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J.A. Exhibit 3
6/12/85

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of ARIZONA PUBLIC SERVICE COMPANY, et al. (Palo Verde Nuclear Generating Station, Units 2 and 3)	Docket Nos. STN 50-529 STN 50-530

TESTIMONY OF THE REVIEW BOARD

(DRS. CHARLES R. CURTIS AND DELBERT C. MC CUNE)

SUBMITTED BY JOINT APPLICANTS

Qualification of the Review Board

1. Q. Dr. Curtis, would you please state your full name and address.

   A. My name is Charles R. Curtis and my address is 1421 Castleton Road-North, Columbus, Ohio 43220.

2. Q. By whom are you employed and in what capacity?

   A. I am currently employed in the Department of Plant Pathology at the Ohio State University, Columbus,

Ohio, as a professor and chairperson of the department.

3. Q. Please describe your previous employment.

A. Previously, I was Professor of Plant Pathology and Chairperson of the Department of Plant Science at the University of Delaware, Newark, Delaware. Prior to that employment I was Professor of Plant Pathology in the Botany Department of the University of Maryland, College Park, Maryland. I have served on thirty-five graduate examining committees in the areas of agronomy, soil science, horticulture, botany and plant pathology and have served as the major advisor for seven graduate students. My academic appointments have included teaching, research, extension and service. My formal teaching assignments have included General Botany, Research Methods, Physiology and Biochemistry of Pathogens, seminars in pathology and plant sciences, biology, thesis and dissertation research. Research emphasis has been on the effects of environmental pollution (ozone) on vegetation, physiology of disease and cooling tower saline aerosol effects on vegetation. I have also served as secretary and chairman of a multi-state U.S. Department of Agriculture Regional Research Technical Committee NE-121

"Reducing the Effects of Air Pollution on Plant Productivity in the Northeast."

4. Q. What other activities have you been engaged in?

A. I have served as an environmental consultant or advisor to Ocean Science and Engineering, Inc., Delmarva Light and Power Company, Tampa Electric Company (TECO), Stone and Webster Engineering Corporation, Intera Environmental Consultants, U.S. Reduction Co., and the Maryland Power Plant Siting Program (Chalk Point, MD). In addition, I have been the principal organizer or participant in numerous symposia, workshops or meetings dealing with the impact of cooling towers on the environment, air pollution and environmental pollution. I have also served as a reviewer for scientific manuscripts for the scientific journals *Phytopathology, Radiation Botany, American Journal of Botany, Canadian Journal of Plant Science, Nuclear Safety, Journal of Environmental Quality, Canadian Journal of Forest Research, and Science.*

5. Q. Would you please expand upon your involvement with the Maryland Power Plant Siting Program?

A. The Chalk Point Cooling Tower Project (CPCTP) began in 1972 under the State of Maryland Power Plant

Siting Program. One of the objectives of the CPCTP was to determine the environmental impact of saline drift emissions from a brackish water cooling tower on soils, agricultural crops and native perennial vegetation. I was the project leader for the native, perennial vegetation study from 1973 to 1977. Dr. Charles L. Mulchi was the project leader for agricultural study portion of the program. A major part of the research program was devoted to the acquisition of scientific data to predict long-range effects of drift from brackish water cooling towers on vegetation in a southern Maryland agricultural area. Monitoring was used to assess the validity of such predictions.

6. Q. Please briefly describe the scope and results of this study.

A. The Chalk Point power plant is located approximately 65 km (40 miles) southeast of Washington, D.C., at the confluence of the Patuxent River and Swanson Creek in the southeast corner of Prince Georges County, Maryland. The Potomac Electric Power Company (PEPCO) maintains and operates the Chalk Point Station. Units 1 and 2 are coal-fired, rated at 330 MW(e) net, and use once-through cooling. Two crossflow, natural draft, hyperbolic cooling towers

provide closed-cycle cooling for units 3 and 4, each rated at 630 MW(e) net.

The botanical research was divided into three areas:

(1) To generate pre-operational and post-operational data on levels of sodium and chloride in foliage of native tree species;

(2) To maintain and monitor selected tree species in field plot test areas near Chalk Point; and

(3) To utilize cooling tower basin water to simulate drift and determine its effect on foliage under field conditions.

Symptoms of salt toxicity were never observed at any of the native and agricultural sampling sites in the vicinity of Chalk Point.

In simulated drift studies where saline drift was applied to various tree species, toxicity was noted only on flowering dogwood (*Cornus florida L.*), which is considered to be a salt sensitive species. Similar injury was not observed on Virginia pine (*Pinus virginiana Mill.*), tulip tree (*Liriodendron tulipifera L.*), privet (*Ligustrum ovalifolium L. Hassk.*), Norway spruce (*Picea abies L. Karst.*) and white ash (*Fraxinus americana L.*). Conclusions

drawn from these multi-year studies were that, generally, cooling tower drift effects would be negligible on native vegetation growing in the vicinity of Chalk Point. [See publications listed in Exhibit RB-1, Section V as items B.14, B.16, F.7, F.8, G.1, G.2, G.3, G.5, G.6, G.7, G.8 and G.10].

Substantially similar conclusions were reached from the agricultural crops included in this phase of the program. [See Mulchi, C.L., J.A. Armbruster, and D.C. Wolf. 1982. Chalk Point: A Case Study of the Impact of Brackish Water Cooling Towers on an Agricultural Environment. *J. Environ. Qual.* 11:212-220].

7. Q. Was the *Curriculum Vitae* attached to this testimony as Exhibit RB-1 prepared by you and does it accurately present your biographical data and professional experience?

A. Yes, I prepared Exhibit RB-1, and it is true and correct.

8. Q. Dr. McCune, would you please state your full name and address.

A. My name is Delbert C. McCune and my address is Boyce Thompson Institute at Cornell University, Tower Road, Ithaca, New York 14853.

9. Q. By whom are you employed and in what capacity?

A. I am employed as a Plant Physiologist at Boyce Thompson Institute for Plant Research at Cornell University (BTI).

10. Q. Please describe your previous employment.

A. I have been a member of the Environmental Biology Program at BTI since 1960. During this period my research has comprised the development of certain techniques in air and environmental monitoring, investigations into the effects and mode of action of air pollutants on vegetation, and the problems of formulating air quality criteria and standards for certain air pollutants. Since 1973, my research has included the effects of saline drift on plants and the interaction of aerosols with plants.

11. Q. Would you please expand on your work and experience with respect to saline drift effects.

A During the periods of 1973 to 1974 and 1976 to 1978, I was the project leader and principal investigator of two projects on the potential effects of

saline cooling tower drift on vegetation, which were funded by Consolidated Edison of New York and the Empire State Electric Energy Research Corporation, respectively. Our goals were to determine: (i) the susceptibilities of different species of plants to drift from cooling towers using brackish water; (ii) to what degree changes in the conditions of environment or exposure could affect the phytotoxicity of saline drift. Several factors were found to influence the response of plants to saline drift: (1) botanical factors, such as species and developmental stage of the foliage; (2) exposure factors of total deposition, dose-rate, and salinity and size of particles; (3) environmental factors of relative humidity during and after exposure and rainfall after exposure. Because of the substantial effect of both these environmental factors, we recommended they be included in predictions of environmental impacts for the cooling tower proposed for the Indian Point Nuclear Generating Station.

I have also been project leader on other projects that were undertaken to determine the effects of (i) the solubility of particles, (ii) relative humidity, and (iii) mist prior to exposure on the

phytotoxicity of fluoride-containing particles and to determine the kinetics of removal of particles from foliage by precipitation.

12. Q. Was the *Curriculum Vitae* attached to this testimony as Exhibit RB-2 prepared by you and does it accurately present your biographical data and professional experience?

A. Yes, I prepared Exhibit RB-2, and it is true and correct.

Function of Review Board

13. Q. Who organized the Review Board and selected its members?

A. Snell & Wilmer organized the Review Board to collegially advise and assist in the formulation and conduct of a program to assess the potential effects of the foliar depositions of drift from cooling towers on agricultural crops grown in the vicinity of the Palo Verde plant. The members of the Board were individually selected and engaged by Snell & Wilmer in February, 1983. Dr. Curtis was designated as board chairman to coordinate meetings and field visits and other activities of the Board.

14. Q. Were there any other members of the Review Board in addition to those who are sponsoring this testimony?

A. Yes. Dr. Leon Bernstein, a past Director of the Salinity Laboratory at the University of California at Riverside, was selected at the outset by Snell & Wilmer to serve as a member, because of his preeminence achieved over many years in the field of saline research and studies. During the early stages of the program Dr. Bernstein actively participated in several of the Board's meetings with the University of Arizona (U of A) in Phoenix and Tucson and once in the Los Angeles area arranged for his convenience. During his period he participated in the decisions made respecting the nature and scope of the drift studies undertaken by the U of A and visited the facilities utilized by the U of A in implementing the program. Unfortunately, Dr. Bernstein was unable for personal and health reasons to actively participate in all the Board's activities during the later stages of the program.

15. Q. Would you explain the functions of the Review Board?

A. The initial mission of the Board was to provide advice and consultation to Snell & Wilmer on a

technically sound research program to evaluate the impacts of saline drift on agricultural productivity. Snell & Wilmer selected the U of A to conduct the program because of its expertise in agriculture in the arid southwest. The Board's function was to provide the expertise of its members in the development and conduct of saline drift research programs to assure that the U of A program would be technically sound and expeditiously completed.

Subsequently, the Board provided oversight of the U of A's implementation of the program and technical advice and consultation to the U of A project team. The Board also kept Snell & Wilmer informed as to the progress and results of the program.

16. Q. How did the Board perform these functions?

A. The Board functioned principally through an extensive series of conferences and site visits. Exhibit RB-3 provides a tabulation of such meetings and a brief description of the purposes of each of them and significant results or actions taken.

In addition to these meetings, the Board held numerous telephone conferences and engaged in correspondence with the U of A project team. Also, to

expedite the initiation of the project the Board made arrangements to make Mr. Terry L. Lauver available to the U of A. Mr. Lauver, who is now employed by Boyce Thompson Institute on studies of plant-particle interactions and who was formerly a member of the Chalk Point Cooling Tower Project, served as a consultant to the U of A in the development of systems for particle sizing and monitoring, nozzle technology, and particle generation systems. Also, Mr. Lauver made arrangements for the loan to the U of A of certain nozzle systems and pressure-tanks until the U of A obtained its own equipment.

17. Q. How did the Review Board assist in the development of the U of A program?

A. The study program was first formulated by the Office of Arid Land Studies (OALS) of the U of A College of Agriculture through the submission of a proposal to Snell & Wilmer. The first proposal draft was submitted in February, 1983, after an initial meeting at the Snell & Wilmer offices in Phoenix between members of Snell & Wilmer, the Board and representatives of the U of A College of Agriculture. OALS was ultimately designated by the U of A to take responsibility for the conduct of

the program with scientists and other personnel released from the Department of Plant Sciences, College of Agriculture.

Essentially, the Board provided guidance to OALS and Snell & Wilmer in defining the scope, rationale and objectives of the U of A proposal. The Board participated in deliberations respecting the crops to be included in the program, the means to be used in simulating drift depositions, the establishment of the original application levels of drift, *i.e.*, controls and nominal 10, 100 and 500 lbs/a-yr,[1] the need for dedicated and redundant facilities and equipment and the other elements incorporated in the U of A proposal. We also advised both the U of A and Snell & Wilmer respecting the need for appropriate financial support necessary to accomplish the project in the required time.

