LEAD INDUSTRIES ASSOCIATION, INC.

292 MADISON AVENUE

NEW YORK, N. Y. 10017

TELEPHONE – AREA CODE 212

OR 9-0000

January 7, 1965

To All Members of the LIA-ILZRO Health and Safety Committee:

RESEARCH PROPOSAL--"EFFECTS OF AIR POLLUTANTS ON PLANTS"

We have received the attached unsolicited research proposal from Professor Hill at the University of Utah.

Professor Hill appears to be a competent investigator who has had considerable experience working on the side of industry in the area of air pollution investigation. He visited us here in the office a few months ago while in the East soliciting work for his newly organized department and I was not impressed at the time with the desirability for our industry to engage in his type of research. However, I may be wrong and I would appreciate your opinion.

Will you please examine the proposal and, if you think it is the type of work in which our industry should be engaged, write to me saying so. If I do not hear from a majority of our Committee within thirty days, I will let Professor Hill know that we are not interested.

Very truly yours,

Don G. Fowler
Secretary
Health and Safety Committee

DGF:md

Lead Ahead with Lead

UNIVERSITY OF UTAH
SALT LAKE CITY, UTAH 84112

DIVISION OF BIOLOGY

DEPARTMENT OF BOTANY

December 30, 1964

Mr. Don Fowler
Lead Industries Association
292 Madison Avenue
New York, New York

Dear Mr. Fowler:

Since I talked to you in October, I have discussed air pollution research needs with a number of other industry representatives. Response to the idea of an industry-financed air pollution research program at our university was generally favorable, and, as a result, I have prepared the enclosed proposed research project. Copies are also being sent to other company representatives for consideration.

Although a number of companies have expressed a definite interest in supporting our research, it does not appear to be practical to try to obtain all of the funds needed for a sound air pollution research program from industry at this time. For this reason I have divided the research into two separate projects; one to be submitted to industry, and the other to be submitted to the Public Health Service for support. The latter is designed to evaluate the claim that is frequently made that air pollutant concentrations too low to cause visible injury to plants still cause reduced growth and yield. The majority of the people that I talked with were in favor of obtaining Public Health support for a portion of the research program. Current plans are to obtain one-third of the financial support from the Federal government and two-thirds from industry. I believe that both projects will be of definite value to industry.

A meeting of sponsor representatives will be held annually, at which time results of all studies will be presented and the next year's program discussed. Annual and semi-annual reports will be submitted to all participants.

Money cannot be obtained from the Public Health Service until the fall of 1965 at the earliest. Funds will have to be obtained from industry early in 1965 if full advantage is to be taken of the summer growing season.

Any comments or suggestions that you have will be appreciated.

Sincerely,

A. Clyde Hill
A. Clyde Hill
Associate Research Professor

ACH:jd

Proposed Research Project

Effects of Air Pollutants on Plants

A. Clyde Hill

Associate Research Professor

Project Director

Department of Botany
University of Utah
Salt Lake City, Utah
Phone: 801-322-7329

I. Summary

A review of the scientific literature indicates that present knowledge of the effects of air pollutants on plants is inadequate to solve the air pollution problems with which industry is being confronted. There is a particularly pressing need for applied research in this important phase of the air pollution problem. Since this need is not generally being met by government financed research an industry financed research program is proposed.

The program is designed to develop a sounder basis for diagnosing and evaluating injury from air pollutants, establishing safe or harmful concentrations, and measuring atmospheric concentrations. In the studies outlined in this proposal many different plant species will be exposed to a range of concentrations of the important air pollutants and the effects of exposure determined.

Basic facilities and experienced personnel are available to initiate the program and it is anticipated that additional equipment and technical personnel will be added as the program develops. The proposed project will require a minimum of 5 years and a minimum budget of approximately $50,000 a year.

