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1972 SURVEY AND ASSESSMENT OF AIR POLLUTION DAMAGE TO VEGETATION IN NEW JERSEY

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1972 SURVEY AND ASSESSMENT OF AIR POLLUTION DAMAGE TO VEGETATION IN NEW JERSEY

by

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ABSTRACT

The economic impact of air pollution on vegetation was studied for a second year, from May 1972 through May, 1973. Direct losses to agronomic crops and ornamental plantings were evaluated; crop substitution and indirect yield reduction were not accounted for. The total losses to these crops for 1972-73 amounted to $128,019. Forty-seven percent of the plant damage was caused by oxidants, 18% by hydrogen fluoride, 16% by ethylene, 4% by sulfur dioxide and 1% by anhydrous ammonia. Cumberland, Warren, Atlantic and Salem Counties sustained the greatest degree of injury. Damage reported in this survey was only 11% of that reported for 1971-1972 in New Jersey. Reduced losses did not result from decreased air pollution concentrations but rather from altered environmental conditions. The unusual rainfall patterns in 1972 placed the plants under water stress and probably protected them from air pollution injury. In addition to evaluating crop losses, unknown problems were documented and research needs assessed.

INTRODUCTION

The history of the air pollution problems on vegetation began in the 1890's when sulfur dioxide was first recognized as a phytotoxicant (24,27). Since then many air pollutants have been characterized as toxic, among them fluoride (HF), ozone (O_3), peroxyacetyl nitrate (PAN) and nitrogen dioxide(NO_2). In New Jersey air pollution problems on vegetation became apparent in 1944. Defoliation of deciduous and coniferous species, tip burn of gladiolus and tulip, mottling of corn foliage and early fruit drop of peach were among the symptoms attributed to hydrogen fluoride gas emitted from certain industrial processes (8). The fluoride problem provided the initiative for establishment of a permanent air pollution research laboratory at the Rutgers Experiment Station. Since then various symptoms on plant species in New Jersey have been attributed to all major air pollutants currently recognized. The ozone problem (presently the most serious) was first observed on spinach in 1958, the same year that it was first reported in the literature on grape (23). New Jersey is the most densely populated and one of the most heavily industrialized states in the United States. Since New Jersey's agricultural regions interface on the industrial sections of the state, the serious air pollution problems confronting crops come as no surprise.

There are many implications to air pollution phytotoxicity, among them:

(1) the economic impact of air pollution on agricultural and ornamental crops,

(2) the role of vegetation as an indicator of the presence of air pollutants in the ambient atmosphere,

(3) the role of vegetation as a sink for air pollutants (25).

The importance of the problem on vegetation generated a need to quantify and and qualify these effects. The Division of Ecological Research of the Environmental Protection Agency initiated continuous surveys to establish the economic impact of air pollution damage to vegetation in California, Pennsylvania and New Jersey. The objectives of these surveys were manifold. Initially researchers hoped to determine the relative sensitivity of plant species to specific pollutants and the severity and extent of the ensuing damage. By observing air pollution effects over a period of years researchers could evaluate (a) the annual variability of damage to crops and, (2) the geographical distribution of the damage. Many uses could then be made of the data:

(1) It would provide a basis for estimating and evaluating losses.

(2) It would provide a base for estimating the necessity and economic practicality of control measures. If instituted, success of controls could be evaluated during the course of the survey.

(3) It would identify unknown and important problems serving as a source of new research direction.

California conducted two types of surveys. Stanford Research Institute developed a model to study the potential air pollution effects on vegetation(1). The most populated areas in the United States i.e. those in the statistical Metropolitan area, and those with the greatest fuel consumption were analyzed in this model. Air pollutant concentrations were based on fuel consumption and point source emission data. Tables of species (agronomic, ornamental and forest) sensitive to specific pollutants and the percentage injury expected from exposure to different levels of specific air pollutants were prepared from existing literature.

The market value of these crops was considered and the data described above utilized to calculate the dollar loss according to a formula developed by the Institute. The SRI reported an average loss of $35,230,000 to the State of California in the years 1969 and 1970, and a $7,391,000 loss to the State of Pennsylvania in the years 1969-1970 and 1970-1971. It should be stressed that this model is predictive. The model has incorporated effects such as corp substitution but could not incorporate factors such as climatic or meteorological variability, hence, estimates by the Stanford technique could be expected to vary from yearly results in individual states.

Both California and Pennsylvania conducted surveys in which qualified personnel made on-the-spot investigations of individual air pollution episodes and quantified the results from their observations. In 1969 California sustained a $44.5 million loss to agriculture by this method. These results did not include losses to forest, vegetation or ornamental plantings (20). In another survey in 1970, losses to agronomic crops in California amounted to $25.7 million (20). In a two-year survey conducted in Pennsylvania losses to agronomic crops and ornamental plantings resulted in an $11.5 million in 1969, and a $225 thousand loss in 1970 (26).

In 1971 New Jersey embarked on a similar EPA sponsored survey using the same protocol. Feliciano (9) reported a loss of $1, 183,754. His survey was concentrated on effects on agronomic crops but did include acute effects on ornamental plantings. The following report will describe the survey which was conducted in New Jersey in 1972-73.

RATIONALE

In undertaking the study, I considered the following areas to be of importance to the success of the survey.

1. Evaluation of dollar loss as a result of air pollution damage to vegetation. Since the profile of the agricultural industry is shifting from rural agronomic crops to urban-related ornamental crops, an effort was made to obtain more data regarding ornamental vegetation.
2. Consideration of the relative importance of the individual air pollutants injuring vegetation.
3. Identification of those plants particularly sensitive to a pollutant.
4. Documentation of unknown problems which may be of air pollution origin.

This last area is important since our knowledge of the effects of air pollution on plants is limited to a few pollutants. We would do a great disservice to our research efforts if we merely pursued areas already defined.

