living in highly polluted cities have a much higher rate of lung cancer than smokers in rural areas. Emphysema has doubled every 5 years since World War II. The death rate for chronic diseases of the respiratory system tripled from 1950 to 1965 —from 10 per 100,000 population in 1950 to 33 in 1965. Air pollution is cited as one of the primary causes for this increased death rate.

The total damage caused by air pollution in the United States cannot be precisely calculated but they amount to many billions of dollars a year. Annual damage to agricultural crops and livestock is estimated at more than $ 1/2 billion, and it is increasing each year. The cost of repainting steel structures damaged by air pollution is estimated at $ 100 million per year. Commercial laundering, cleaning, and dyeing of fabrics soiled by air pollution cost about $ 800 million. Washing cars dirtied by air pollution cost about $ 240 million annually. Adverse effects of air pollution on air travel cost from $ 40 to $ 80 million a year. Even more difficult to estimate is the cost of replacing and protecting precision instruments or maintaining cleanliness in the production of foods, beverages, and other consumable products.

It is equally difficult to assess damage due to soiling and added maintenance to homes and furnishings, or to determine the impact of pollution on property values. The cost of fuels wasted in incomplete combustion, and of valuable resources such as sulfur wasted in the air, is also hard to estimate. It is still more difficult to determine the dollar value of medical costs and of time lost from work because of air pollution, or to calculate the drop in productivity of agricultural businesses and industry.



The cost of controlling air pollution at the source will also be enormous. The investment that will be needed through 1975 for control of the major industrial and municipal sources of particulate matter, sulfur dioxide, hydrocarbons, and carbon monoxide within acceptable standards in 100 metropolitan areas of the United States —has been estimated at $ 2.6 billion. This includes costs for controlling both existing and new sources of air pollution. It is also estimated that by 1975 it will cost another $ 1.9 billion for operation, maintenance, depreciation, and interest. In spite of the seemingly high total, the yearly cost for control of these four major pollutants is relatively low: less than 1 % of the value of the annual output of the industries involved. However, the cost to some industries will be greater.

According to estimates made by industry, the cost of devices that will control emissions within Federal motor vehicle standards is rising rapidly. This is because of general increases in prices and the increasing stringency of standards. In 1968 and 1969 the cost was $ 18 to $ 19 per automobile. In 1970 the estimate is $ 36 per car. For 1971 automobiles, the estimated cost is $ 49 each. The cost for installing air pollution control devices on the 10 million new cars produced in 1971 will be approximately $ 500 million. However, this cost is barely equal to the annual losses caused by air pollutants to crop plants. Assuming that the average life of a vehicle is about 10 years, the cost is still only $ 5 per car per year for air pollution control.

STATE OF THE ART AND RESEARCH IN PROGRESS

Damage to biological receptors from air pollutants can be reduced or prevented by: (1) control of air pollutant emissions at the source; (2) removal of air pollutants from the atmosphere by use of vegetation screens and by mechanical filters; and (3) reduction of the damage caused by air pollutants by breeding resistant varieties and developing mechanical and chemical protectants. Agricultural laboratories must play a greater role in the future by conducting research, the results of which will be used as criteria for the development of ambient air standards and source emission standards at levels that biological receptors will tolerate. Technology for filtering air pollutants from the atmosphere, and the development of genetic, mechanical, and chemical methods for minimizing damage to plants and animals must be accelerated. Agricultural scientists must play a significant role in achieving these objectives.

Agricultural scientists are currently conducting research for the development of chemical and bioassay techniques to detect the kinds, and measure the quantities of chemical pollutants in the air. They are determining the effects of these pollutants on plants and animals. Special growth and exposure chambers are being developed to study the effects of air pollutants on biological receptors under both controlled and field conditions. These systems will permit the study of both acute and chronic effects. Emphasis is being given to systems for exposing plants and animals throughout their life cycle to very low known concentrations of individual pollutants, known mixtures, and pollutant complexes to determine their individual and interacting effects on plants and animals.