II. Introduction

The need for applied research on the effects of air pollutants on plants is becoming more apparent each year. During the last 10 years, research on plant effects has largely been directed along academic lines because of the investigators' academic interests and background. As a result most research has been conducted with extremely sensitive indicator plants such as petunias, pinto beans, orchids and gladioli; and the data obtained has dealt largely with effects on enzyme systems or other phases of cellular physiology and mechanisms of injury. The value of these studies cannot be denied, but they have frequently added to speculation and concern over effects of pollutants on plants without providing any basis for evaluation of the practical aspects of the problem. Generally industry's needs are not being met by present research programs.

Industry's interest in the vegetation aspects of air pollution usually falls into the following 3 areas:

1. Evaluation of Claims. Allegations are increasing that air pollutants from industrial operations are damaging crops, ornamental plants and native vegetation. These claims require sound diagnosis and evaluation before they can be accepted or rejected with confidence. Even if an air pollutant is not causing damage or if the pollutant involved does not come from the suspected source, the problem requires that the facts be established.

2. Control of Emissions. Design of new or modified industrial facilities frequently requires knowledge of the concentration of pollutants that is harmful. Air pollution control systems may tend to be over-designed or under-designed when such knowledge is absent. Also, since plants are sensitive to many of the air pollutants of most concern,

examination of vegetation in the vicinity of industrial operations is frequently the best and most economical way to evaluate the effectiveness of abatement equipment. When the background is available for reliable diagnosis, periodic examination of vegetation is usually much more practical than air sampling in evaluating presence of phytotoxic air pollutants.

3. Air Quality Criteria or Standards. This year, through the Clean Air Act, the Federal Government has made available $4,500,000. for the expansion of air pollution control agencies and for the establishment of new control programs. As this new program gets under way, questions of which pollutants to control and to what level will arise in many parts of the country. Since plants are much more sensitive to many air pollutants than either man or animals, values established as standards will frequently be based on effects on plants. It is to industry's best interest to have criteria for ambient air quality based on sound experimental data.

Air pollutants that affect plants fall into two groups: (1) primary pollutants that are produced directly (e.g. sulfur dioxide, hydrogen fluoride, ethylene and oxides of nitrogen) and (2) secondary or photochemical pollutants such as ozone, peroxyacetyl nitrate and certain aldehydes that are produced during atmospheric photochemical reactions from oxides of nitrogen and hydrocarbons. The secondary pollutants are of considerable interest to industry because the oxides of nitrogen and hydrocarbon from which they are derived come from their operations and from the consumption of fuel and the use of the automobiles that they produce. Also, injury caused by these pollutants will tend to be attributed to local industrial operations unless the pollutant responsible and its source is established.

Present knowledge of the effects of air pollutants on plants is meager and often inadequate for reliable evaluation of the problem. Sulfur dioxide and hydrogen fluoride have been studied more extensively than other pollutants. Even when we try to determine if injury to vegetation is caused by these pollutants and separate out injury caused by them from injury caused by other factors the need for more information regarding symptom expression and susceptibility for the particular plant species involved often becomes apparent. In addition, we need to know more about the effects on plants of exposure to low concentrations over a long period, and in the case of hydrogen fluoride, short time exposure to high concentrations that might occur from emissions during failure of equipment.

Quantitative studies of the effects of realistic concentrations of ethylene on plants are limited to about 6 species. Few quantitative data are available for chlorine, nitrogen dioxide, and the other primary pollutants. Current research under way at the University of California at Riverside indicates that nitrogen dioxide may be a more important phytotoxicant than has been previously thought.