MATERIALS AND METHODS

Method of Collection

In order to accumulate the greatest volume of data and describe the greatest number of air pollution episodes, we contacted three groups.

1. Extension Service: county agents and extension specialists.
2. Christmas tree growers' association - all Christmas tree growers.
3. Flower growers' association - major flower growers of New Jersey.

Communication between the county agents and the survey leader included air pollution report forms (9) and investigations of all reported air pollution episodes. The counties were inspected even when damage was not reported in order that no air pollution episodes be overlooked. In order to compare air pollution effects both years' surveys* accurately, all the species on which Feliciano (9) reported injury were examined.

There have been mounting reports of the importance of air pollution effects on conifers (2, 7). We did not have the personnel to assess air pollution effects on conifers throughout the state, therefore we sent questionnaires concerning air pollution damage on trees to all the Christmas tree growers. When responses indicated potential air pollution problems, the Christmas tree plantation was visited.

Similar report forms and a descriptive letter were sent to the major flower growers to inform them of our service and to make the growers cognizant of potential air pollution problems. Any air pollution episodes were investigated.

*Survey I - The 1971-1972 survey was conducted from April 1971-April, 1972.
Survey II - The 1972-1973 survey was conducted from May 1972- May, 1973.

Air pollution damage was identified by symptoms, and when meaningful, by chemical analyses of plant tissue for pollutant residues.

Method of Assessment

There were essentially two modes of assessing value loss:

Method of Evaluating Complete Loss

If an entire agronomic crop or portion of the ornamental crop was completely destroyed, the loss was expressed as cost of replacement. In the case of the conifers the replacement value was calculated at an average of $1.00 to $1.25 per foot. The additional cost of property taxes and maintenance were not included. The value of agronomic and ornamental crops was based on market value.

Method of Evaluating Partial Loss

In most species, particularly those that were not ornamental, partial injury did not result in complete loss of a crop but reduced its value. These values were calculated according to the rule of thumb previously utilized (9, 20). The inaccuracies of this method will be discussed later.

When we observe injury to a portion of a particular crop we can either report that specified damage as the loss, or we can extrapolate to include the damage on the entire acreage of the crop grown in the state. I have rejected the idea of extrapolating for two reasons: (a) we do not have data to prove that air pollutants were present at every site where a sensitive crop was growing; (b) from our field and laboratory experience we know that plants grown in the same atmosphere sometimes respond differently. Therefore, it is invalid to extrapolate to effects on acreage we have not observed. Since we are not in a position to present a predictive model (1), we confine our report to actual observations only.

Method of Data Analysis

The data were evaluated from two perspectives:

1. Comparison with New Jersey survey data of 1971-1972.

   The data were compiled according to the pollutant and affected crop on a statewide basis (Table I). In Table II the data were tabulated according to county. Data on crop substitution were not included.

2. Evaluation of Field Problems

   The serious field problems will be discussed in detail with an emphasis on the difficulty of accurate diagnosis. In this section unknown field problems will be elaborated as well.

RESULTS AND DISCUSSION

I. Comparison between New Jersey survey data from Survey I and Survey II.

In Survey II air pollution damage to vegetation resulted in $128,019 losses to New Jersey growers (Table I and Table II). This value was only 11% of the $1,183,754 loss reported for Survey I (9). When losses were compared on a per county basis (Table II), we found that Cumberland County sustained the greatest losses followed by Warren, Atlantic and Salem counties respectively. In Survey I Cumberland, Burlington, Atlantic and Salem counties suffered the severest effects of air pollution injury to vegetation. While Warren County sustained a $33,777 loss in Survey I, and $26,000 loss in Survey II, these values reflected only a 2% of the total in the former opposed to 20% of the latter total. The absolute degree of damage in a particular county was a function of the presence of sensitive species as well as the presence of air pollutants· proportional distribution of damage was also a function of total loss. Forty-six percent of the dollar loss in Survey II resulted from damage to vegetable crops compared to 51% in Survey I. In Survey I, 36% of the air pollution damage occurred on field crops but in Survey II there was only a 2% loss to these crops. In Survey II there was virtually no injury to alfalfa, clover or soybean which explains the decreased damage to field crops. The absence in damage to field crops also explains the decrease in dollar losses in Burlington County since $120,592 of the $150,764 losses incurred in this county in Survey I resulted from air pollution damage to field crops. Ornamentals are often injured as the result of accidental exposures to air pollutants. While the number of episodes of air pollution damage in Survey I and Survey II were similar, the percentage

Table I. Statewide estimates of crop loss tabulated according to crop and pollutant

Crop	Pollutant	Acreage Affected	$ Loss	State ** Harvest Value
Field Crops				
Alfalfa	O_3	10	0	xxx
White potato	PAN	300	2,106	7,582,000
			2,106	
Fruit				
Grape	O_3	67.5	10,730	369,112
			10,730	
Nursery and Cut Flowers				
Gladiolus	HF	240	22,890	1,916,532
Easter lily	ethylene	2000 a	20,000	xxx
Chrysanthemum	aldehyde	3300 a	1,925	xxx
Chrysanthemum	phenol	2600 a	53	xxx
African violet, Azalea and Begonia	products of oil combustion	2000 a	5,000	xxx
			49,868	
Trees (Christmas)				
Norway spruce	unknown II	504 a	5,042	xxx
Norway spruce	unknown II	16 a	0	xxx
Jap. black pine	SO_2	12 a	120	xxx
White pine	unknown I	78 a	975	xxx
White pine	unknown stack source	2 a	30	xxx
Norway spruce Scotch pine White pine	NH_3	100 a 50 a 25 a	800	xxx
			6,967	