Chemical air pollutants that are being investigated include, ozone, the sulfur compounds, ethylene, peroxyacyl nitrates and other oxidants, fluorides, nitrogen oxides, chlorine, hydrogen chloride, automobile exhaust mixtures, and other air pollutants. One type of research, which has received far too little effort to date, attempts to locate the sites of action, to understand the mechanisms of action, and to determine the metabolism and fate of pollutants in plants, animals, and the environment. Current emphasis is also on research to: (1) determine crop yield and quality reductions under field conditions; (2) understand the influence of climatic, edaphic, and genetic factors as they relate to plant and animal susceptibility; (3) assess the economic impact of pollutants on crops, timber, and animal production; and (4) develop biological indicators of pollutants.

Plant breeding research has been initiated to develop varieties of crop plants that reduce, prevent or eliminate damage caused by chemical air pollutants. As a first step, germ plasm and crop varieties are being screened for resistance. The effectiveness of chemical protectants to inhibit or reduce phytotoxicity is also under investigation.

Results of current research will permit us to establish classes of resistance and susceptibility of field and horticultural crops to the major chemical air pollutants and pollutant complexes. An extension of the longterm chronic studies will aid us in the establishment of ranges of concentrations of air pollutants tolerated by our major crops at various stages of growth throughout their life cycle. The data from such studies will be used to establish air quality criteria, set safe tolerances and standards, and for development of other regulations for improving pollution control and reducing losses in crop and livestock production.

Current research is also designed to determine the effects of airborne herbicides, defoliants, desiccants, growth modifiers, nematicides, fungicides and insecticides on plant growth and to understand their fate in air, water, soil, plants and in other components of the environment. One of the objectives of this research on agricultural chemicals, including pesticides, is to determine the physiological and biochemical effects on photosynthesis, respiration, and metabolism. The synergistic, antagonistic, and interacting effects of combinations of these chemicals as air pollutants on plants are also being studied.

Research is being emphasized to develop an understanding of the processes by which pesticides are dissipated from the air. Drift and spray particle distribution, deposit, and volatilization are being studied.

Processes of absorption, photodecomposition, absorption by plants, degradation by microorganisms, volatilization, chemical reactions, and movement in rainfall and on airborne particulates are under examination.

Methods to prevent the pollution of the air by pesticides are being developed. Low volatile pesticides, subsurface soil treatments, techniques to prevent evaporation and drift, formulations with controlled rates of release, and biological, mechanical, and ecological techniques to reduce pesticide residues in the air are receiving major emphasis.

Research on infectious agents and airborne allergens should help us determine the meteorological conditions that influence the periodicity and frequency of release of spores of pathogenic organisms. This applies also to toxic plant pollens and other infectious agents and allergens. Research also seeks effective all safe chemical methods for control of ragweed and other weeds on agricultural lands. These practices should reduce the allergenic pollen produced by such weeds.

Crop residues in fields are often burned as a means of disposal and for the control of insects, weeds, and plant disease organisms. We are trying to determine the relative effectiveness and safety of burning as a method of disposal and for the control of such pests in relation to possible harmful effects of carbon residues, smoke, and other airborne particulates on adjacent crops, subsequent crops, and other components in the environment.

Research is being expanded to develop cultural, ecological, chemical, mechanical, and other farm management practices that will minimize the build-up of populations of soil inhabiting pests. Special efforts are being made to develop new non-polluting techniques for disposal of crop residues without burning.

Studies, to reduce or minimize the problems caused by the dust that originates from agricultural fields and from agricultural processing equipment, are also in progress. Filtering devices for cotton gins and alfalfa-processing plants offer an excellent potential for reducing dust from these operations. By developing plants and soil management practices that stabilize the soil, agricultural scientists are making significant contributions towards a reduction in air pollution from windblown soil.

KNOWLEDGE GAPS AND RESEARCH NEEDS

Although good progress has been made in the development of methods to control, limit, and minimize the damage of air pollutants, the problem remains beyond the scope of current research resources required for solutions. Among the most critical national problems related to agriculture that require greater, immediate research effords are:

1. Time - Concentration - Injury Relationships.

Something less than complete elimination of pollutants can be anticipated even when the most stringent standards are enforced. It is essential, therefore, that the response of a wide variety of agricultural crops to various pollutant concentrations, and lengths of exposure, be known so that production of food and fiber can be accomplished in conjunction with industrialization and urbanization. Interactions with environmental variables should also be assessed.