In contrast to the primary pollutants, which have been known to cause injury to plants for many years, toxic quantities of photochemical pollutants are apparently relatively new to our atmosphere and we know relatively little about them. Although plant injury from one of the photochemical pollutants was recognized in Los Angeles as early as 1944, and has been observed in many other areas since that time, the pollutant

responsible, peroxyacetyl nitrate, was not identified until 1960. Extensive studies were conducted prior to 1960 with the reaction products of ozone and olefines but most workers do not now believe that these compounds are important phytotoxicants, so the data obtained in these investigations are of little value. Since peroxyacetyl nitrate was identified as a phytotoxicant, studies of its effects on plants have been limited primarily to pinto beans and petunias. Most studies have dealt with effects on enzyme systems or light relationships, and quantitative data regarding concentrations that cause injury and symptom descriptions are extremely limited.

Ozone injury to agricultural crops and forest trees was first reported in 1959 although the injury symptoms had been observed in various parts of the country for several years prior to that time. In 1964 it was reported that aldehydes resulting from atmospheric photochemical reactions are causing plant injury in New Jersey.

Much more research will be required before our knowledge of symptomatology and the concentration-time relationship required to produce injury to a wide variety of plants will permit confident evaluation of claims, effluent emissions and values for standards.

It has been our experience that it is definitely to industry's advantage to establish the facts with respect to pollutant effects. When the facts are not available, speculation by farmers and home owners based on fragmentary data frequently results in undue concern over the effects of air pollutants. Since this type of research is too expensive for each company to conduct individually, the logical solution appears to be a project financed by a number of corporations. This proposed research project is designed to provide much needed information in the field with the cost spread as widely as is practical.

III. Objectives

The objectives of the proposed research program are as follows:

1. To produce and study the symptom expression of the important pollutants on a wide variety of plant species and thus provide a sound background for diagnosis.

2. To determine the concentration of each pollutant and exposure time that is required to cause injury to a wide variety of plants.

3. To determine the relationship between injury and ultimate growth and yield of selected species.

4. To evaluate and further develop methods of atmospheric analysis.

IV. Methods

Different species and varieties of agronomic crops, vegetable crops, fruit crops, ornamental plants, and native vegetation will be exposed to different concentrations of each pollutant and the effects determined. Ozone, nitrogen dioxide, peroxyacetyl nitrate, hydrogen fluoride, sulfur dioxide, ethylene, aldehydes, chlorine and perhaps other pollutants will be studied.

The plants will be grown in greenhouses in which the environment closely approximates that of the ambient during the growing season. These greenhouses have been specially designed for air pollution studies. In these greenhouses no shading material or evaporative cooling is used for temperature control; thus the light intensity and humidity are modified little, and normal plant growth results. Air, filtered through orlon bags to remove particulates and through activated carbon to remove gaseous pollutants, is circulated through each greenhouse at a rate of 2½ changes per minute. Air entering the greenhouses is cooled during the summer and heated during the winter to produce the desired growing conditions by circulating cold or hot water through banks of finned coils in the air inlet ducts. Past experience indicates that response of plants grown in these greenhouses to air pollutants is typical of response in the field.

During the study, plants will be exposed to the air pollutant either in the greenhouses or more frequently in plant growth chambers that are specifically designed for plant fumigation studies. Each plant growth chamber will have provisions for light, temperature and humidity control. Air will be circulated uniformly through the chamber at a rate of one mile per hour. With the growth chambers it will be possible to subject plants to pollutant treatments under the same conditions of environment at different times so that results with different exposure times, concentrations, species, etc., can be compared. The pollutant concentration will be carefully controlled and measured continuously.

Ozone will be generated electrostatically from tank oxygen, the concentration in the chamber measured with a "Mast" ozone instrument, and the level controlled by regulating the voltage and oxygen flow rate. Peroxyacetyl nitrate will be made by photolysis of ethyl nitrate in oxygen. After dilution with nitrogen it will be metered into the chamber air system and the concentration determined by gas-liquid chromatographic and electron capture techniques. Hydrogen fluoride will be generated from hydrofluoric acid solution and measured with a fluoride recorder. Nitrogen dioxide and other pollutants will be metered into the chambers from a pressurized tank of the diluted gas mixture and measured by standard methods.