Crop	Pollutant	Acreage Affected	$ Loss	State Harvest Value
Vegetables				
Cucumber	O_3	37	2,530	1,700,000
Dandelion	PAN	3	1,015	14,328
Endive & Escarole	PAN	15	811	1,871,000
Fall lettuce	PAN	800	15,736	1,180,000
Spring lettuce	PAN	15	880	1,534,000
Spring lettuce	HCl mist	2	6,000	1,534,000
Lima bean	O_3	605	3,690	412,800
Muskmelon	O_3	515	11,529	298,200
Okra	O_3	100	xxx	xxx
Onion	O_3	xxx	xxx	xxx
Pumpkin	O_3	17	111	xxx
Scallions	O_3	1	10	xxx
Shallots	O_3	20	605	xxx
Spinach	O_3 PAN	74 3	5,071 225	423,000
Squash	O_3	1	15	xxx
Sweet corn	O_3	10	44	4,883,000
Swiss Chard	PAN	2	60	15,792
Tomato	PAN SO_2	25 5040 b	4,789 5,123	7,543,000
Turnip	PAN	.25	xxx	xxx
Watermelon	O_3	81	104	15,587
			58,348	
		Total	128,019	

Key: Table I and II

*	Data not provided.
**	New Jersey Crop Reporting Service.
***	Harvest value not available.
a.	Trees or plants affected.
b.	Square feet.

Table II. Estimated dollar and acreage loss to crops tabulated according to county and pollutant

County	Pollutant	Crop	Acreage Affected	$ Loss	County** Harvest Value
Atlantic	O_3	Grape var.		10,730	165,462
		Elvira	1		
		Fredonia	3		
		Ives	1.5		
		Niagara	1		
		Noah	25		
		Riesling	36		
		Scallions	1	10	xxx
		Shallots	20	605	xxx
				11,345	
	PAN	Endive	10	660	66,250
		Spring lettuce var.	15	880	40,287
		Iceberg & Romaine			
				1,540	
	unknown I	White pine	15 a	210	xxx
	unknown II	Norway spruce	500 a	5,000	xxx
				18,095	
Bergen	Aldehyde	Chrysanthemum var.	300 a	125	xxx
		Princess Anne			
				125	
Burlington	O_3	Cucumber	2	675	24,250
		Spinach	2	34	xxx
				709	
	PAN	Endive	2	100	xxx
				100	
	unknown II	Norway spruce	2 a	20	20
	unknown III	Norway spruce	3 a	0	30
				829	
Camden	O_3	Squash	x	x	x
	Phenol ?	Apple	x	x	xxx
		Azalea			
		Blue spruce			
		Chestnut			
		Daisy			
		Forsythia			

County	Pollutant	Crop	Acreage Affected	$ Loss	County Harvest Value
Camden (continued)	Phenol ?	Gladiolus			
		Grapes			
		Peony			
		Roses			
		Sycamore			
		Yew			
				x	
Cape May	O_3	Lima bean var. Fordhook & baby lima	500	2,700	393,000
				2,700	
Cumberland	O_3	Alfalfa	5	0	
		Cucumber	3	1,012	724,800
		Lima bean var. Pole	-	display	-
		Muskmelon	10	439	120,171
		Okra	100	xxx	xxx
		Onion	x	x	x
		Watermelon	81	104	15, 587
				1,555	
	PAN	Dandelion	1	200	4,776
		Escarole	2	34	132,500
		Galinsoga	-	0	0
		Fall lettuce var. bibb, boston, iceberg leaf, romaine	800	15,736	420,820
		Spinach	3	225	xxx
		Tomato	x	x	50,509
		Turnip	.25	xxx	xxx
				17,750	
	HF	Gladiolus var. White friendship and pilgrim	240	22,890	1,281,024
				40,640	
Gloucester	O_3	Cucumber	20	337	276,330
		Muskmelon	5	110	29,310
		Pumpkin	2	39	300,000
		Squash	1	15	xxx
				501	
	HF	Fir	x	x	xxx
		Maple	x	x	xxx
		Oak	x	x	xxx
		Spruce	x	x	xxx
				501	

County	Pollutant	Crop	Acreage Affected	$ Loss	County Harvest Value
Hunterdon	unknown III	Norway spruce	3 a	0	xxx
				0	
Mercer	unknown I	White pine	8 a	80	xxx
	unknown II	Norway spruce	1 a	12	xxx
	unknown III	White spruce	10	0	xxx
				92	
Middlesex	O_3	Spinach	53	3,042	11,600
		Sweet corn	10	44	
				3,086	
	PAN	Dandelion	2	815	9,552
		White potato	300	2,106	210,600
				2,921	
	Unknown I	White pine	55 a	685	xxx
	unknown II	Norway spruce	1 a	10	xxx
	unknown III	Jap. black pine	-	0	xxx
		Austrian pine			
				6,702	
Monmouth	PAN	Escarole	1	17	84,800
		Swiss Chard	2	60	xxx
				77	
	SO_2	Jap. black pine	12	120	xxx
				120	
	NH_3	Norway spruce	100 a		xxx
		Scotch pine	50 a	800	xxx
		White pine	25 a		xxx
				800	
	oil combustion product	African violets, Azalea, Begonia	2000 a	5,000	xxx
				5,997	
Morris	SO_2	Tomato var. Michigan, Ohio	5040 b	5,123	xxx
				5,123	