18. Q. What was the nature of the guidance and oversight provided by the Review Board in the implementation phase of the U of A Study?

A. The Board provided specific guidance to OALS with respect to the methods to be employed in generat-

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1 The notation "a-yr" used throughout this testimony signifies "acre-year". Thus, "10 lbs/a-yr." means "10 pounds per acre per year.

ing, applying and monitoring the simulated saline drift. For example, we provided advice as to the nozzles required to produce the desired aerosols and droplet sizes. We also provided guidance as to the data to be collected and plant responses to be measured or observed. We participated in the deliberations respecting the design of the study and the experimental protocols consonant with conditions and agricultural practices in Arizona. In general, the Board and OALS identified the problems and issues which had been addressed in their respective fields of expertise and then collectively agreed upon the appropriate protocols to be adopted. Thus, for example, recognizing that it was not practical for OALS to conduct the field study in the vicinity of the Palo Verde Station, OALS made arrangements for use of a convenient agricultural site near Marana, Arizona, for the field study. The Board then advised OALS as to the environmental monitoring which should be accomplished at the Marana site and in the agricultural area near Palo Verde. The purpose of such monitoring was to obtain correlative data useful in assessing the applicability of the results obtained from the Marana field site to agriculture in the Palo Verde area.

As the Board's oversight continued throughout the implementation phase of the study, we participated in decisions to adjust or modify various elements of the study. Two notable examples of such revisions are:

(1) An additional level of treatment, an effective rate of 740 lbs/a-yr[2] was added to the experimental design where practicable, *i.e.*, to alfalfa in the field where additional plots could be sited in an existing stand and to greenhouse experiments where a second (the south) greenhouse was available to accommodate an expanded design. These experimental units were added when the previously planned highest level of treatment was without apparent effect as judged by phenologic measurements.

(2) A sequential sampling approach to tissue analyses, *e.g.*, first analyze controls and high-

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2 As stated in the U of A Report, analyses of the drift simulant applied to the plants showed that treatment at nominal rates of 10 lbs, 100 lbs, 500 lbs, and 1,000 lbs/a-year to be equivalent to the treatment at effective rates of 7.4 lbs, 74 lbs, 370 lbs and 740 lbs/a-year, respectively. To avoid confusion and be consistent with the analysed data, all references to

CONTINUED ON FOLLOWING PAGE

est rate of treatment with the archiving of the other samples for analyses if the presence of effects warranted them. This decision was made to achieve timely results given the constraints that developed in the availability of analytical facilities.

19. Q. What was accomplished during the several visits the Review Board made to the study facilities?

A. In March, May, July and October of 1983, members of the Board visited the experimental sites and facilities. In these visits, the Board was able to observe: (1) the construction of the facilities and equipment; (2) the methods used to apply and monitor the treatments, in which we agreed with OALS that normal agronomic practices of the grower should be used for cultivation, irrigation and pesticide application; (3) the condition of the experimental plants in greenhouse and field, which included inspection of the experimental plants for symptoms induced by salt and other agents; (4) methods used to harvest in the greenhouse experi-

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rates or levels of treatment with drift simulant in this testimony are in terms of <u>effective</u> treatment unless otherwise expressly indicated.

ments and evaluate the response of plants to treatment as well as the condition of plants in field plots as affected by rain, low temperatures early in the growing season and other unique ambient factors.

An important part of the Board's site inspections were our visits to Palo Verde, including ground and aerial observations of the plant site and the vegetation and terrain around the Station and inspection of a cooling tower during tours of several plant facilities.

20. Q. What were the purposes of the visits and meetings subsequent to October, 1983?

A. During conferences in December, 1983, January, 1984, and April, 1984, the Board and OALS discussed their concerns in three areas: (i) the schedule for the report's preparation and delivery; (ii) the format and content of the report; and (iii) the representation of the data and statistical models for its analysis. OALS and the Board mutually sought the best means for obtaining a timely, clear, and correct presentation of the results of the project. Subsequently, the Board was furnished drafts of the report by OALS and by telephone,

correspondence and in conferences with OALS in April and July, 1984, conveyed critiques of the drafts. Essentially, the Board, through its comments and suggested revisions, functioned as an editorial body and as a scientific referee. As to the former, we recommended changes in style or organization of the report. As to the latter, we were concerned with establishing the accuracy and validity of the scientific matter. Concurrence between the panel and OALS was usually obtained as to style and substance, but when it was not, the panel's concern was that the conclusion of OALS be stated as clearly as possible. It should be made clear that the conclusions stated in the report are those of OALS.

21. Q. Is the document entitled "An Assessment of Salt Drift on the Productivity of Agricultural Crops in the Vicinity of the Palo Verde Nuclear Generating Station," *University of Arizona College of Agriculture*, August, 1984 and marked as Exhibit RB-4 a copy of the final report of the U of A Study?

A. Yes, it is, and references in this testimony to the "Report" mean the document marked as Exhibit RB-4.

22. Q. Why did the U of A program include both greenhouse and field studies?

A. Estimations of the effects of air pollutants, ambient or artificially added, on crop yields and predictions of the risks of these effects cannot be derived from any single kind of study. Field experiments can provide a sample of responses that might be expected under the ambient conditions found to occur. Such conditions, of course, change from year to year and are rarely precisely duplicated in nature. Greenhouse studies on the effects of certain factors and modes of action ca. provide ancillary data to broaden the range of inference and aid in the interpretation of field data.

23. Q. The U of A Report in several instances uses the term "significant difference." Please explain the meaning of this term.

A. "Significant difference" is a term used in statistical analyses. The most common tasks of statistics are to estimate the value of some parameter and to test the validity of some assertion. An example of the former is to estimate the means of two samples of plants-treated and untreated. The latter would be to infer as to likelihood that the two samples came from the same population, *i.e.*,

that treatment had no effect. In making such an inference, there are risks of making two kinds of errors, frequently referred to as Type I and Type II. The Type I error is to assert that there is a difference when in reality there is not. The Type II error is to assert there is no difference when a true difference is present. It is customary in biological research to declare a difference (*e.g.* effect of treatment) as significant when there is a 5 percent probability of the difference being due to chance alone (or of making the Type I error.) However, other levels of significance can be used, and data in the Data Summary Volume can be applied to this purpose. Generally, however, a decrease in the risk of the Type I error increases the risk of the Type II error in a given test, or vice versa (*i.e.*, the two types of errors are inversely related).

Conclusions of the Review Board

24. Q. You have stated that the conclusions found in the U of A Report are the conclusions of the Office of Arid Land Studies. Has the Review Board arrived at any conclusions respecting the potential impacts of cooling tower drift from Palo Verde on agricultural productivity. If so, would you please state such

conclusions and explain the bases on which you have arrived at them.

A. Yes, we have reached several conclusions respecting the effects of saline drift on agricultural productivity as further explained below for each crop included in the study. The bases for such conclusions are (i) our general experience and knowledge in the botanical and agricultural sciences, (ii) our research in connection with other saline drift studies, (iii) our review of the data collected and reported in the U of A Report, and (iv) our participation in and familiarity with all stages of the U of A study, together with our knowledge of the U of A scientists and other personnel who conducted the study, which have given us great familiarity with the data collected and the reported results.

In general terms, we would not expect any adverse effects from depositions of saline drift from the Palo Verde towers on the productivity of crops included in the U of A study. In arriving at this conclusion we have given credence to the testimony of Mr. Karl Wilber and Dr. Morton I. Goldman, but our conclusion would not be changed even if their collective description of drift and deposition rates were in error by an order of magnitude.

In this connection, it should be noted that in constructing the experimental treatments, consideration was given to "bracketing" the anticipated biological response to saline drift based on our prior experience. Thus, it was felt that treatment at a high level of 370 lbs/a-yr (nominal 500 lbs/a-yr) would be sufficient to demonstrate an effect. Similarly, it was expected that a level corresponding to a mid-range of 74 lbs/a-yr (nominal 100 lbs/a-yr) could result in a "moderate" injury due to saline drift. However, as shown by the yield data, no significant effects were demonstrated at any dose-rate under these conditions.

<u>Cantaloupe</u>

25. Q. What conclusions have you reached from the U of A data regarding the effect of saline drift on yields of cantaloupe?

A. The data demonstrate that there was no effect of salt drift on yield or reproductive development of cantaloupe at effective treatment rates up to 370 lbs/a-yr, the maximum rate applied to cantaloupe. Also, such treatment did not produce any measured physiological responses. It is also apparent that the effective rates of treatment were below those that would induce foliar lesions. The use of leaf

washes and measures of eluted salt do not furnish a measure of exposure below an effective treatment rate of 370 lbs/a-yr.

Barley

26. Q. What conclusions have you reached from the U of A data regarding the effect of saline drift on yields of barley?

A. No adverse effect of treatment at effective rates of 370 and 740 lbs/a-yr was evident on yield, or on components of yield or on vegetative growth (biomass) and development. The results also indicate that the dose-response relationship may not be monotonic as 370 lbs/a-yr increased seed set and 740 lbs/a-yr had no effect.

27. Q. What do you mean when you say that the dose-response relationship may not be monotonic?

A. A monotonic relationship is one where an effect produced by one dose is greater than an effect produced by a lower dose. Where the dose-response relationship is not monotonic, one cannot conclude that increasing doses will increase effects.

28. Q. What other conclusions have you drawn from the U of A data on barley?

A. Neither effective rate (*i.e.*, 370 or 740 lbs/a-yr, of treatment affected the physiological function of leaves.

Treatment by simulated saline drift did increase the incidence of certain foliar lesions, i.e., marginal necrosis, spot chlorosis, and general chlorosis; increased incidence of necrotic lesions occurred at an effective rate of 740 lbs/a-yr and increased incidence of chlorosis at 370 lbs/a-yr. An increased incidence of these foliar lesions was not associated with adverse effects on growth and yield.

Quantities of salts resident on foliar surfaces were not associated with effective treatment levels below 370 lbs/a-yr. At or above this level (740 lbs/a-yr), treatment resulted in an increased amount of resident salts. An effective rate of treatment of 370 lbs/a-yr significantly increased the level of sodium in foliar tissue but had no significant effect on levels of chloride.

Alfalfa

29. Q. What conclusions have you reached from the U of A data regarding the effect of saline drift on yields of alfalfa?

A. There was not a significant effect of treatment with simulated saline drift, up to an effective rate of 740 lbs/a-yr, on the yield of alfalfa in the field or greenhouse. Nor were any statistically significant changes in measures of physiological responses observed in the field or greenhouse.

Cotton

30. Q. What conclusions have you reached from the U of A data regarding the effects of saline drift on cotton?

A. The yield and other responses of cotton to saline drift appear to be more complex than with other crops. Looking first at the greenhouse study, the statistics in the U of A Report do not demonstrate any clearly marked threshold level at which the application of saline drift at rates up to 370 lbs/a-yr affected yields. Table 18 of the Report (page 97) provides the following data on yields:

Effective Treatment Levels (lbs/a-yr)	Yield	
	Seed Cotton (g/plant)	Lint (g/plant)
0.0	63.90	24.92
7.4	83.31	32.49
74.0	81.56	30.81
370.0	88.94	34.69

However, there was some indication that such a threshold might become apparent with applications at rates of 740.0 lbs/a-yr and above (see pages 105-107 of U of A Report).