Usually plants will be exposed at 2 stages of growth and usually at least 8 plants of each species will be exposed in each treatment. Each species and variety will be exposed to enough different pollutant concentrations to establish the concentration required to cause injury. Injury symptoms will be photographed and described in detail. In cases where the symptoms appear to warrant it, histological effects will be determined. Special attention will be given to the position of injury on the plant, the time following exposure required for injury to develop and the sequence of stages of injury development. Because the injury symptoms caused by several air pollutants on a given species are often similar, particular attention will be paid to differences that might be used for diagnostic purposes. When practical, injured plants and control plants will be returned to the greenhouse and allowed to grow to maturity. Yield or dry weight measurements will be made, and the effect of the injury, if any, on yield determined.

Selected representative species will be exposed to each pollutant under different conditions of environment to determine the effect of environment, if any, on expression of symptoms and the concentration required to cause injury. Temperature, light intensity, humidity, state of plant growth, and duration of exposure will be varied one at a time as the others are maintained under standardized conditions.

More extensive studies will be conducted with the most common pollutants, and less extensive evaluation will be made with materials such as chlorine and aldehydes.

To the extent that funds are available, methods of measuring the concentration of each pollutant in the ambient air will be evaluated and if necessary, attempts will be made to automate them. Methods and instruments currently available for ozone, peroxyacetyl nitrate, hydrogen fluoride, ethylene, and oxides of nitrogen all need to be more thoroughly evaluated in ambient air. Specifically it is proposed to automate the electron capture method for peroxyacetyl nitrate determination (Darley et. al, Anyl. Chem. 35:589-91), evaluate the fluoride recorder currently being developed at the University of California at Riverside, and evaluate current methods of ozone determination, particularly in atmospheres containing nitrogen dioxide and sulfur dioxide as well as ozone. These studies will be conducted in chambers in which various combinations of the pollutant and possible interfering substances will be mixed with purified air or ambient air.

V. Facilities and Equipment

Facilities presently available include the following:

1. Three greenhouses that were designed specifically for air pollution studies. Each greenhouse is 9 x 36 feet and is equipped with an air circulation system that will provide 2½ air changes per minute. The air circulating system includes a baghouse to remove particulates, charcoal filters to remove gaseous contaminants, a large fan, hot and cold water coils to control temperature, and a steel duct system to provide uniform air circulation. The University spent over $20,000 during the past year moving these facilities on to the campus.

2. Over 1800 square feet of office and laboratory space including a partially equipped laboratory.

3. Ozone generator and "Mast" ozone recorder.

4. Hydrogen fluoride generator and distillation bank for fluoride analysis.

5. Fumigation chamber and related equipment.

Additional equipment that would be purchased from project funds over a 5 year period include a controlled environment plant fumigation chamber, nitrogen dioxide analyzer, sulfur dioxide autometer, fluoride recorder, and an additional ozone measuring instrument.

VI. Personnel

The following personnel are presently available to work on the project:

A. A. Clyde Hill, Associate Research Professor and Project Director.

1. Education
   a. B. S. Brigham Young University-Agronomy and Chemistry, 1949.

   b. Ph.D. Rutgers University - Soil Chemistry and Plant Physiology, 1952

2. Experience.
   a. Plant Physiologist, 1954-1956, and Supervisor, Agricultural Research and Technology, 1956-1964. United States Steel Corporation, Provo, Utah. Directed a 10 year research program to determine the effects of several air pollutants on plants. Also supervised research in air sampling and analysis.

   b. Plant Physiologist, Agricultural Research Department, Monsanto Chemical Company, St. Louis, Missouri, 1952-1954. Conducted research dealing with the effects of toxic organic compounds on plants.