County	Pollutant	Crop	Acreage Affected	$ Loss	County Harvest Value
Ocean	O_3	Cucumber	12	506	xxx
		Lima bean var. Ford Hook	5	750	xxx
				1,256	
	aldehydes	Chrysanthemums var. Baby Tears, Cameo, Dan Fuley, Gambler, Gold Strike, Grand Child, Jessamine Williams, Joan Helen, Lipstick, Minn White, Princess, Roll Call, Small Wonder, Wee Willie, Yellow Supreme, Yellow Jess.Williams, Zonta	3000 c	1,800	xxx
				3,056	
Salem	O_3	Lima bean var baby lima & dixie pea	100	240	121,400
		Muskmelon var. Gold star	500	10,980	119,194
		Pumpkin	15	72	63,000
		Spinach	19	1,995	xxx
				13,287	
	PAN	Tomato	25	4,789	148,668
				18,076	
Somerset	Phenols ?	Chrysanthemum var. Deep Mermaid, Mountain snow, Princess Anne	2600 a	53	xxx
				53	
Union	unknown stack source	White Pine	2 a	30	xxx
				30	

County	Pollutant	Crop	Acreage Affected	$ Loss	County Harvest Value
Warren	ethylene	Easter lily	2,000 a.	20,000	xxx
				20,000	
	HCl acid mist	Escarole & Endive	4	0	202,725
		Lettuce var. Romaine	2	6,000	4,000
				26,000	
			TOTAL	128,019	

damage to floriculture (39%) was much higher than in Survey I (7%) due to the reduced total loss values.

The oxidants i.e. ozone and PAN were responsible for 47% of all damage, sulfur dioxide (SO_2) for 4% and ammonia (NH_3) for 1%. Ethylene caused 16% and HF 18% of air pollution damage in Survey II as opposed to 3% and 2% in Survey I respectively. The ethylene was responsible for $20,000 loss to Easter lilies and exposure of gladiolus to HF resulted in $22,890 damage. Aldehydes and phenols were suspected toxicants to a variety of ornamentals.

We had a 20% response to the Christmas tree questionnaire. There were nine positive responses which upon inspection revealed an estimated $6,967 damage. The most interesting result of this survey was the documentation of three problems, one on white pine and two on norway spruce: hypotheses concerning the origin of these symptoms will be discussed in the next section.

The damage reported this year (1972-1973) is substantially lower than the $1,183,754 figure accrued during Survey I. When results are substantially reduced from one year to the next we must examine the possibility that air pollution levels had declined. We considered this possibility and carefully studied air pollution monitoring data. The New Jersey State Department of the Environmental Protection, Bureau of Air Pollution Control monitors the air for nitrogen oxides, nitric oxide, nitrogen dioxide, sulfur dioxide, oxidants, aldehydes, carbon monoxide (CO), Carbon dioxide, hydrocarbons and smoke shade at four sited, Bayonne, Camden, Elizabeth and Newark (11) (Figure 1). We selected to evaluate the data obtained from the Camden trailer since it was closest to the agricultural region of the state. We compared the concentrations