31. Q. What is your analysis of the U of A data collected from the field study?

A. The results obtained from the field study appear to be more complex. The increased complexity resulted in major measure from the introduction in the study of two practices which are impractical for commercial agriculture: *i.e.*, (i) the application of sprayed water; and (ii) the hand-harvesting of bolls as they matured durng the season. This observation is not intended as a criticism of the field study, since the use of non-commercial, experimental practices may lead to an improved understanding of plant processes and responses to varied factors.

Nonetheless, if one looks only at the field data which is applicable to commercial agriculture

(i.e., machine harvesting at the end of the growing season and excluding daily treatment with "distilled" water), then the only conclusion which may be drawn from the field data is that the application of sprayed simulant drift at rates up to 370 lbs/a-yr had no significant effect on yields. This is demonstrated from the following data extracted from Table 26 of the U of A Report at page 124.

Effective Treatment Levels (lbs/a-yr)	Yield	
	Seed Cotton (lbs/a)	Lint (Bales/a)
No Treatment	2,269.6	1.62
7.4	2,316.2	1.66
74.0	2,238.8	1.60
370.0	2,124.4	1.52

None of the differences in this yield data are statistically significant.

32. Q. Do you have any comments respecting the water spray treatment in addition to its non-commercial characteristics?

Yes. Irrespective of the commercial practicability of spraying cotton plants with water on a daily basis, we consider this treatment to have been a proper component of the experimental design, as were measurements of depositions in plots receiving this treatment and the continual chemical analyses of the water itself.

The results of these measurements, as reported in Tables 9, 10, 13 and 14 of the U of A Report make it clear that the treatment characterized as "0 (control with sprayed distilled water"[3] contained measurable total dissolved solids (TDS). Moreover, it is evident from an examination of Section C the Data Summary Volume (pp. C-15 to C-20 and C-116, [C-107 to C-109]) of the Report that the TDS consisted of a variety of minerals, several of which are classically nutrients for plant growth, such as calcium, magnesium, nitrate, potassium and sulfate.[4]

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3 The use of phrase "distilled water" throughout the Report is inconsistent with Procedure C-25 (Revision 2) of the Project Study Plan which provides for the use of "demineralized water." For the reasons explained in the text of this testimony, we consider the term "demineralized water" to be the more accurate characterization and have adopted such term in lieu of "distilled water."

4 It should be noted in this connection that the data in Tables 13 and 14 of the Report (pp. 66 and 68) are subject to correction. Under the Effective Treatment Level column of Table 13 the ratios should be 1.51, 1.43, 1.38 and 1.22 rather than 2.34, 1.51, 1.40 and 1.23, respectively. This is because the 6.1 lbs/a-yr value at "0" treatment level was not subtracted from each succeeding value in computing the ratio. Thus, at 7.4 lbs/a-yr the ratio should be calculated as $\frac{17.3 \text{ minus } 6.1}{7.4} = 1.51$. Similar recalculations are needed for Table 14. The corrections are offered to achieve accuracy in the representation of the data, and in our view do not reflect upon the validity of the Report or its conclusions.

Because of the concentrations of ions found in the water, which are substantially greater than what is found in precipitation in Arizona [see National Atmospheric Deposition Data Reports -- Precipitation Chemistry attached as Exhibit RB-5], we conclude that the spray with such demineralized water should be characterized as a "treatment," not as a control nor as "0 effective treatment."

Additionally, the use of the term "distilled water" in the U of A Report should not be taken to mean that the sprayed water used in such treatments was free of nutrients or contaminants.

Nevertheless, if the machine-harvested yield data for demineralized water spray treatment (*i.e.*, 2,594.4 lbs/a for seed cotton and 1.86 bales/a for lint) is included in the comparison, the differences are still not statistically different from the untreated plots. Neither the treatment with demineralized water containing trace nutrients nor the treatments with drift simulant at the rates of 7.4, 74.0 or 370.0 lbs/a-yr produced a significant effect on yield in comparison with the "no treatment" controls.

33. Q. What is your evaluation of the yield data reported for hand-harvested cotton?

A. The comments we have just made respecting the demineralized water treatment of machine-harvested cotton also apply to the yield data reported for hand-harvested cotton. If the treatment with demineralized water is excluded from the comparisons of yield data for hand-harvested cotton, the conclusion is that there is no statistical difference in yield between the control (no treatment) plants and those receiving treatment with drift simulant at rates of either 7.4 lbs/a-yr or 74 lbs/a-yr. This is demonstrated by application of the Least Significant Difference (LSD) test to the following yield data taken from Table 26 of the Report (p. 124):

Effective Treatment Level (lbs/a-year)	Yield Seed Cotton (lbs/a)
No treatment	2,527.2
7.4	2,356.5
74.0	2,237.4
370.0	1,905.2

34. Q. Do you have any comments respecting the statement at page 2 of the Report that there was a trend in the sprayed plot of hand-harvested field-grown cot-

ton toward reduced yields with increasing treatment levels.

A. In our view the data does not support the conclusion of a uniform trend of reduced yields with increasing treatment. Although the highest dose did reduce yield, there are insufficient data points to show where the reduction starts to occur.

If the differences in yield data for all treatments, including the no treatment controls, are analyzed as a comparison of treatments, it is apparent that the response (*i.e.* yield) at the greatest level of treatment (*i.e.* 370 lbs/a-yr) in contrast to the responses at all other levels of treatment (where the differences in responses are not statistically significant) accounts for almost as much variation in response as would a linear trend. This raises the question, given the distribution of the dose variate used, as to whether a uniform trend should be inferred because of the weight given to the response at the greatest level of treatment. In other words, in the absence of additional data respecting the effect of intermediate doses between 7.4 and 370.0 lbs/a-yr, we are reluctant to draw any conclusions respecting uniform trends.

Also we are not prepared to accept the premise that the response (*i.e.* yield) of cotton to treatment with drift simulant is monotonic over the entire range of doses. We consider the premise that there is a zero threshold for effect versus dose to be suspect with respect to cotton for several reasons:

1. The data from the greenhouse study showing an increase in yield at all levels of treatment with drift simulant contradict the zero threshold premise. The potential for a threshold effect was not evidenced until drift simulant was applied at rates of 370.0 lbs/a-yr or more.

2. The yield data for machine-harvested field-grown cotton show an increase in yield (not statistically significant) with treatment with drift simulant at rates of 7.4 bs/a-yr and virtually no difference in yield between the controls (no treatment) and treatment at rates of 74.0 lbs/a-yr. On basis of this data alone, it seems that a threshold effect is not reached until treatment with drift simulant exceeds 74.0 lbs/a-yr.

3. A non-monotonic dose-effect relationship which would be expected of a salt tolerant species

such as cotton is corroborated by the Chalk Point 3-year field studies which demonstrated with respect to tree species a critical threshold of leaf chloride accumulation before effects were observable. [See publications listed in Exhibit RB-1, Section V as items B.16 and F.8, pp 9 and 11.]

Finally, we should make the comment that conclusions based on the inference of a uniform trend among data points that are not statistically different are questionable.

In summation, we do not consider that the data in the Report is sufficient to support a finding of a uniform linear trend. Nor are we prepared to conclude that a threshold effect on yield would be observable with treatments of drift simulant at rates less than 74.0 lbs/a-yr without additional data from treatments at intermediate dose levels between 7.4 and 74.0 lbs/a-yr.

COMPARISONS OF THE MARANA AND PALO VERDE AREAS

35. Q. Do you consider that the results of the field study at the Marana site are relevant to agriculture in the vicinity of the Palo Verde Station?

A. Yes, the U of A field study at Marana is relevant

to agriculture in the vicinity of Palo Verde. Both areas are situated in the same arid region. Cotton and alfalfa included in the Marana field study are the major crops grown in the vicinity of Palo Verde. The cotton and alfalfa were grown at the Marana site using common commercial agricultural practices. These facts, coupled with analyses of the monitoring data obtained for both areas, give us confidence that the information gained from the field study at Marana would not be significantly different from that produced by a comparable study in the Palo Verde area. Of course, the monitoring program for the two areas was designed intentionally to permit an assessment of the differences in the principal climatic factors which could affect plant responses to saline drift.

36. Q. What are the principal climatic factors that could affect plant responses to saline drift?

A. The three climatic factors most important to plant responses to saline drift are: relative humidity; temperature; and rainfall. Each of these factors was monitored at Marana and Palo Verde.

37. Q. What differences were observed with respect to temperatures, and would you expect such differences to have effect on plant responses to saline drift?

A. Temperatures were generally higher at the Palo Verde site than at the Marana site. Inasmuch as the deliquescence point of sodium chloride is relatively insensitive to temperature (at the ranges found), the differences in temperature between the two sites probably would have no physical effect on saline particles that would alter their absorption or retention by the foliage and their potential phytotoxicity to the plants.

38. Q. Why do you consider rainfall to be a significant climatic factor?

A. Rainfall can affect the phytotoxicity of foliar salt deposits by solubilizing, rinsing and eluting or leaching salt from leaves. Which of these processes predominates and determines the response of the plant depends on the amount of precipitation and duration of contact. If precipitation is only sufficient to wet the surface of the leaf, the uptake of surface salts may be increased, but resident salts are removed as precipitation continues and water falls from the foliage. With continued precipitation, salts may be leached from the

foliage. In our experience, the rate of removal of surface salts is initially rapid and then slowly decreases with increasing duration of precipitation; the preponderance of surface deposits are removed by about 0.5 cm of rainfall at an intensity of about 1 cm per hour. Experimental evidence also indicates that the effectiveness of rainfall in removing deposits decreases as the time between exposure to particles and the application of rain increases. In other words as the span between rainfall events increases, the rainfall effects decrease.

39. Q. Please give us your observations of the differences in the rainfall and your opinion respecting the significance of such differences.

A. The total rainfall at Marana was greater than at the monitored Palo Verde site. However, from a standpoint of effects of rainfall on plant responses, our evaluation is that the two sites were more similar than the disparity in total rainfall might otherwise indicate. We arrived at this judgment, which is admittedly qualitative, on the basis of two observations apparent from the rainfall data. Firstly, from May until late September the data show that the frequency of rainfall events, the

spans between them and the amount of rainfall were approximately the same for both sites. Thus, for most of the growing season, the influence of rainfall at both sites would be expected to be approximately equivalent. Secondly, from late September to the end of the study, Marana experienced substantially heavier rainfalls than the Palo Verde site. However, the amount of rainfall at the Palo Verde site during this period probably was sufficient to produce approximately the same magnitude of effects (*i.e.*, solubilizing, rinsing, and eluting or leaching) as the heavier rainfalls at Marana.

To the extent that rainfall at Marana may have resulted in reducing the effect of simulant drift depositions, a counter-balancing effect is found in the higher relative humidity found at Marana.

40. Q. Would you please explain the counter-balancing effect of higher humidity found at Marana?

A. Relative humidities above 75% (the deliquescence point of sodium chloride) would hydrate salt deposits on the leaf and thereby increase the absorption of surficial salt by the foliar tissue. A comparison of the relative humidities monitored in cotton

fields at the two sites (Marana and Palo Verde) shows higher incidences of relative humidity above the 75% at the Marana site. The higher incidences of relative humidity above 75% would make salt-induced injury more likely there than at the Palo Verde site.