2. Chronic Effects.

Effects of pollutants on growth, development, and quality of crop plants, ornamentals, forests, and other native species require further study. The expression of symptoms of acute injury are usually recognized and associated with a particular pollutant. However, relatively little is known about their possible effects on the production of marketable fruits, pollination and fertilization, or on vegetative growth in the absence of visible symptoms.

Excessive amounts of some pollutants may accumulate in plant tissue without producing readily detectable injury, but considerable economic loss may occur. Adverse levels of fluorides or other accumulative pollutants in plant tissues should be determined.

In fumigation experiments, attention has been focused on effects of relatively uniform and continuous exposure to toxicants. In nature, plants are seldom exposed under such conditions. Realistically, exposures would fluctuate over a rather wide range of concentrations and times, and would occur under a broad range of environmental conditions. Such conditions must be used in studying the effects of pollutants on biological receptors.

3. Pollutant Uptake Evaluation.

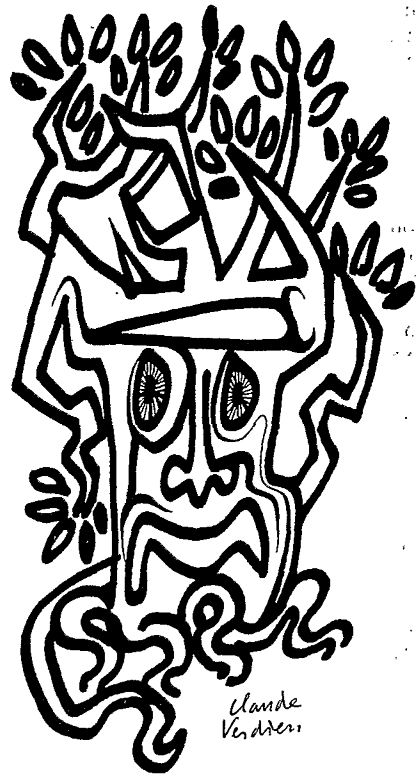
We must know more about the role that plants play as sinks for air pollutants. This is essential to the development and use of plants for cleansing the atmosphere, and in developing an understanding of the accumulation of toxic substances in plants, injury development, nutrition effects, and changes in the chemical composition and quality of edible parts.

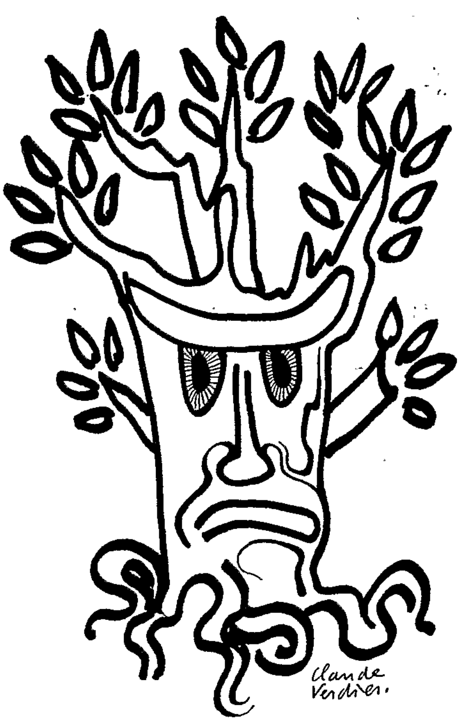
4. Interaction of Pollutants.

Polluted atmospheres seldom contain a single toxicant. A complex mixture of toxic substances, many of which may be present in very low concentrations, is normally found in the atmosphere near urban or industrial centers. Pollutant measurements are needed in rural areas for comparison with urban values and as a guide to agricultural practices and development. Much research is needed to determine the possible synergistic, antagonistic, or additive effect of multiple toxicants at low levels.