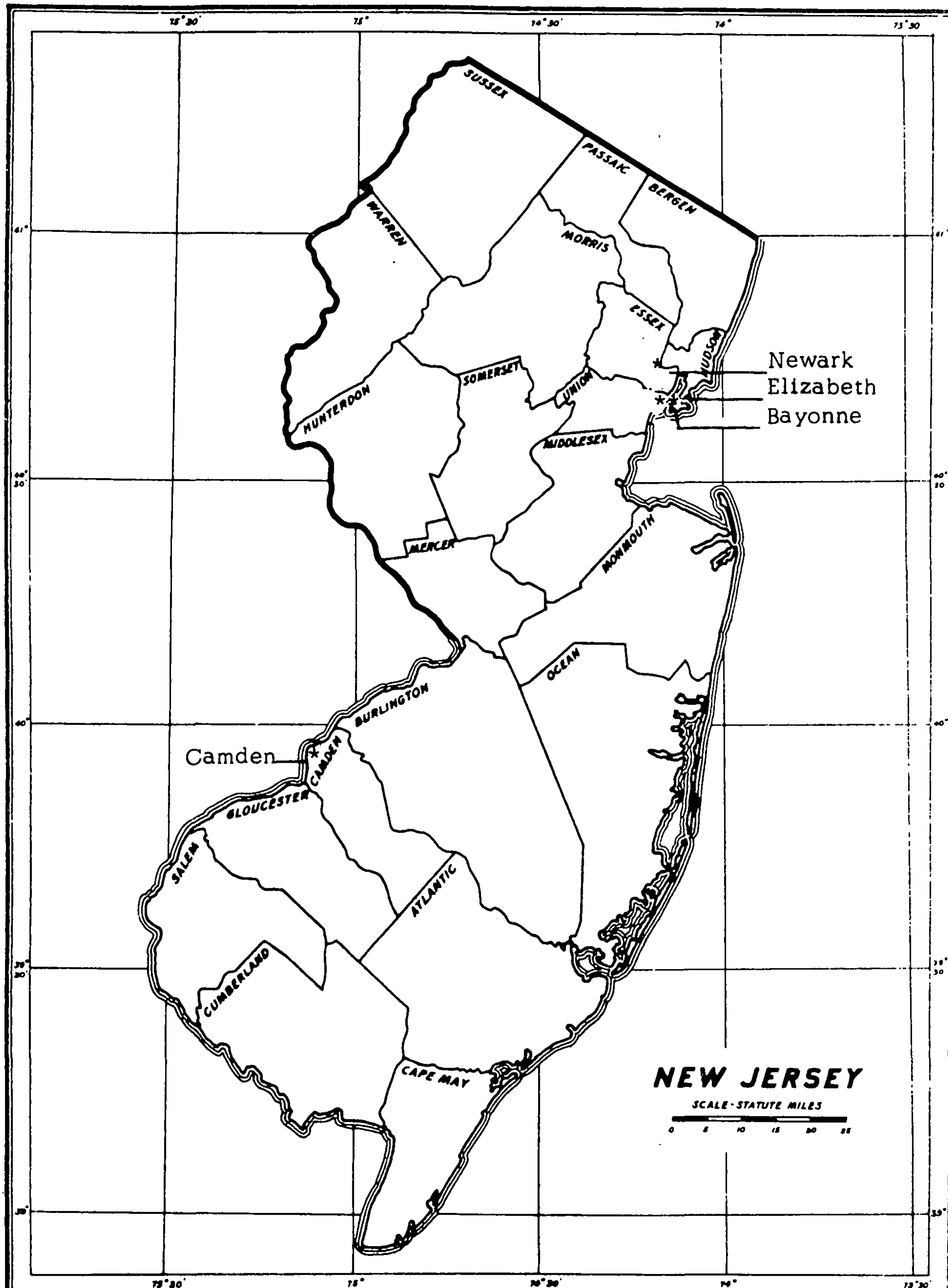


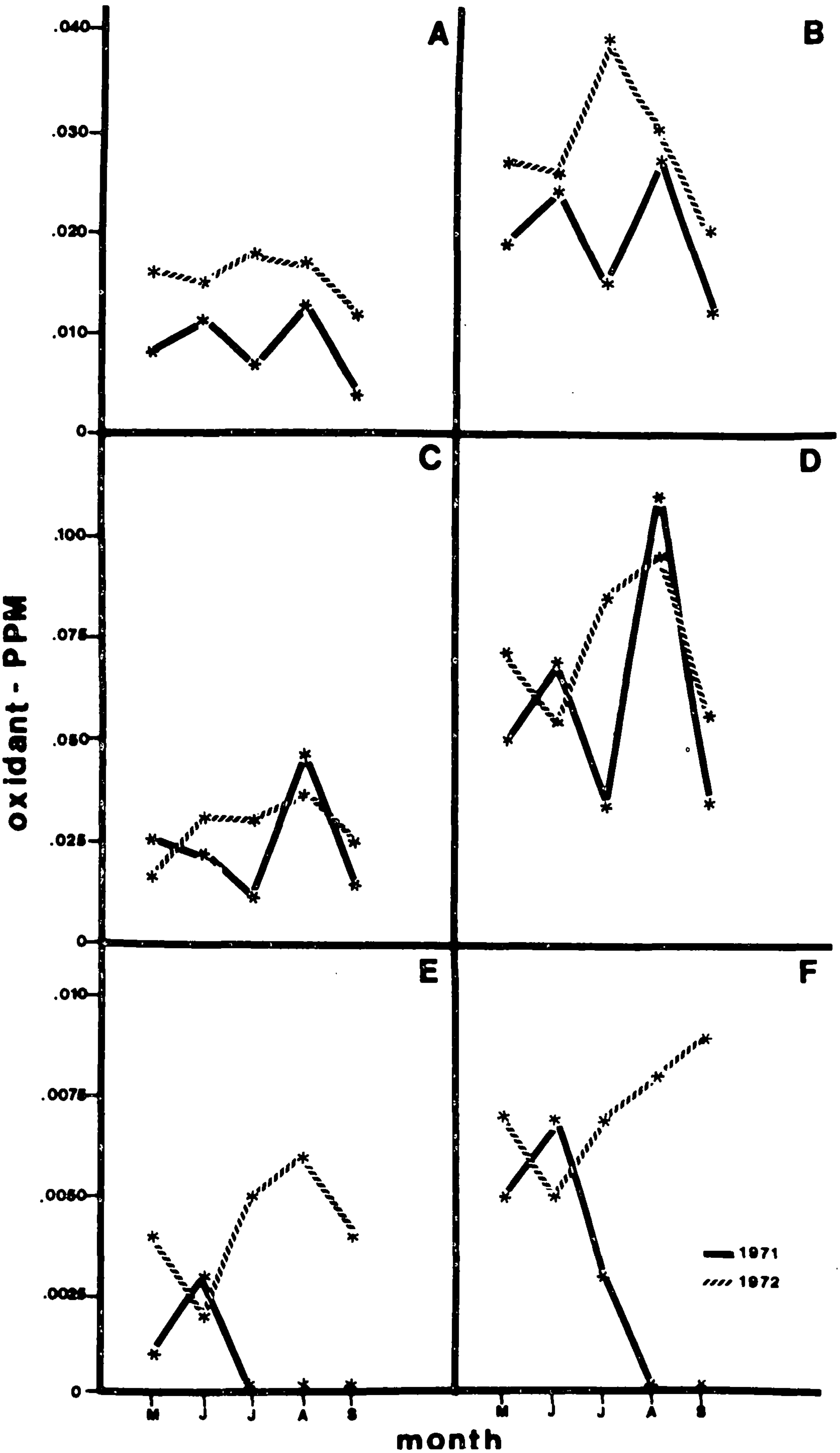
Figure 1. County Map of New Jersey

of NO_2, SO_2, oxidants, aldehydes, CO and hydrocarbons for the months of May through September of the years 1971 and 1972; the data was compiled according to monthly averages, minima and maxima, each of these categories being divided into averages and maximums. We studied 180 pairs of data: in 142 cases concentrations of the six pollutants were higher in 1972 (Survey II) than in 1971 (Survey I), and in 38 cases the reverse was true. CO never was as high in 1971 as it was in 1972 for the months studied. The other pollutants showed a similar distribution of 1971/1972 ratios of pollutant concentrations. Concentration differences were often only several ppb in magnitude, and would probably not be construed as significant. Since oxidants were responsible for 47% of the air pollution damage to vegetation, I have selected these gases as an example for graphic representation of this data (Figure 2). The conclusion is apparent: reduction in air pollution, injury to plants in 1972 cannot be attributed to a reduction in the concentrations of known air pollutants.