In connection with the significance of relative humidity, it is important to note that the humidity which is relevant is that in the microclimate to which plants are exposed. This means that humidity measurements must be taken among the plants in a growing field where humidity levels due to irrigation and the plants themselves are considerably different from levels measured some distance away.

41. Q. Were the humidity measurements made at Marana and Palo Verde sites performed at the proper locations?

A. Yes. At both places the relative humidity measurements were made at locations in the plant canopy which would show the humidity levels to which the cotton plants were exposed.

CONCLUSION

42. Q. Please give us any concluding remarks you wish to make?

A. In our opinion the U of A Study is an important piece of documented scientific research which has added significant data for evaluating the effects of saline drift depositions on crops in an arid environment. To our knowledge this is the only comprehensive study of its type for arid agro-ecosystems. We concur in the conclusions expressed except for the characterization of the "0" treatment as constituting a "control" and the conclusions that were drawn as a result of the characterization. We wish strongly to emphasize that our comments in these areas are matters of data interpretation of a well-documented, unique scientific study.

~~Exhibit 15~~

EXHIBIT RB-1

CURRICULUM VITAE OF DR. CHARLES R. CURTIS

Name: Charles R. Curtis

Rank: Professor of Plant Pathology and Chairperson, Department of Plant Pathology

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I. Personal Data:

A. Date of Birth: October 6, 1938

B. Place of Birth: Ault, Colorado

C. Marital Status: Married Louise Johnson Willett of Wimberly, Texas; two children, Willy 14, Robert 16.

II. Education:

Degree	Year	Institution	Major	Minor
B.S.	1961	Colorado State University	Physical Sciences	Physics-Chemistry
M.S.	1963	Colorado State University	Botanical Sciences*	Pathology
Ph.D.	1965	Colorado State University	Plant Pathology**	Biochemistry

*Master's Thesis: Effects of light on Hypomyces (Fusarium) solani f. sp. cucurbitae.

**Ph.D. Dissertation: Gravitational effects on plant disease.

III. Experience in Higher Education:

A. University Experience:

1. Assistant Professor of Plant Pathology, Botany Department University of Maryland, June 1967-July 1972.

2. Associate Professor of Plant Pathology, Botany Department University of Maryland, July 1972-July 1977.

3. Visiting Professor (Sabbatic) Department of Botany and Cell Research Institute, University of Texas, Austin, January 1975-June 1975. Studies histone chemistry in laboratory of Dr. David Block.

4. Professor of Plant Pathology, Botany Department, University of Maryland, July 1977-January 1978.

5. Professor of Plant Pathology and Chairperson, Department of Plant Science, College of Agriculture, University of Delaware, Newark, January 1978-June 1984.

6. Special Assistant to the President and to the Provost as University of Delaware Title XII Representative for international programs, November 1980-June 1984.

7. Professor and Chairperson, Department of Plant Pathology, The Ohio State University, Columbus, May 1984-present.

B. Undergraduate and Graduate Experience at Colorado State University:

1. Undergraduate laboratory assistant, Department of Botany and Plant Pathology, 1958-1961.

2. Completed teaching certificate requirements for secondary science education, Colorado State University, 1961.

3. National Science Foundation Grantee, Colorado State University, 1961-1963. Master's degree program.

4. NASA-Pre-Doctoral Research Fellow, Colorado State University, 1963-1965. Ph.D. degree program.

5. Acknowledged research performed as a graduate student:

   (a) Salisbury, F.B. 1963. Biological timing and hormone synthesis in flowering of xanthium. Planta 59: 518-534.

   (b) Salisbury, F.B. 1963. The flowering process. International series of monographs on pure and applied biology. Division: Plant Physiology, Vol. 4. Pergamon Press, Oxford, 234 p.

IV. Experience Other Than Higher Education:

A. Military Service Schools:

1. Infantry Officer Basic Course, Completed at Fort Benning, Georgia, August 1965-October 1965.

2. Army Security Agency, Officer Familiarization Course, Completed at Fort Devens, Massachusetts, October 1965-December 1965.

B. National Aeronautics and Space Administration (NASA) assignment to NASA Ames Research Center, Exobiology Division, Life Detection Branch, Moffett Field, California, 1966-1967 as Military Detailee.

1. Performed experiments on effects of environmental extremes on microoganisms (Curtis, C. R. 1967. Nature 13: 738-739).

2. Supervised construction of a large extraterrestrial environmental simulator designed to test life-detection systems.

3. Biosatellite I, December 1966; assisted in preparations for Bios I launch and monitoring capsule temperature during orbital flight. Cape Kennedy, Florida.

4. Honorably Discharged from U.S. Army June 1967, final rank of Captain.

C. Honor Societies and Awards

1. Omicron Delta Kappa (Leadership honorary)
2. Beta Beta Beta (Biological Sciences honorary)
3. Phi Kappa Phi (Scholastic)
4. Sigma Xi (Research)
5. American Men and Women of Science, 14th ed.
6. Who's who in the East, 17th ed.
7. Who's who in America, 41st ed.
8. Who's who in the world, 5th ed.
9. NASA Cosmos Achievement Award 1981, Cooperative USA - Soviet Biosatellite Experiment

V. Publications:

A. Abstracts of Papers Presented at Professional Meetings (*Speaker):

1. Curtis*, C.R., and N. Oshima 1962. Effects of light and sporulation of Alternaria solani. J. Colo-Wyo. Acam. Sci. 5: 28.
2. Curtis, C.R., 1963. Effects of light on sexual reproduction in H. solani f. cucurbitae. Phytopathology 53: 873 (Abstr.).
3. Curtis, C.R. 1964. Effects of ultrasonics on plant and disease development. Phytopathology 54: 891 (Abstr.).
4. Curtis, C.R. 1965. Bean rust development on horizontally rotated plants with and without indole acetic acid treatment. Phytopathology 55: 1054 (Abstr.). Paper not given due to military service.
5. Curtis*, C.R., and G.A. Bean. 1968. Inhibition of perithecial pigmentation in Nectria haematococca by dimethylsulfoxide (DMSO). Phytopathology 58: 884 (Abstr.).
6. Curtis, C. R. 1969. Comparison of fruiting ability of Nectria haematococca on media con-

taining L-tyrosine, L-phenylalanine, and D-glucose + NaN03 as sole carbon and nitrogen sources. Phytopathology 59: 1555 (Abstr.).

7. Curtis, C. R. 1970. Disc electrophoresis of proteins from bean leaves infected with Agrobacterium tumefaciens. Phytopathology 60: 1014 (Abstr.).

8. Barnett*, N.M., and C.R. Curtis. 1970. Release of peroxidase and hydrolytic enzymes. Plant Physiol. 46:14 (Supplement).

9. Barnett*, N.M., and C.R. Curtis. 1971. Hydrolytic release of cell wall peroxidase and electrophoretic comparison with cytoplasmic peroxidase. Plant Physiol. 47: 44 (Supplement).

10. Curtis, C.. 1971. Action spectrum of the photoinduced sexual stage in the fungus Nectria haematococca Berk & Br. Plant Physiol. 47: 12 (Supplement).

11. Habeck*, H., and C.R. Curtis. 1971. Induction and photoreversal of peroxidase in leaves of Phaseolus vulgaris var. Pinto III. Phytopathology 61: 893 (Abstr.).

12. Curtis, C.R. 1972. Ozone-induced isoenzyme changes in bean leaves detected by isoelectric focusing. Phytopathology 62: 752 (Abstr.).

13. Curtis*, C.R., and R.K. Howell. 1973. Peroxidase response of Wye and York soybeans to ozone. Second International Congress of Plant Pathology, Abstract number 0577, University of Minnesota, St. Paul.

14. Burnett*, C., and C.R. Curtis. 1973. Isoenzymes of pinto bean leaves infected with Agrobacterium tumefaciens. Second International Congress of Plant Pathology, Abstract number 0101, University of Minnesota, St. Paul.

15. Schmidt*, A., and C.R. Curtis. 1974. Two-dimensional mapping of peroxidases by combined isoelectric focusing and gel-slab electrophoresis. Proc. Amer. Phytopath. Soc. 1: 154 (Abstr.).

16. Francis*, B. A., and C.R. Curtis. 1976. Simulated drift effects on vegetation. Proc. Amer. Phytopath. Soc. 3: 324-325 (Abstr.).

17. Curtis*, C.R., T.L. Lauver, B.A. Francis, A. Stansbury, and E. Mathis. 1976. Foliar salt in native species of Virginia pine, sassafras and black locust. Proc. 4th North American Forest Biology Workshop, Syracuse, N.Y., August 1976 (Abstr.).

18. Curtis*, C.R., T.L. Lauver, B.A. Francis, and L.W. Douglass, 1976. Seasonal variations in the salt load of native dogwood trees near Chalk Point, Maryland. Proc. Botanical Soc. Amer., Tulane University, May 30-June 4 (Abstr.).

19. Epstein*, L., C.R. Curtis, and M.K. Corbett. 1977. Ultrastructural changes induced in leaves of Phaseolus vulgaris 'Pinto' by foliar application of saline solutions. Proc. Amer. Phytopath. Soc. 4:215.

This paper received the Graduate Student Research Award at the 34th annual meeting of the Potomac Division, American Phytopathological Society, University of Maryland, March 16-18, 1977.

20. Curtis, C.R. 1977. The Application of Electrophoretic Techniques in the Plant Sciences. Abstract no. 445. (By invitation, Electrochemical Society, Symposium on Technology, 152nd meeting, Atlanta, Georgia October 9-14, 1977).

21. Stahly*, G.P., B.B. Jarvis and C.R. Curtis. 1977. Roridins and Verrucarins isolated from Myrothecium verrucaria. Proc. Amer. Phytopath. Soc. 4: 219.

22. Mulchi*, C.L., C.R. Curtis, and B.L. Shipley. 1977. Comparison of four remote sensing techniques for investigating potential salt drift effects on vegetation near cooling towers. Northeast Branch, American Society of Agronomy. p. 23.

23. Pleass, C.M., C.R. Curtis, W.H. Mitchell and A. Ben-Israel*. 1979. Wave-Powered and

Wind-Powered Reverse-Osmosis Desalination: A Feasibility Study. International Conference on Operations Research in Agriculture and Water Resources, Sponsored by The Operations Research Society of Israel, Jerusalem, November 26-29, 1979.

24. Curtis, C.R. 1978. Cooling towers: an environmental problem? Third International Congress of Plant Pathology, Abstracts of papers. p. 345, Munich, Germany, August 16-23, 1978.

25. Podleckis*, E.V., and C.R. Curtis. 1981. Ozone sensitivity in sweet corn (Zea mays 1.) and potential for a biochemical marker. Phytopathology 71: 770 (Abstr.).

26. Curtis*, C.R., R.B. Carroll, J.B. Helbig. 1983. Field evaluation of oxidant injury on Delaware soybeans. Phytopathology 73: 364 (Abstr.).

27. Sparks, D.C. and C.R. Curtis*. 1984. Dynamics of cation release from Delaware soils subjected to simulated acid rain. Phytopathology 74: 842. (Abstr.).

B. Scientific Articles:

1. Curtis, C.R. 1964. Physiology of sexual reproduction in Hypomyces solani f. cucurbitae. II. Effect of radiant energy on sexual reproduction. Phytopathology 54: 1141-1145.