3. Supplemental information.
   a. Member of the Committee on Community Air Quality Criteria, American Industrial Hygiene Association.

   b. Member Ozone Task Group, Air Pollution Control Association.

   c. Consultant - E. I. du Pont de Nemours and Company

4. Publications in Air Pollution

   a. An Investigation of the "Hidden Injury" theory of Fluoride Injury to Plants, Agronomy Journal. 50:562-565. 1958

   b. Facilities and Techniques for Maintaining a Controlled Fluoride Environment in Vegetation Studies, APCA Journal. 9:22-27. 1959

   c. Effects of Atmospheric Fluorides and Various Types of Injury on the Respiration of Leaf Tissue, Plant Physiology. 34:11-16. 1959

   d. Determination of Gaseous and Particulate Inorganic Fluorides in the Atmosphere. Am. Soc. Testing Materials Spec. Public 281:27-44. 1959

   e. Plant Injury Induced by Ozone, Phytopath 51:356-363. 1961.

f. Sampling Atmospheric Fluorides with Glass Fiber Filters. Journal of the Air Pollution Control Association. 13:374-377, 1963

g. Further Evaluation of Glass Fiber Filters for Sampling Hydrogen Fluoride. Journal Air Pollution Control Assoc. (In press).

B. Ray J. Downs, Research Associate

1. Education

B. S. Utah State University, Agronomy - 1941.

M. S. Utah State University, Agronomy - 1952

2. Experience

a. Agronomist, Agricultural Research and Technology, United States Steel Corp., 1954-1964. Conducted greenhouse and field studies to evaluate effects of atmospheric pollutants on plants.

b. Agronomist, Southern Oregon Agronomy Experiment Station, Medford, Oregon, 1953-1954. Supervised operation of 40 acre experiment farm. Conducted studies with fertilizers, herbicides, etc.

c. Agronomist and Assistant Field Branch Chief, Agricultural Division, Dugway Proving Ground, Dugway, Utah, 1951-1953. In charge of field testing and evaluation of certain biological agents related to agriculture.

C. I. B. McNulty, Associate Professor, Botany

1. Education

a. B. S. University of Utah Botany, 1942

b. M. S. University of Utah Botany, 1947

c. Ph.D. Ohio State University Plant Physiology, 1952

2. Experience

a. Head Department of Botany, University of Utah, 1959-1964
b. Seven years experience in conducting research on the effects of air pollutants on plant metabolism.

3. Publications in air pollution

a. Some Effects of Fluoride on Phosphate Metabolism. Plant Physiology, 37: XIX 1962 Supplement
b. Mechanisms of Fluoride Induced Chlorosis. Plant Physiology, 36:305-308. 1961

c. Possible Explanation of Fluoride Induced Respiration in Chlorella Pyrenoidosa, Science 132:1553-1554. 1960

d. Effects of Atmospheric Fluoride on the Respiration of Bush Bean and gladiolus leaves, Plant Physiology. 32:121-123. 1957

e. Effects of Fluoride on the Chlorophyl content of Leaves Proc. of Utah Acad. of Sci. Arts and Let. 34:134. 1957

D. Michael Treshow, Associate Professor Botany

1. Education
   a. B. S. Univ. of California at Los Angeles 1950

   b. Ph.D. Univ. of Calif. Davis. 1954 Plant Pathology

2. Experience
   a. Associate Professor Botany, University of Utah. 1961 - Present. Conducting research on effects of fluorides and other effluents of plant diseases.

   b. Plant Pathologist. U. S. Steel Corp. Provo, Utah 1953-1961. Conducted field air pollution studies to evaluate alleged production losses and other claims. Conducted research to establish causal factors.