While 1971 air pollution concentrations were not higher than in 1972, there were six air stagnation advisories in 1971, and only two in 1972 growing season (Table III). "An air stagnation episode occurs when meteorological conditions develop which may inhibit dispersion of airborne wastes for extended periods of time and consequently cause elevated pollution levels that pose a threat to public health (11)." During periods of stagnation plants are exposed to pollutants for an extended time; the plants are, therefore, more likely to be injured. However, such extended periods of air stagnation that are required for air pollution advisories are not a prerequisite for plant damage.

Figure 2.* Average, maximum and minimum oxidant values for 1971 and 1972. (A) Monthly average of daily averages, (B) Monthly average of maximum hourly average, (C) Monthly maximum of daily averages, (D) Maximum hourly average, (E) Monthly minimum of daily averages, (F) Maximum minimum hourly average.

* Data provided by the New Jersey continuous air monitoring network. New Jersey Department of Environmental Protection, Trenton, New Jersey.



A
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1971
1972

Table III. Air Stagnation Advisory for New Jersey for the Years 1971 and 1972

YEAR 1971

August 18,	11:30 am start
August 19,	12:30 pm end
October 15,	2:30 pm start
October 16,	12:00 noon end
October 21,	12:00 noon start
October 22,	11:00 am end
October 27,	4:00 pm start
October 28,	11:00 am end
October 30,	11:00 am only local condition, no alert reported.
November 17,	4:00 pm start
November 19,	10:00 am end

YEAR 1972

February 9,	4:00 pm start
February 11,	12:00 noon end
July 18,	12:00 noon start
July 20,	12:00 noon end

The decrease in plant damage in 1972 could be explained partly by meteorological differences but other explanations must be sought. The decrease in air pollution damage to crops may be explained in part by some crop-related phenomenon. The tonnage of harvested vegetable crops was reduced 11% from the values in 1971. Harvested acreage of major vegetable crops in 1972 totaled 89,990 compared with 98,050 in 1971. Hurricane Agnes was partially responsible for destroying a considerable quantity of the June crop. While the acreage harvested was lower, the prices were higher so dollar loss for a specific crop was not affected by crop reduction per se. However, it rained 22 out of 42 days (in Hightstown, N.J.) for the month of June and the first two weeks of July accumulating over 12 inches. Many spring crops grew slowly or had to be plowed under. From July 12 until the end of September we had only 2.13 inches of rain (Table IV).

The climatic conditions just described are an important factor in explaining the crop reduction but perhaps even more important in explaining altered effects of air pollution on vegetation. It has been shown experimentally that plants grown under water stress have an altered morphology and physiology, and are less sensitive to air pollutant injury than are those turgid plants grown under adequate watering conditions (18, 19, 21). Celery, onion, cabbage, soybean, eggplant, clover and mustard on which Feliciano (9) reported injury did not show symptoms in 1972, and quite likely climatic conditions were responsible for this variation. A similar observation was made by Benedict (1); he pointed out that a severe air pollution episode in New Jersey, New York and Pennsylvania at the end of July, 1970 resulted

Table IV. Average rainfall for the months June-September for the years 1971 and 1972 in Hightstown, New Jersey*

	1971	1972	Normal**
June	0.83	7.29	3.83
July	6.08	5.37	4.46
August	12.04	1.16	4.52
September	5.13	0.97	3.99
	24.08	14.79	16.80

* Data provided by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service.

** Mean values over a 30-year period.

in only slight injury to sensitive species. Benedict suggested that climatic conditions may have been responsible for the results. Other environmental factors contribute to the susceptibility of vegetation to air pollutants. For example, increases in humidity increase sensitivity of begonia to ozone and sulfur dioxide injury (15, 16). Plant nutrition also affects species sensitivity: plants grown at optimum nitrogen concentrations are more sensitive than those grown at luxuriant or deficient levels (17). There are many interacting factors which determine to what degree a plant will be damage. Figure 3 summarizes these factors.

The following field observations illustrate the relative decrease in air pollution damage to vegetation from Survey I to Survey II. One striking example of this decrease was observed at the Renault Vineyard in Atlantic County. In 1971 (Survey I) a severe ozone episode in early July resulted in typical stippling of grape leaves leading to rapid necrosis and early leaf abscission. The resulting damage was estimated at $67,089. This year the vineyard was inspected several times; the grape leaves showed minor degree of stipple but from personal accounts (county agent and grower), and from comparisons with photographs from the summer of 1971, injury in 1972 (Survey II) was negligible when compared with damage the previous year. Most of the damage this year ($10,730) was attributed to reduced yield because of the dieback of the vines last year.

Leone and Brennan (14) also demonstrated the decrease in air pollution injury to vegetation between this year and last. In 1971 and 1972 Bel W-3 Tobacco was grown in ambient air in New Brunswick, New Jersey. On the