2. Curtis, C.R. 1966. Effect of light on germination of Uromyces phaseoli uredospores. Phytopathology 56: 1316-1317.

3. Curtis, C.R., 1967. Bean rust development in relation to gravity. Phytopathology 57: 1025-1027.

4. Curtis, C.R. 1967. Response of fungi to diurnal temperature extremes, Nature 213: 738-739

5. Curtis, C.R. 1969. Photo-induced perithecial formation by Nectria haematococca on media containing either L-tyrosine; L-phenylalanine; or D-glucose + Na N03, as sole carbon and

nitrogen sources. Can. J. Microbiol. 15: 863-868.

6. Curtis, C.R. 1970. Comparison of UV-induced delay in germination in pigmented and pigment-inhibited conidia of Aspergillus carbonarius. Radiation Botany 10: 125-130.

7. Curtis, C.R. 1971. Disc electrophoretic comparisons of proteins and peroxidases from Phaseolus vulgaris leaves infected with Agrobacterium tumefaciens. Can. J. Bot. 49: 333-337

8. Curtis, C.R., and R.K. Howell. 1971. Increases in peroxidases isoenzyme activity in bean leaves exposed to low doses of zone. Phytopathology 61: 1306-1307.

9. Curtis, C.R. 1972. Action spectrum of the photoinduced sexual stage in the fungus Nectria haematococca Berk & Br. var. cucurbitae (Snyder & Hansen) Dingley. Plant Physiol 49: 235-239.

10. Curtis, C.R., and N.M. Barnett. 1974. Isoelectric focusing of peroxidases released from soybean hypocotyl cell walls by Sclerotium rolfsii culture filtrate. Can. J. Bot. 52: 2037-2040.

11. Habeck. H., and C.R. Curtis. 1974. Induction and photoreversal of bean leaf peroxidase isoenzymes by germicidal and near ultraviolet radiation. Radiation Botany 14: 243-250.

12. Curtis, C.R., R.K. Howell, and D. Kremer. 1976. Soybean peroxidase from ozone injury. Environ. Pollut. 11: 189-194.

13. Schmidt, A.L., C.R. Curtis. and G.A. Bean. 1977. Electrophoretic comparisons of aflatoxin-producing and nonproducing strains of Aspergillus flavus and Aspergillus parasiticus. Can. J. Microbiol. 23: 60-67.

14. Curtis, C.R., T.L. Lauver, and B.A. Francis. 1977. Foliar salt in native vegetation; Seasonal variations Environ. Pollut. 14: 69-80.

15. Jarvis, B., G.P. Stahly, and C. R. Curtis. 1978. Antitumor activity of fungal metabolities: verrucarin B-9, 10-epoxides. Cancer Treatment Reports: 62: 1585-1586.

16. Francis, B.A. and C.R. Curtis, 1979. Effect of simulated cooling tower drift on tree foliage. Phytopathology 69: 349-353.

17. Podleckis, E.V., C.R. Curtis and H.E. Heggestad. 1984. Peroxidase enzyme markers for ozone sensitivity in sweet corn. Phytopathology 74: 572-577

C. Laboratory Manual and Lecture Guides

1. Curtis, C.R., N.M. Barnett, and E.L. Higgins. 1976 General Botany Laboratory Manual. Kendall-Hunt Publishing Company, DuBuque, Iowa. 127; P. (6300 copies for use in undergraduate botany course, University of Maryland).

2. Curtis, C.R., and G.W. Patterson, 1980. Outlines General Botany. Revised 1978, 1980, 1983, 1984 Copyrighted, Reproductions, Inc., Rockville, Maryland. 114 p.

3. Berg. L., C.R. Curtis and E.L. Higgins. 1981. General Botany Laboratory Manual 2nd Edition. Kendall-Hunt Publishing Company, DuBuque, Iowa p. 122 (6000 copies printed).

D. Chapter in Book:

Curtis, C.R., and L. H. Weinstein. 1979. Chapter 16: Special Techniques A. Electrophoresis, P. 16-1 to 16-10. In W. W. Heck, S. V. Krupa and S.N. Linzon (eds.) Methodology for the Assess-ent of Air Pollution Effects on Vegetation. Air Pollution Control Assoc., Pittsburg PA.

E. Book Review and Careers Booklet:

1. Careers in Botany, 1978. Botanical Society of America 19 p. - prepared by a subcommittee of the Committee on Education of the Botanical Society of America (W.L. Stern, C.R. Curtis, S.A. Graham, and O. Tippo).

2. Curtis, C.R., 1980. Book Review; W.M. Laetsch. 1979. Plants: Basic Concepts in Botany. Little-Brown & Co., In Plant Science Bulletin 26:30-31.

F. Invitational Symposium Articles, Meetings and Conference Proceedings:

1. Curtis, C.R., H.G. Gauch, and R. Sik. 1973. Possible effects of salt drift on annual, perennial, and ornamental species of plants, p. 32-42. In R. L. Green (coordinator) Chalk Point Cooling Tower Study, Water Resources Research Center, University of Maryland, College Park. Preprint of First International Symposium on Cooling Tower Environment College Park, MD.

2. Curtis, C.R., H.G. Gauch, and R. Sik. 1974. Sodium and chloride concentrations in native vegetation near Chalk Point, Maryland, p. 370-378. In S. R. Hanna and J. Pell (eds.) Cooling Tower Environment - 1974. E.R.D.A. CONF-7403032 Tech. Inform. Center, Oak Ridge, Tennessee. Second International Symposium on Cooling Tower Environment, College Park, MD.

3. Curtis, C.R., T.L. Lauver, B.A. Francis, C.L. Mulchi, and L.W. Douglass. 1976. "Field Research on Vegetation Near the Chalk Point, Maryland Cooling Tower". Proceedings of the Energy Conservation Conference, Desert Research Institute, Las Vegas, Nevada, December 7-9, 1975.

4. Curtis, C.R., T.L. Lauver, B.A. Francis, C.L. Mulchi, and L. W. Douglass. 1977. Potential cooling tower drift effects on native vegetation, p. 187-199. In Proc. of the Cottrell Centennial Symposium on Air Pollution and Its Impact on Agriculture, California, California State College, Stanislaus, Turlock, California, January 13-14 1977.

5. Mulchi, C.L., D.C. Wolf, J.E. Foss., J.A. Armbruster, C.R. Curtis, and G. Israel. 1978. Potential Environmental Effects Associated with Brackish Water Cooling Towers at Chalk Point, Maryland, p. 329-346. In D.C. Adriano and I. Lehr Brisbin, Jr. Environmental Chemistry and Cycling Processes, D.O.E. Symposium

Series 45, Augusta, Georgia, April 28-May 1, 1976. CONF-760429. National Technical Information Service.

6. Curtis, C.R. 1977. The Application of Electrophoretic Techniques in the Plant Sciences. Abstract no.445. By invitation of the Electrochemical Society, Symposium on Technology, 152nd meeting, Atlanta, Georgia, October 9-14, 1977.

7. Lauver, T.L., C.R. Curtis, G.W. Patterson, and L.W. Douglass 1978. Effects of saline cooling tower drift on seasonal variations of sodium and chloride concentrations in native perennial vegetation, p. 49-63. Proceedings of a Symposium on Environmental Effects of Cooling Tower Emissions, May 2-4, 1978. PPSP-CPCTP-22, Water Resources Research Center Special Report No. 9, University of Maryland, College Park, MD.

8. Curtis, C.R., B.A. Francis, and T.L. Lauver. 1978. Dogwood as a bioindicator species for Saline drift, p. 65-77. Proceedings of a Symposium on Environmental Effect of Cooling Tower Emissions, May 2-4, 1978. PPSP-CPCTP-22, Water Resources Research Center Special Report No. 9, University of Maryland, College Park, MD.

9. Hosokawa, G., T.L. Lauver, C.R. Curtis, and G.W. Patterson. 1978. Preliminary results of the effects of saline aerosols,sulfur dioxide, or saline-acid aerosols on selected ornamental woody species, p. 131-139. Proceedings of a Symposium on Environmental Effects of Cooling Tower Emissions, May 2-4, 1978. PPSP-CPCTP-22, Water Resources Research Center Special Report No. 9, University of Maryland, College Park, MD.

10. Curtis, C. R. 1978. Cooling Towers: an environmental problem: Third International Congress of Plant Pathology, Abstracts of papers. p. 345, Munich, Germany August 16-23, 1978.

11. Curtis, C.R. 1981. Title XII at the University of Delaware and Women in Development Programs, p. 78 -80. Proc. of Women in De-

velopment Conference, May 7, 1981. University of Delaware, Newark, Title XII publication No. 1.

12. Curtis, C.R. 1983. Goals and Progress of the University of Delaware Title XII Strengthening Grant p. 11-14. In Students from Developing Countries: Their Educational Experience at University of Delaware. Title XII Publication No. 6, University of Delaware. October 7, 1983.

G. Contract Research Reports for State, Federal, and Public Utility Agencies:

1. Curtis, C.R. and T.L. Lauver. 1974. Chalk Point Cooling Tower Project: 1973 Field Research and Native Vegetation and Projected Research for 1974. Maryland Water Resources Research Center, Maryland Department of Natural Resources - Power Plant Siting Program. 49 p.

2. Curtis, C.R., T. L. Lauver,and B.A. Francis. 1975. Chalk Point Cooling Tower Project: 1974 Field Research on Native Vegetation, Semi-annual report. Maryland Water Resources Research Center. Maryland Department of Natural Resources - Power Plant Siting Program. 11 p. and appendix 1, 25p.

3. Curtis, C.R., L.R. Krusberg, T.L. Lauver, and B.A. Francis 1975. Chalk Point Cooling Tower Project: Field Research on Native Vegetation. Maryland Water Resources Research Center, Maryland Department of Natural Resources - Power Plant Siting Program. 107 p.

4. Environmental Effects of Schuylkill Oil Spill II (June 1972) 1975. Environmental Protection Agency, Office of Water Program Operations. EPA 430/9-75-019.

5. Curtis, C.R., T.L. Lauver, and B.A. Francis. 1976. Chalk Point Cooling Tower Project: Field Research on Native Vegetation. Post-operational report No. 1, Vol. 1, PPSP-CPCTP-14. Water Resources Research Center, University of Maryland. 108 p.

6. Curtis, C.R., T.L. Lauver, and B.A. Francis. 1976. Cooling Tower Effects on Native Vegeta-

tion - Preoperational Report. Vol. 1, PPSP-CPCTP-7. Water Resources Research Center, Special Report No. 2. University of Maryland. 51 p.

7. Curtis, C.R., T. L. Lauver, and B.A. Francis. 1976. Cooling Tower Effects on Native Perennial Vegetation - Preoperational Report. Appendices. Vol. 2, PPSP-CPCTP-7. Water Resources Research Center, Special Report No. 2. University of Maryland. 204 p.

8. Curtis, C.R. 1977. Chalk Point Cooling Tower Project: Field Research on Native Vegetation. PPSP-CPCTP-18. Water Resources Research Center Special Report No. 7. Water Resources Research Center, University of Maryland, College Park, 179 p.

9. Curtis, C.R. 1977. Chalk Point Cooling Tower Project: A Selected and Annotated Bibliography on Interactions Between Vegetation and Saline Aerosols, Sulfur Dioxide and Ozone. PPSP-CPCTP-21, Water Resources Research Center Special Report No. 6. Water Resources Research Center, University of Maryland, College Park, 23 p.