3. Supplemental information
   a. Member, TR7 Agricultural Committee, Air Pollution Control Association.

   b. Consultant - U. S. Steel Corp. and Harvey Aluminum Co.

   c. Training Program Director. U. S. Public Health Service, Air Pollution Division Training Grant TI AP 20-01 1963-1966 ($58,414)

4. Publications in Air Pollution
   a. The Effects of Fluoride on the Anatomy of Chinese Apricot Leaves (Abst.) Phytopath 46:640. 1956

   b. Similarities Between Leaf Markings Caused by Atmospheric pollutants and other Agents. I. Moisture Stress and Fluoride Supression. Proc. Utah Acad. Arts and Lts. 41:49-52. 1964

   c. Plant Injury Induced by Ozone (Dr. A. C. Hill, Senior Author). Phytopath 51:356-363. 1961

   d. Effects of Sodium Fluoride on Growth of some Pathogenic fungi. Phytopath 53:891-892. 1963

   e. Evaluation of Vegetation Injury as an Air Pollution Criterion. Presented at 1964 APCA meetings and currently in press.

5. Publications not directly involving air pollution:

The following have helped establish the true cause of conditions alleged to be due to air pollutants:

a. Terminal bleach of cereals. Plant Disease Reporter. 41: 118-119. 1947

b. Red Raspberry Degeneration in Utah. Its Causes and Control. Utah State Univ. Circ. 140. 16 pp. 1958.

c. The Importance of Controlling Cytospora Canker in Fruit Trees. Proc. Utah. State Hort. Soc. 41-44. 1959.

d. Pathogenic Variation of Cytospora Rubescens Isolates on Stone Fruit Varieties. Phytopath. 50:86. 1960

e. Powdery Mildew of Potato in Utah. Plant Disease Reporter 45:354-355. 1961

f. Aphid-transmitted Yellows Type Spinach Virus in the Eastern United States. Plant Disease Reporter 45: 720-721. 1961

VII. Budget

It is anticipated that a budget of at least $50,000 a year will be required over a 5 year period. Recognizing the fact that the full budget potential will probably not be met the first year the following slightly reduced budget is proposed for 1965.

Personnel	
A. Clyde Hill Half time	$ 6,000
R. J. Downs Half time	5,000
I. B. McNulty (environmental studies)	500
M. Treshow (histological studies)	500
One technician Full Time	6,000
Student labor	1,000
Fringe benefits (9%)	1,710
Equipment	
1 Plant Growth Chamber	9,000
1 "Mast" ozone recorder	1,500
Supplies	5,000
Travel	1,000
Overhead	8,414
Total	$45,624

VIII. Significance of this Research to Industry

Past experience indicates that this research will be of value to industry in the following ways:

1. The evaluation of claims of air pollution injury to vegetation around an industrial operation would be put on a much sounder basis. As the public becomes more aware of air pollution, the tendency to blame many crop production problems of unknown causes on the polluted atmosphere increases. Knowledge of symptom expression and the concentration of the pollutant required to cause injury to the species in question is necessary to diagnose the problem and evaluate such claims. When the evaluation is based on such experimental data it is almost always possible to convince the parties involved of the facts. When it is not, all parties are free to speculate. If the problem is caused by an air pollutant, adequate analytical techniques and instrumentation are necessary to establish the pollutant source. This may or may not be the operations involved in the allegation. Also when a pollutant is involved, it is often necessary to have data relative to the effect of the pollutant on crop production as well as leaf symptoms.

2. Monitoring or surveillance programs would be strengthened because examination of vegetation (especially species that are sensitive to the pollutant involved) is often the best means of monitoring emissions from a source. Periodic examination of vegetation is being used more and more by industry to determine the presence and relative level of pollutants in areas of interest. These surveys are not only of value in evaluating emissions from an operation but they are often used in future planning for plant expansion or new site selection in areas of multiple sources of pollution.

3. As air quality standards come up for consideration in various localities the data obtained in these studies could be of value in trying to see that standards are based on sound plant data and analytical methods. Knowledge of the concentrations required to adversely effect many plant species may tend to discourage the basing of standards on the few extremely sensitive species.

4. Methods, techniques, facilities and experienced personnel developed in this program would be invaluable as specific problems arise for individual companies. Pollutants or plant species not included in this program could be studied and evaluated readily and with comparatively little cost only if such a program were under way.

December 1964