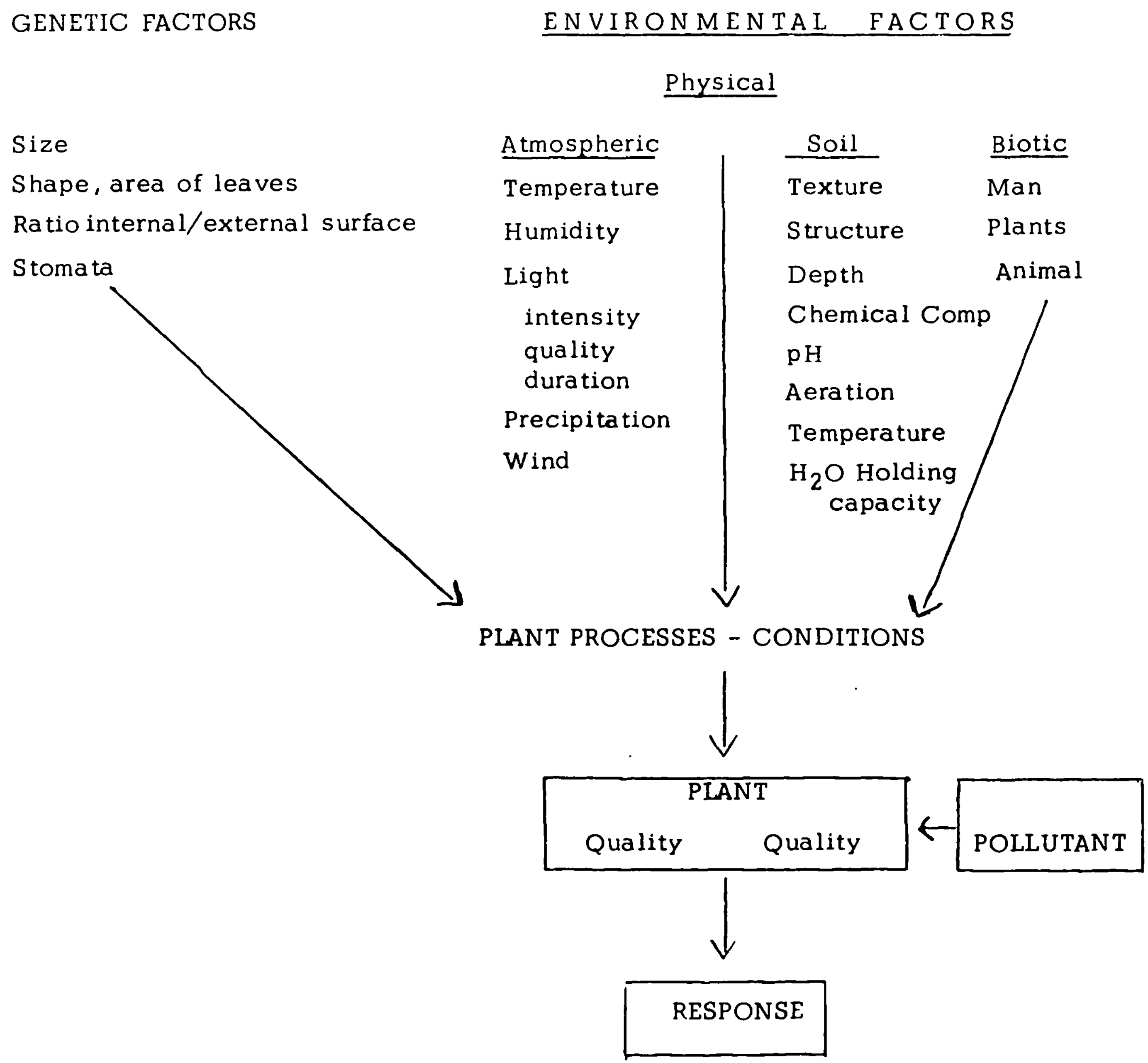

Figure 3. Interacting factors responsible for effects of air pollutants on plants.

basis of a rating system established by the NE-56 (13) plants were evaluated periodically from June to September. When 21 pairs of (according to date of the observations in 1971and 1972) results were compared, there were 11 instances when injury was greater in 1971, 5 when it was less and 5 when equivalent. BelW-3 is an indicator only for the presence of ozone; these results are consistent with the statistics we have accrued and with the opinions and observations of the county agents and extension specialists.

II. RESEARCH NEEDS

In this section I will elaborate on the research needs which became apparent during the course of this survey.

A. The "Oxidant" Symptom on Lima Beans

For many years we have observed a bronzing-stippling symptom on lima beans and on potatoes as well. This symptom also has been reported on okra in New Jersey and elsewhere (12). Generally we have attributed this symptom to ozone, however, an acute dose of ozone under controlled conditions produces a somewhat different symptom in the chamber, namely a combination of whitish fleck or bleach and sometimes some stipple as well. To our knowledge the field symptom has not been reproduced under controlled conditions. Preliminary results (22) indicate that many long exposures at low levels may be responsible for this symptom on lima bean var. baby lima. We could not reproduce this symptom on the Ford Hook variety of lima bean which also shows this symptom in the field. Whether it is the dosage, the growing conditions or the response to a combination of pollutants is unclear at this time. The problem is compounded since the symptom often shows up on scattered plants throughout a field of healthy plants or will show up in several fields and not others in a single geographic location.

B. PAN — A Problem of Diagnosis

In New Jersey we have what appear to be PAN episodes in the spring and fall. Whether these episodes occur because this is when the pollutant is present at high concentrations or because this is when the sensitive leafy vegetables are grown is not clear. Our basic problem is that reported PAN episodes usually occur when there has been the possibility of a local frost. Since frost can cause symptoms similar to those caused by PAN, it is at times difficult to make an absolute diagnosis.

An example occurred in October, 1972, when 800 acres of lettuce, escarole, spinach, dandelion and turnip in Cumberland County were reported to have a bronzing or glazing of the leaf tissue. While "classically" this symptom has been defined as undersurface injury many of our observations occurred on both surfaces and in Romaine lettuce typically on the tips of the upper surfaces of the leaves. We had several lines of evidence that PAN was responsible for the injury:

1. The field symptom resembled the PAN symptom described in the literature.
2. A haze was observed on the morning that the injury developed.
3. Plants known to be sensitive to PAN were injured.
4. Galinsoga, a PAN indicator (3,6) was injured in all instances where PAN symptoms were observed on other crops.

Unfortunately, New Jersey does not monitor the atmosphere for PAN concentrations, therefore we have no chemical evidence of its existence, and we cannot be positive frost was not present.

Further research to differentiate between PAN and frost injury on the same species to solve these diagnostic difficulties is essential. PAN is a pollutant about which little is known. If it is as serious a problem as it seems to be, much more research must be conducted in this area.