10. Patterson, G.W., C.R. Curtis, T.L. Lauver, and G. Hosokawa. 1978. Chalk Point Cooling Tower Project Native Vegetation Study, PPSP-CPCTP-24. Water Resources Research Center, Special Report No. 10. Water Resources Research Center, University of Maryland, College Park. 231 p.

11. Expanded Task II Report - A Pilot Study Using Remote Sensing to Detect Vegetation Stress Around a Cooling Tower. February 1978. Contract No. AT(29-24)-0365 Technical Assistance to Test the Sensitivity of Certain Aerial Photographic Techniques. Prepared for the U.S. Nuclear Regulatory Commission by INTERA Environmental Consultants, Inc., Houston, Texas. 51 p. + attachments.

12. Cotnoir, L.J. Jr., D.R. Frey, C.R. Curtis, D.L. Sparks, W.H. Mitchell, and W.C. Liebhardt. 1980. A preliminary investigation on conditions necessary for revegetation and possible reclamation of a fix flue gas desul-

furization (FGD) waste disposal site. Final report to Delmarva Power and Light Company. Delaware Agriculture Experiment Station, College of Agricultural Sciences, University of Delaware, Newark. 115 p.

13. Vegetative Studies. 1980. In Solid Waste Disposal Plan. Supplement to Amended Application for Certificate of Public Convenience and Necessity, Volume 2 Appendix D, Vienna Power Station Unit 9, Delmarva Power & Light Co., Wilmington, DE.

14. Curtis, C.R. and J.A. Duke. 1983. An Assessment of Land Biomass and Energy Potential for the Republic of Panama. 61 p. + appendix. AID contract 31-80-DG, to Instituto de Recursos Hidraulicos y Electrification (IRHE). Panama City, Panama.

H. Technical Memoranda

1. Baker, R., Hendrix, J., and Curtis, C.R. 1981. Experiment Number K 301 Long-Term effects of weightlessness on a biological system, p. 29-44. In M.R. Heinrich and K.A. Souza (eds.) Final Reports of U.S. Plant and Radiation Dosimetry Experiments flown on the Soviet Satelite Cosmos 1129. NASA Technical Memorandum No. 81288. National Aeronautics and Space Administration, Ames Research Center, Moffett Field, California, 94035.

2. Curtis, C.R., Podleckis, E.B., and Golt, C.A. 1981. Experiment Number K 301 Supplemental Report 1 - Longterm effects of weightlessness on a biological system - Isoenzyme Analysis, p. 45-56. In M. R. Heinrich and K.A. Souza (eds.) NASA Technicial Memorandum No. 81288. National Aeronautics and Space Administration, Ames Research Center, Moffett Field California, 94035.

I. Research Bulletins

1. Mulchi, C.L., C.R. Curtis, H.E. Heggestad and L.P. Moore. 1983. Air Pollution Impacts on Agriculture and Forestry. Northwest Regional Research Publication, Project NE-121 Maryland Agricultural Experiment Station, College Park, MD 35 p.

J. Miscellaneous

1. Curtis, C.R. 1976. The Biological Scene: Opinion and Comment on the Three-Hour Lecture Block. Faculty Forum Vol. 2, No. 2, p. 18-20, University of Maryland, University College, College Park, MD.

2. Curtis, C.R., 1984. Editorial. The Jersey-Delmarva Peninsula Coalition: Forty years of Professionalism. Plant Disease 68: 747.

VI. Professional Activities:

A. Memberships, Activities and Offices Held in National and Regional Societies and Organizations:

1. American Photopathological Society (National):

-Committee on Air Pollution Damage to Plants, 1971-1973

-Environmental Quality Committee, 1973-1974

-Presiding Officer, Air Pollution Damage to Plants, Session 9, Mexico City, Mexico, APS annual meeting, 1972

-Vice-Chairman, Pollution Effects Committee, 1979-1980, attend APS committee meeting, Washington, D.C., Aug. 1979

-Chairman, Pollution Effects Committee, 1980-81 - plan program for 1981 APS meeting

-Potomac Division representative to Association of Department Heads of Plant Pathology, 1978-1979

-Potomac Division representative to mid-year Council meeting, Feb. 27-29, 1980.

-International Cooperation Committee 1984-present

-Disease Physiology Committee, 1984-present

2. Potomac Division, American Phytopathological Society (Regional):

-Abstract Committee, 1971-1972

-Auditing Committee, Chairman, 1973-1974

-Nominations Co .ittee, Chairman, 1974-1975

-Program Committee, 1975-1976

-Awards Committee, 1975-1976

-Program Committee, Chairman, 1976-1977

-Program Committee, 1977-1978

-Awards Committee, Chairman, 1979-1980

-Vice-President 1979-1980

-President 1980-1981

3. Botanical Society of American (National):

-Teaching Section, Vice-Chairman and Program Officer, 1977-1978

-Teaching Section, Chairman, 1978-1979

-Education Committee, 1976-1977

-Education Committee, Chairman, 1977-1978

-Presiding Officer, Teaching Section, Teaching Methods and Techniques, AIBS/Botanical Society Meeting (13 papers) June 25-29, 1979, Stillwater, Oklahoma

-Presiding Officer, Symposium on Faculty Evaluation, Botanical Society of America, June 25-29, 1979, Stillwater, Oklahoma

4. Air Pollution Workshop (National), Steering Committee 3 year term 1977-1980, plan annual workshops in U.S.A.

5. Advisor and Member, Delaware-Maryland Plant Food Association (Regional)

6. American Society of Plant Physiologists (National), and "What's New in Plant Physiology."

7. Society of Natural History of Delaware (Regional)

8. Delaware Partners of the Americas (International) President 1981-1982

9. Delaware-Maryland Vegetable Growers Association (Regional)

10. University of Delaware Agricultural Alumni Association (Regional)

11. Chairman, Northeast Council for International Development (NECID), 1982- Nine Univeristy Council of the Northeast states.

12. Ohio Partners of the Americas, Agriculture Committee Chairman 1984-present

13. Ohio Academy of Science 1984-present

14. Council for Agricultural Science and Technology Member 1984-present

B. Professional Meetings, Symposia, and Workshops Organized:

1. "Aerosols, Acid Rain and Drift", Chairman and Organizer, 8th Air Pollution Workshop, April 26-29, 1976, Corvallis, Oregon.

2. "Teaching General Botany", Symposium Organizer, Botanical Society of America Annual Meeting, Plant Sciences Conference, June 26-30, 1978, Blacksburg, Virginia.

3. Air Pollution Effects on Vegetation, Workshop Coordinator, Sponsored by the Air Pollution Training Institute, Environmental Protection Agency, Delaware Agricultural Experiment Station, and Cooperative Extension Service, January 31, February 1 and 2, 1979, University of Delaware.

4. Newark Farm Field Day, Co-Chairman, University of Delaware, August 6, 1978.

5. Delaware-Maryland No-Tillage Conference, Co-Chairman, University of Delaware with Cooperative Extension Service, December 13, 1978.

6. Air Pollution Workshop, Co-Chairman Program Committee, Colorado State University, May 1980.

C. Miscellaneous Professional Activities:

1. In-Flight Centrifuge Conference, NASA, Ames Research Center, Moffett Field, California, January 13-14, 1969.

2. AIBS/NASA Committee. The Role of the Lunar Receiving Laboratory in Post-Apollo Biological and Biochemical Activities. Section II. Standardized Biological Test Systems for Extra-Terrestrial Material. Final Report NAS 9-9728,1970.

   Study group met at four sites for deliberations: Ames Research Center, California; Manned Space Flight Center, Houston, Texas; University of Maryland, College Park, Maryland; and Boston, Massachusetts.

3. "Effects of Hurricane Agnes on Riverbank Vegetation." Guest speaker, Washington Section, American Society of Plant Physiologists, 1973.

4. Second Ecology-Meterology Workshop panel (by invitation only): Deposition and Uptake of Airborne Material by Plants. Energy Research and Development Administration (ERDA), University of Michigan Biological Station, August 16-20, 1976, Pellston, Michigan.

5. Invited Speaker. "Workshop on Air Pollutants: Their Effects on Human Health and Welfare." University of Minnesota, October 16-20, 1976, St. Paul, Minnesota.

6. Invited Speaker. 11th Argonne National Laboratory Biology Symposium, April 19, 1978. "Documented Environmental Effects of Energy Production." Chicago, Illinois.

7. Specialty Conference Speaker. APCA TE-2 Agricultural Committee, Methodology for the Assessment of Air Pollution Effects on Vegetation - Session III Special Topics. Hosted by Upper Midwest Section, April 21, 1978. Minneapolis, Minnesota.

8. Invited Speaker, Air Pollution Workshop, South Carolina Department of Health and Environmental Control, Columbia, South Carolina, May 1979.

9. Invited Speaker. Air Pollution Workshop, University of Minnesota, St. Paul, December 1979.

D. Invited Speaker at Seminars or Conferences

-"Air pollution and vegetation." Department of Plant Biology, Cook College, Rutgers University, New Brunswick New Jersey, 1974.

-"Air pollution and vegetation." Department of Plant Pathology and Physiology, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 1974.

-"Electrophoretic methods." Department of Biology, New York City University, New York, 1974.

-"Assessment of the effect of a cooling tower on the environment." Department of Botany and Cell Research Institute, University of Texas,Austin, 1975.

-"Assessment of the effect of a cooling tower on the environment." Department of Horticulture, Texas A & M College Station, 1975.

-"Air pollution effects on vegetation." Biology Club, Southwest Texas State University, San Marcos, 1975.

-"Air pollution effects on vegetation." Department of Botany and Plant Pathology, Colorado State University, Ft. Collins, 1976.

-"The use of gel electrophoresis in Plant Science Research." Department of Plant Pathology, Pennsylvania State University, April, 1979.

-"Future of Agriculture." Twenty-second annual convention of Ohio National Association of A.S.C.S. County Office Employees, and Ohio Association of Farmer-Elected Committeemen. Columbus, November 10, 1984.

-"Future of Research in Ohio." Thirty-nineth Annual Celeryville Muck Crops School. Willard, February 1, 1985.

-"Biotechnology: Blueprint for the Future." Second Biennial OSU Legislative Conference, Columbus, January 17, 1985.

-"What are the Prospects of Biotechnology in the College of Agriculture?" New Administrative Faculty Seminar Series, Columbus, Wooster/OARDC, March 26 and 27, 1985

-"Biotechnology in Agriculture" Putnam County Ohio State University Alumni Association, April 18, 1985, Ottawa, Ohio.