5. Mechanism of Toxicant Action.

The effects of various toxicants on basic physiological and biochemical processes of both plants and animals, and the mechanisms of action of these toxicants at the cellular and subcellular levels must be better understood. Recognition and understanding of such mechanisms are essential for progress in this field, and should





enhance selection for resistance and genetic manipulation in order to produce more resistant varieties or strains. Development of protective chemical treatments may also be enhanced by such knowledge.

6. Development of Resistance.

Ideally, pollutants will be controlled to some designated low level, but elimination is unlikely. It would, therefore, be advantageous if varieties or strains of resistant crops could be selected and propagated to minimize the economic effect of low levels of pollutants.

7. Anti-pollutant Chemical Treatments.

Application of protective chemicals would be feasible in some instances. Specialty crops of high value might be protected from low levels of toxicants, or from infrequent but predictable exposure to elevated concentrations by periodic application of protective chemicals. An effort should be made to develop such treatments.

8. Interaction with Nutrient Balance.

Some experiments have been conducted to determine the effect of nutrition on susceptibility of plants and animals to pollutants, but the findings have been inconclusive. These studies should be continued and expanded.

9. Interaction of Pollutants with Disease Organisms, Nematodes and Insects.

Interaction of organisms with pollutants may influence sensitivity of plants to such toxicants. Direct action of the pollutant on the disease or pest, as well as possible preconditioning of plant tissue to provide increased resistance or sensitivity, should be investigated.

10. Standardization of Effects Evaluation.

Standardization of methods of assessing economic damage from pollutants is needed to estimate losses due to the overall effects of industrial effluents on agricultural operations. Such studies should also develop diagnostic tests and techniques that will help differentiate the effects of pollutants from disease, nutrient imbalance, pests, or environmental factors.

11. Comparable Experimental Techniques.

Greater standardization of methods for sampling and measuring air pollutants is needed. These studies should include development of acceptable methods of sampling atmospheres and plant or animal tissue for various types of toxicants.

The areas listed above are an estimation of the most urgent needs for agricultural research in the field of air pollution. They do not include all the research needs that should be encouraged. Some areas of research may be critical in certain localized regions, but they are not recognized as a widespread national need.

FUTURE TRENDS

Man lives by dilution alone! It will probably never be feasible to eliminate all the sources of air pollution. Therefore, the primary mission of agriculture will undoubtedly continue to be the implementation of research, regulatory, educational and information programs designed to assure the production of an abundant supply of high quality food, feed, fiber, and timber to sustain the human, domestic livestock, and wildlife populations of our country. Agriculture can and should play a major role in using its technological know-how to achieve this objective and at the same time provide greater technology for reducing air pollution and for protecting our resources and improving environmental quality.

One of the most important needs of agriculture is to make an assessment of those agricultural practices that cause air pollution. If their risks outweigh their benefits, such practices should be modified, corrected, or discontinued and replaced by safer alternates. If such alternates are not available, research should be emphasized to develop them. This role will require greater commitments of scientific resources than have been heretofore allotted to agriculture. We will need well trained scientists to tackle the complex and sophisticated problems of air pollution control.

Agriculture has an unparalleled reservoir of information on economic plants and domestic animals. Plants and animals provide unusual bioassays for identifying and quantitating the effects of air pollutants. They tell us much about the quality of the environment that can not be obtained in any other way. By conducting comprehensive research on the effects of air pollutants, agriculture can contribute both the basic and applied information essential to the establishment of air pollution criteria, standards, and acceptable tolerance limits for a wide variety of components in our environment.

Agricultural curriculums in secondary schools and colleges should be strengthened by including more emphasis on scientific disciplines related to the improvement of the quality of our environment. Through its adult education and extension programs, agriculture is in a unique position to contribute to a full spectrum of educational programs that will create a sensitivity, awareness, and consciousness for protecting our environment on the part of all Americans.