C. Aldehydes: Problems on Chrysanthemums

We have observed a generalized necrosis of Chrysanthemum leaves on 17 varieties of Chrysanthemum. We have evidence that this injury may have been caused by acetaldehyde (dissolved in rain water) emissions from an X-ray incineration factory (22). In previous research, aldehydes have been reported to cause injury on Petunia (4). Since aldehydes are a product of automobile combustion as well as of industrial processes, the phytoxicity of this chemical should be thoroughly investigated.

D. Products of Oil Combustion: Injury to Begonia, African Violets and Azalea Flowers.

An oilburner in a greenhouse was improperly ventilated and burned oil inefficiently; as a result begonia plants were severely injured. The injury varied from necrosis to cupping and distorting the color of the leaves. The flowers of begonia,, african violets and azalea showed necrotic spots on the petals. This is an unusual symptom; only ethylene has been reported to be responsible for injury to flowers. It would be interesting to know which fraction of incomplete combustion is responsible for this symptom.

E. Unknown Problems: Conifers

There are three problems which we observed on conifers for which the causal agent is unknown. These are widespread problems and because they may be caused by air pollutants they are worthy of discussion.

1. Unknown I — White Pine

Throughout the state there are white pines which exhibit severe tip burn, sometimes extending almost the entire length of the needle. There is variation such that a small number of sensitive trees will show the symptom while the majority will be healthy in appearance. Berry and Ripperton (2) described this symptom and suggested that ozone or some oxidant could be responsible for the symptom. When Costonis (7) exposed white pine to sulfur dioxide or ozone, the tip burn symptom developed. We have observed tip burn of white pine as a result of an anhydrous ammonia accident. All of these air pollution symptoms develop differently, the end result being the same. In order to differentiate between symptoms we must know (a) what the preliminary symptoms looked like, (b) which pollutants were present at the time of needle injury. This symptom could also be caused by other stresses. We should determine which other stresses—air pollutant and other environmental stresses—could cause the same symptom.

2. Unknown II — Norway Spruce

We originally observed a mottling symptom on spruce needles in one location in Atlantic County. Since first observed, this symptom has been observed in three other counties, Burlington, Mercer, and Middlesex Counties. There seems to be no correlation between drainage problems and the observed symptoms. Nor does the symptom correlate with any nutrient deficiency. At present we could not say that this symptom is of air pollution origin, but it is worth pursuing.

3. Unknown III — Norway and White Spruce, White Pine, Japanese Black Pine and Austrian Pine

Over the last few years we have observed a discrete white spot on a number of species namely Norway and white spruce, white pine, Japanese black pine and Austrian pine. This symptom is widespread. We have observed it in urban and rural counties alike. We have been able to protect needles from developing this symptom by covering branches with plastic bags (5), and we feel this is evidence that the problem is of air pollution origin. The symptom generally appears in the winter when needles are hardened; we have hypothesized that acid gases washing out in rain or in snow burn the needles in this manner. There is evidence that acidic rainwater causes another Christmas tree symptom, short-long needle disease on Scotch pine (10). Precipitation should be monitored for acid content; controlled experiments should be conducted to determine whether an air pollutant could be responsible for this symptom.

F. Evaluation of Rule of Thumb as Method of Assessment

While the rule of thumb is an accepted method, it has serious limitations which merit discussion. There is no doubt that leaf injury can alter yield, however time of injury is critical. If a leaf is injured early in plant development, prior to flowering or fruit set, there is no question that yield reduction will occur. If a substantial portion of the leaf is injured the photosynthetic activity is reduced and hence the plant vigor as well. The yield of most species may be reduced but whether the geometric progression relationship described for leaf injury by the rule of thumb pertains to all species is questionable. There is also the possibility that leaf tissue will be injured in the growing season and then the effect of air pollution on plant yield would not be marked. Furthermore, it is possible that there will be no effect on yield in terms of weight loss but more pronounced effect on quality in terms of carbohydrate, vitamin, protein or trace element content.

The experiments necessary to determine the relationship between leaf injury and yield would be extensive and time consuming. It would only be beneficial to study effects on yield, particularly where quality may be affected, where damage is extensive.

CONCLUSION AND SUMMARY

Air pollution damage to agronomic and ornamental crops in Survey II resulted in $128,019 loss to New Jersey growers . Forty-seven percent of the damage resulted from ozone and PAN damage. The Survey II losses were 11 percent of the Survey I losses. After comparing the air pollution data for the months of May through September, we concluded that the decrease in damage could not be attributed to improved air quality. We know from the literature that there are only certain conditions under which plants will be injured by air pollutants. Apparently some factor(s) necessary for plant damage which were present in the summer of 1971 (Survey I) were absent in 1972 (Survey II). One important factor was rainfall. It is very possible that the unusual rainfall pattern in 1972 (Survey II) was partially responsible for the apparent resistance which the vegetation had to air pollution in that year.

One of the aims of any survey is to utilize previous research to explain current problems. Another goal is to define new problems and set new research vistas. I believe priority should be given to probing for the answers to questions concerning the resistance mechanism of plants and to developing better methods of diagnosis.

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16. Abstracts The economic impact of air pollution on vegetation was studied for a second year, from May 1972 through May, 1973. Direct losses to agronomic crops and ornamental plantings were evaluated; crop substitution and indirect yield reduction were not accounted for. The total losses to these crops for 1972-73 amounted to $128,019. Forty-seven percent of the plant damage was caused by oxidants, 18% by hydrogen fluoride, 16% by ethylene, 4% by sulfur dioxide and 1% by anhydrous ammonia. Cumberland, Warren, Atlantic and Salem Counties sustained the greatest degree of injury. Damage reported in this survey was only 11% of that reported for 1971-1972 in New Jersey. Reduced losses did not result from decreased air pollution concentrations but rather from altered environmental conditions. The unusual rainfall patterns in 1972 placed the plants under water stress and probably protected them from air pollution injury. The report also documents unknown problems, and assesses research needs.

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