VII. Courses Taught

DEPARTMENT OF PLANT SCIENCE, UNIVERSITY OF DELAWARE, SPRING 1978 to present

Course	Title	Credits	Year	Semester	Enrollment (Approx.)
PLS 101	Botany I (3 lectures and 1 laboratory per week	4	1978-82	Fall	668
PLS 101	Botany Honors (new)	4	1981-82	Fall	18
PLS	Seminar in Plant Science	1	1978	Fall	departmental

DEPARTMENT OF BOTANY, UNIVERSITY OF MARYLAND, SPRING 1973-FALL 1977

Course	Title	Credits	Year	Semester	Enrollment (totals)
BOTN 100	General Botany (2 lectures and 2 laboratories per week)	4	1973-77	Spring/Fall	1692

BOTN 399	Research Problems	3	1975	Fall	1
BOTN 422	Research in Plant Pathology	2	1973	Spring	15
BOTN 625	Physiology and Biochemistry of Pathogens	3	1973-77	Fall	47
BOTN 698B	Seminar in Pathology	1	1974-77	Spring	27
BOTN 698G	Special Problems in Pathology	3	1976-77	Spring	2
BOTN 699	Special Problems in Plant Pathology	2	1973-76	Fall/Spring	11
BOTN 799, 799D, 799G	Master's Thesis Research	1-7	1973-77	Spring/Fall	35
BOTN 899	Doctoral Dissertation Research	1	1977	Fall	1

UNIVERSITY COLLEGE, UNIVERSITY OF MARYLAND (Evening division)

Course	Title	Credits	Year	Semester	Enrollment (Approx.)
ALSC 101	Organization and Interrelationships in the Biological World (no lab)	3	1972-73	Spring/Fall	134

BIOLOGY DEPARTMENT, NORTHERN VIRGINIA COMMUNITY COLLEGE, FAIRFAX, VIRGINIA

Course	Title	Credits	Year	Semester	Enrollment (Approx.)
BIOL 101	Biology (lecture and laboratory)	3	1971-73	Spring/Fall	164

VIII. Research Grants and Awards, 1961-1982

-National Science Foundation Grantee, 1961-1963, Colorado State University.

-National Aeronautics and Space Administration Fellow, 1963 1965, Colorado State University.

-General Research Board Award, University of Maryland Graduate School, "Photobiology of sexual reproduction in Hypomyces solani" 1967. $1925.

-Co-investigator, Biomedical Sciences Award, University of Maryland Graduate School, "Physiological Effects of Dimethyl sulfoxide on Fungi", 1968 $2400.

-National Science Foundation Grant GB-8354, "Photobiology of reproduction Nectria haematococca", 1969. $11,000.

-Biomedical Sciences Award, University of Maryland Graduate School, "Occurrence & Control of Enzymes Associated with Neoplastic Growth", 1970. $1300

-Biomedical Sciences Award, University of Maryland Graduate School, "Biochemical & Physiological Changes in Plants Exposed to Polluted Air", 1971. $550

-Restricted research gifts to C.R. Curtis: Scientific research on Schuylkill riverbank vegetation affected by Hurricane Agnes. Ocean Science and Engineering, Inc., 1972. $1400

-Ocean Science and Engineering, Inc., 1973. $1160 (Sub-contracted through EPA). This research is summarized in EPA report EPA 430/0-75-019 (1975) and deals with the effects of an oilspill on the

Schuylkill riverbank vegetation after Hurricane Agnes.

-National Science Foundation Grant. "Biological and Physiological Changes in Plants Exposed to Sub-lethal Doses of Ozone", 1972-1973. $12,600.

-Biomedical Sciences Award, University of Maryland Graduate School, 1976. "Production of New and Potent Anticancer Drugs fromMicrobial and Plant Sources". B.B. Jarvis, C.E. Holmlund, and C.R. Curtis $1000.

-Biomedical Sciences Award, University of Maryland Graduate School. 1976. "Production of New and Potent Anticancer Drugs from Microbial and Plant Sources." B.B. Jarvis, C.E. Holmund, and C.R. Curtis $1000.

-Water Resources Research Center, University of Maryland, Chalk Point Cooling Tower Project: Effect of a Cooling Tower on the Environment. Funded throgh the Power Plant Siting Program, Maryland Department of Natural Resources. Project concerned acquisition of scientific data to predict longrange effects of a large cooling tower on vegetation in a southern Maryland agricultural area, C.R. Curtis project leader.

1973-1974	$ 29,005
1974-1975	39,979
1975-1976	42,900
1976-1977	43,300
1977-1978	62,600
	$216,884

-National Aeronautics and Space Administration Grant, Cooperative US/USSR Biological Satellite Program 1978, Cosmos 80 Mission, "Long-Term Effects of Weightlessness on a Biological System." R. Baker (Colorado State Univ.) J. Hendrix (Colorado State Univ.) and C.R. Curtis (Univ. Delaware). $36,000. NASA Supplement to C.R. Curtis (Univ. Delaware) $1000.

-Delmarva Power & Light Company, Wilmington, Delaware. Initiated and negotiated grant for agronomy/soils team. 1979. "A Preliminary Investigation of Conditions Necessary for Revegetation and Possible Reclamation of a Fixed Flue Gas Desulfurization

(FGD) Waste Disposal Site". L.J. Cotnoir, D.R. Frey, C.R. Curtis, D. L. Sparks $36,400.

-Project Team Member on Biomass Assessment and Agriculture, Proposal to Instituto de Recursos Hidraulicos y Electrification (IRHE), 1979, Republic of Panama, "Assistance in Developing a Master Plan for Utilizing Renewable Energy Resources of the Republic of Panama." Submitted by the Institute of Energy Conversion, University of Delaware in cooperation with the Center for Energy and Environmental Research, University of Puerto Rico. Proposal involved multidisciplinary research on energy and renewable resources for Panama. $202,967.

-UNIDEL Teaching-Equipment Grant Proposal for College Agriculture undergraduate/graduate education, 1979. Wrote text and rationale for Plant Science Department. Funded Spring 1980. $1000,000.

-Office of Water Resources & Technology (OWRT), University of Delaware, "An Assessment of acid rain on leaching of elements from Delaware soils into groundwater." D.L. Sparks and C.R. Curtis. $12,000.

-Agency for International Development (AID). Education for Rural Development, College of Agriculture, University of Panama. $297,000 (1982-1984).

IX. Cooperative Experiment Station Projects:

A. MD-K-12 State.Biochemical and Physiological Effects of Ozone on Plants. (Maryland)

B. J-102 Hatch. Photobiology of Fungal Reproduction. (Maryland)

C. Regional Research, USDA, NE-121. "Reducing the Effect of Air Pollution on Plant Productivity in the Northeast (Delaware).

-Technical Committee, Secretary, 1977-1978

-Technical Committee, Chairman, 1978-1979 Prepared annual report for NE-121, April 1979.

-DEL-654-H, State. Maintenance of Greenhouses and Clark Garden (Delaware).

X. Reviewed Manuscripts for:

-Phytopathology

-Radiation Botany

-American Journal of Botany

-Canadian Journal of Plant Science

-EPA documents

-Nuclear Safety

-Science

-Houghton-Mifflin, Canfield Press, Addison-Wesley, Little-Brown, Allan and Bacon

Reviewed Proposals for:

-Lunar Science Institute, Houston, Texas (NASA)

-Natonal Science Foundation (NSF)

-Agricultural Experiment Station (Rutgers)

-Maryland Power Plant Siting Program, through Maryland Academy of Science (MPPSP)

-Environmental Protection (EPA)

XI. Listing of Graduate Students and Graduate Advisory Committees:

A. Principal Advisor:

1. Habeck. H. 1972. Induction and photoreversal of peroxidase isoenzymes by germicidal and near UV radiation. M. Sci. Thesis. University of Maryland. 40 p.

2. Burnett, C. 1973. Survey of isoenzymes induced by infection with Agrobacterium tumefaciens in pinto bean leaves and sunflower

stems. M. Sci. Thesis. University of Maryland 104 p.

3. Schmidt, A. L. 1975. Survey of isoenzymes for numerical taxonomy of aflatoxin-producing and non-producing strains for Aspergillus flavus and Aspergillus parasiticus. M. Sci. Thesis. University of Maryland. 69 p.

4. Francis, B.A. 1977. Simulated cooling tower drift effects on vegetation. M. Sci. Thesis. University of Maryland.

5. Epstein, L. 1977. Electronmicrographic study of salt injury on bean foliage. M. Sci. Thesis. University of Maryland.

6. Hosokawa, Glen. 1977. Ph.D. Candidate, transferred to Dr. Patterson upon leaving Maryland.

7. Podleckis, E. 1982. Potential of enzymatic markers for ozone sensitivity in sweet corn (Zea mays L.) M. Sci. Thesis, University of Delaware.

Graduate Advisory Committees:

MARYLAND - Examining Committee for 11 students, 1968-1976.

DELAWARE - Examining Committee for 24 students, 1978-1982.

B. COMMITTEES (University of Delaware and OSU)

1. Departmental Committees

-Search Committee for Soils Research Technician, Chairman, 1981. (UD)

-Member of Faculty Search Committee. (UD)

-Search Committee Chairman for Molecular Virologist. (OSU 1985)

2. College of Agricultural Sciences:

-Entomology Department Chairperson, Search Committee (Chairman) 1980. (UD)

-Dean's Administrative Group. (UD and OSU)

-Project Review Committee, Delaware Agricultural Experiment Station.

-Newark Farm Field Day Committee 1978 - 1984

-Agronomy Department Chairperson, Search Com_ mittee. 1985. OSU

-Chairman, Task Force on International Biotechnology. 1984 - present. (OSU)

-Chairman, Search Committee for Director of the Ohio Agricultural Research and Development Center (OARDC) OSU. 1984-85.

3. University Committees: (Delaware)

-Ad Hoc Committee on the Education of Women, 1981-82

-Council for International Activities, 1981-1984

-Title XII Officer, 1980-1984

4. State Committee: (Delaware)

-USDA/APHIS/PPQ State Committee

XII. CIVIC

-Board of Directors member, Covered Bridge Farms Civic Association, 1978-1980.

-Secretary, Covered Bridge Farms Maintenance Corporation. 1979-1980.

-Assistant Soccer Coach, Kirkwood Soccer League, 1978.

-Block captain, Arlington Knolls Community, Upper Arlington 1985

~~Exhibit 16~~

EXHIBIT RB-2

CURRICULUM VITAE
(1 January 1985)

1. Name: Delbert C(harles) McCune

2. Present Position: Plant Physiologist
Boyce Thompson Institute for Plant Research
at Cornell University
Tower Road
Ithaca, New York 14853
Telephone: (607) 257-2030

3. Personal: Citizen of the United States
Born on 21 August 1934 at Los Angeles, California
Married, with four children.

4. Educational:

Graduated from John Marshall High School, Los Angeles, California, June 1952

Undergraduate: California Institute of Technology (1952 - 1956); B.S., June 1956. Undergraduate major was in the Biology Division.

Graduate: Yale University, New Haven, Connecticut (1956 - 1960); M.S., June 1957; Ph.D., June 1960.

Graduate training was in the Department of Botany in the speciality of plant physiology. Doctoral research was on the physiology and mode of action of plant growth regulants. Thesis title: "Effect of Gibberellin on Peroxidase Activity and Growth". Henry Dagget Hooker Scholar 1957; National Science Foundation Fellow 1957-58 and 1958-59; and, National Cancer Institute Fellow, 1959-60.

5. Teaching Experience:

1956: Teaching assistant in Marine Biology, California Institute of Technology, Pasadena, California.

1956-57: Teaching Assistant in General Biology, Yale University, New Haven, Connecticut

1965-68: Instructor in Human Anatomy and Physiology, Evening Division of Westchester Community College, Valhalla, New York.

1967-75: Yearly lectures on Air Pollution Effects on Plants, New York University, New York, New York.