Agriculture must review, assess, and strengthen its regulatory programs because they can have a major impact in improving environmental quality. Intensive research and educational programs are needed in agriculture to broaden the base of control technology in order to eliminate, reduce or minimize the damage of air pollution to agriculture. The simple fact is that no other scientific discipline or area of technical competence it as well qualified as agriculture to contribute information needed to accomplish these important goals.

Our most important goal is to achieve and maintain a fine ecological balance. On the one hand, health and comfort, and the production of ample food and fiber. On the other hand, we work toward a better grasp of the ecological significance of agricultural practices in their relation to air pollution and control.

Agriculture must have a voice in the decisions that lead to those regulatory programs which are designed to control air pollution. Criteria, standards, and tolerance limits must be weighed against the needs for food and fiber for an ever-expanding population. We shall certainly have to protect all of the important values in our environment against the potential hazards. Benefits and risks must be carefully weighed before decisions, clearly in the public interest, can be made. We are confident that this can and will be done.

SELECTED BIBLIOGRAPHY

(1) BENNETT (Yvan L., Jr.), 1967. — The World Food Problem. A Report of the President's Science Advisory Committee. Vol. I, 127 pp., Vol. II, 772 pp., Vol. III, 332 pp. Superintendent of Documents, U. S. Govt. Print. Off., Washington, D. C.

(2) BYERLY (T. C.), 1968. — A National Program of Research for Environmental Quality-Pollution in Relation to Agriculture and Forestry. A Report of a Joint Task Force of the U.S. Dept. of Agriculture and the State Universities and Land Grant Colleges. 111 pp. U. S. Dept. of Agriculture, Washington, D. C.

(3) COOPER (Charles F.), 1970. — Man's Impact on The Biosphere. *Journal of Soil and Water Conservation*, July-Aug., 124-127 pp. U. S. Dept. of Agriculture, Washington, D. C.

(4) HEGGESTAD (H. E.), 1970. — The Effects of Air Pollutants on Plants and Information on Research Needs. Crops Research Division, Agricultural Research Service, U. S. Dept. of Agriculture, Beltsville, Maryland.

(5) FREEMAN (Orville L.) and IVAN (L. Bennett, Jr.), 1969. — Control of Agriculture-Related Pollution. A Report to the President submitted by The Secretary of Agriculture and The Director of the Office of Science and Technology. 102 pp. U. S. Dept. of Agriculture, Washington, D. C.

(6) HORNIG (Donald F.), 1965. — Restoring The Quality of Our Environment. Report of The Environmental Pollution Panel, President's Science Advisory Committee. 317 pp. Superintendent of Documents, U. S. Govt. Print. Off., Washington, D. C.

(7) MOORE (Joe G., Jr.), 1968. — Water Quality Criteria. Report of the National Technical Advisory Committee to the Secretary of the Interior. 234 pp. Superintendent of Documents, U. S. Govt. Print. Off., Washington, D. C.

(8) SPILHAUS (Athelstan), 1966. — Waste Management and Control. A Report to the Federal Council for Science and Technology by the Committee on Pollution, National Academy of Sciences, National Research Council. Publication No. 1400, 257 pp. Washington, D. C.

(9) TRAIN (Russell E.), CAHN (Robert) and MAC DONALD (Gordon J.), 1970. — Environmental Quality-The First Annual Report of the Council on Environmental Quality. 326 pp. Superintendent of Documents, U. S. Govt. Print. Off., Washington, D. C.

(10) SHAW (Warren C.), 1970. — Ecological Significance of Research on Pests and Their Control. 5 pp. Crops Research Division, Agricultural Research Service, U. S. Dept. of Agriculture, Beltsville, Maryland.

(11) WADLEIGH (Cecil H.), 1968. — Wastes In Relation To Agriculture and Forestry. Misc. Publication No. 1065. Superintendent of Documents, U. S. Govt. Print. Off., Washington, D. C.

(12) FACTS OF LIFE and DEATH., 1967. — Public Health Service Publication No. 600, 33 pp. U. S. Dept. of Health, Education and Welfare, National Center for Health Statistics, Washington, D. C. Superintendent of Documents, U. S. Govt. Print. Off., Washington, D. C.