6. Research Activities:

Experience:

Since 1960, a member of the Environmental Biology Program at Boyce Thompson Institute (BTI). During this period, research has comprised many aspects of the direct and indirect effects of air pollutants on plants:

(1) Development of methods of analysis for fluoride in air and in plant tissues;
(2) Effects of pollutants on the physiology and metabolism of plants;
(3) Effects of pollutants on plant-pathogen and plant-insect interactions;
(4) Joint-action of air pollutants on plants;
(5) Accumulation of fluoride by vegetation from gaseous and particulate forms;
(6) Occurrence and effects of acidic precipitation;
(7) Effects of saline particles and drift on vegetation;
(8) Kinetics of aerosol deposition and removal by rain in plants;
(9) Formulation of air quality criteria and methods for impact assessment with reference to effects of fluorides and oxides of sulfur on plants.

Past Support:

During the past three years, research projects have been partially supported by contracts with: Aluminum and phosphate industries -- Effects of air-borne fluorides on vegetation (1982-present); Electric Power Research Institute -- Effects of acidic precipitation on plants (1982-1983); Electric Power Research Institute -- Plant/Particle Interactions (1982-1983).

Present Effort:

Presently engaged in the following research projects:
Interaction of wet and dry deposition on plants (funded by BTI) -- 50%
Effects of air-borne fluoride on vegetation (industrial funds) -- 50%

Publications:

A bibliography is appended.

7. Professional Activities:

Consultantships:

During the past three years, a consultant or independent contractor to:

Mathtech, Inc.
ERCO Industries, Ltd., Canada

Eastalco Aluminum Company
Alumax of South Carolina
Air Pollution Effects Branch, Corvallis Environmental Research Laboratory, USEPA
Environmental Strategies, Inc.
Snell & Wilmer
Alcoa
Reynolds Metals Company
ARCO Metals
Chevron Chemical Company

Societies:

Member of: AAAS; American Society of Plant Physiologists; New York Academy of Sciences; and Sigma Xi.

Committees:

Air Pollution Manpower Development Advisory Committee, National Air Pollution Control Administration [ad hoc member, 1968-1969]

Fluoride Panel, Biological Effects of Air Pollution Committee National Research Council - National Academy of Sciences. [Consultant, 1970 - 1971]

Air Pollution Research Grants Advisory Committee, United States Environmental Protection Agency: [Member, 1971 - 1972]

Site Review Committee, Trace Contaminants Program, Division of Environmental Systems and Resources, National Science Foundation [ad hoc member, 1973]

Task Force on Effects of Air Pollution on Plants and Ecologic Systems, Coordinating Committee on Air Quality Studies, National Academy of Engineering [member, 1974]

Environnmental Advisory Council, Village of Tarrytown, New York [member, 1974 - 1978]

Editorial Board, Journal of Environmental Quality [consulting editor, 1975 - 1979]

Environmental Quality Control Commission, Town of Greenburgh New York [member, 1974 - 1978]

Committee on Sulfur Oxides, Board of Toxicology and Environmental Health Hazards, National Research Council - National Academy of Sciences [member, 1977 - 1978]

8. Community Service

Board of Directors, Sleepy Hollow Community Concerts Association (1974 - 1978)
Committee of Troop 2, Ithaca, Boy Scouts of America (1980- present).

Other:

Irregular referee for: Journal of Environmental Quality, Canadian Journal of Botany.
Reviewer for grants to: Natural Environment Research Council (United Kingdom).

PUBLICATIONS OF D. C. McCUNE

McCune, D. C., and A. W. Galston. Inverse effects of gibberellin on peroxidase activity and growth in dwarf strains of peas and corn. Plant Physiol. 34(4): 416-418. 1959.

Galston, A. W., and D. C. McCune. An analysis of gibberellin-auxin interaction and its possible metabolic basis. p. 611-625. In: R. M. Klein (ed.) Plant Growth Regulation, Proc. Int. Conf., 4th, Yonkers, NY, 1959. Iowa State University Press, Ames, Iowa. 1961.

McCune, D. C. Multiple peroxidases in corn. Ann. N. Y. Acad. Sci. 94: 723-730. 1961.

Mavrodineanu, R., J. Gwirtsman, D. C. McCune, and Clark A. Porter. Summary of procedures used in the controlled fumigation of plants with volatile fluorides and in the determination of fluorides in air, water, and plant tissues. Contrib. Boyce Thompson Inst. 21(7): 453-464. 1962.

Weinstein, Leonard H., Richard H. Mandl, D. C. McCune, Jay S. Jacobson, and A. E. Hitchcock. A semi-automated method for the determination of fluorine in air and plant tissues. Contrib. Boyce Thompson Inst. 22(4): 207-220. 1963.

McCune, D. C., Leonard H. Weinstein, Jay S. Jacobson, and A. E. Hitchcock. Some effects of atmospheric fluoride on plant metabolism. J. Air Pollut. Control Assoc. 14(11): 465-468. 1964.

Hitchcock, A. E., Leonard H. Weinstein, Delbert C. McCune, and Jay S. Jacobson. Effects of fluorine compounds on vegetation, with special reference to sweet corn. J. Air Pollut. Control Assoc. 14(12): 503-508. 1964.

McCune, D. C., A. E. Hitchcock, Jay S. Jacobson, and Leonard H. Weinstein. Fluoride accumulation and growth of plants exposed to particulate cryolite in the atmosphere. Contrib. Boyce Thompson Inst. 23(1): 1-11. 1965.

Weinstein, Leonard H., Richard H. Mandl, Delbert C. McCune, Jay S. Jacobson, and A. E. Hitchcock. Semi-automated analysis of fluoride in biological materials. J. Air Pollut. Control Assoc. 15(5): 222-225. 1965.

DeHertogh, A. A., D. C. McCune, J. Brown, and D. Antoine. The effects of antagonists of RNA and protein biosynthesis on IAA and 2,4-D induced growth of pea stem sections. Contrib. Boyce Thompson Inst. 23(2): 23-31. 1965.

Jacobson, Jay S., D. C. McCune, Leonard H. Weinstein, Richard H. Mandl, and A. E. Hitchcock. Studies on the measurement of fluoride in air and plant tissues by the Willard-Winter and semiautomated methods. J. Air Pollut. Control Assoc. 16(7): 367-371. 1966.

Jacobson, Jay S., Leonard H. Weinstein, D. C. McCune, and A. E. Hitchcock. The accumulation of fluorine by plants. J. Air Pollut. Control Assoc. 16(7): 412-417. 1966.

Mandl, R. H., L. H. Weinstein, J. S. Jacobson, D. C. McCune, and A. E. Hitchcock. Simplified semi-automated analysis of fluoride. p. 270-273. In: L. T. Skeggs, Jr. (ed.), Automation in Analytical Chemistry, Technicon Symp. 1965, New York. Mediad Inc., 1966.

McCune, D. C., A. E. Hitchcock, and Leonard H. Weinstein. Effect of mineral nutrition on the growth and sensitivity of galdiolus to hydrogen fluoride. Contrib. Boyce Thompson Inst. 23(8): 295-299. 1966.

McCune, D. C., L. H. Weinstein, D. C. MacLean, and J. S. Jacobson. The concept of hidden injury in plants. p. 33-44. In: N. C. Brady (ed.) Agriculture and the Quality of Our Environment. AAAS, Publication 85, Washington, D.C. 1967.

MacLean, David C., Delbert C. McCune, Leonard H. Weinstein, Richard H. Mandl, and George N. Woodruff. Effects of acute hydrogen fluoride and nitrogen dioxide exposures on citrus and ornamental plants of Central Florida. Environ. Sci. Technol. 2(6): 444-449. 1968.

McCune, D. C. The technical significance of air quality standards. Fluoride criteria for vegetation reflect the diversity of plant kingdom. Environ. Sci. Technol. 3(8): 720, 727, 728, 731, 732, 735. 1969.

McCune, D. C., A. A. DeHertogh, and D. C. MacLean. Relationship between RNA metabolism and the effect of growth regulants in pea seedlings. p. 16-17. In: J. E. Gunckel (ed.) Current Topics in Plant Science. Academic Press, New York. 1969.

Weinstein, Leonard H., A. E. Hitchcock, D. C. McCune, J. S. Jacobson, D. C. MacLean, and R. H. Mandl. Effects of air pollution on plants. p. 60-63. In: J. E. Gunckel (ed.) Current Topics in Plant Science. Academic Press, New York. 1969.

Jacobson, Jay S., and D. C. McCune. Interlaboratory study of analytical techniques for fluorine in vegetation. J. Assoc. Offic. Anal. Chem. 52(5): 894-899. 1969.

McCune, D. C. On the establishment of air quality criteria, with reference to the effects of atmospheric fluorine on vegetation. Air Qual. Monogr. 69-3. American Petroleum Institute, New York. 1969. 33 pp.

Weinstein, L. H., D. C. McCune, Jill F. Mancini, and P. van Leuken. Acid-soluble necleotides of Pinto bean leaves at different stages of development. Plant Physiol. 44(11): 1499-1510. 1969.

Weinstein, Leonard H., and Delbert C. McCune. Implications of air pollution for plant life. Proc. Amer. Philosoph. Soc. 114(1): 18-21. 1970.

McCune, D. C., L. H. Weinstein, and Jill F. Mancini. Effects of hydrogen fluoride on the acid-soluble nucleotide metabolism of plants. Contrib. Boyce Thompson Inst. 24(10): 213-225. 1970.

Weinstein, Leonard H., and Delbert C. McCune. Field surveys, vegetation sampling, and air and vegetation monitoring. p. G1-G4. In: J. S. Jacobson and A. C. Hill (eds.) Recognition of air pollution injury to vegetation: A pictorial atlas. (APCA, TR-7 Agr. Comm. Inform. Rept. #1) Air Pollut. Control Assoc., Pittsburgh, PA. 1970.

Weinstein, Leonard H., and Delbert C. McCune. Effects of fluorides on vegetation. Proc. Conf. Impact Air Pollut. Veg., Toronto, April 1970. Air Pollut. Control Assoc. & Ontario Dept. Energy Resource Mgf. 31 pp.

McCune, Delbert C., and Leonard H. Weinstein. Metabolic effects of atmospheric fluorides on plants. Environ. Pollut. 1(2): 169-174. 1971.

Hitchcock, A. E., D. C. McCune, L. H. Weinstein, D. C. MacLean, J. S. Jacobson, and R. H. Mandl. Effects of hydrogen fluoride fumigation on alfalfa and orchard grass: A summary of experiments from 1952 through 1965. Contrib. Boyce Thompson Inst. 24(14): 363-385. 1971.

Weinstein, Leonard H., and Delbert C. McCune. Effects of fluoride on agriculture. J. Air Pollut. Control Assoc. 21(7): 410-413. 1971.

McCune, D. C., and A. E. Hitchcock. Fluoride in forage: Factors determining its accumulation from the atmosphere and concentration in the plant. pp. 289-292. In: H. M. Englund & W. T. Berry (eds.). Proc. Int. Clean Air Congr., 2nd, Washington, 1970. Academic Press, New York. 1971.

McCune, D. C. Problems involved in devising air quality criteria for the effects of fluorides on vegetation. Amer. Ind. Hyg. Assoc. J. 32(10): 697-701. 1971.

Weinstein, L. H., and D. C. McCune. Environmental analysis of fluoride. Chapter 4. In: Biological Effects of Atmospheric Pollutants -- Fluorides. National Academy of Sciences, Washington, D.C. 1971.

Weinstein, L. H., and D. C. McCune. Effects of fluoride on vegetation. Chapter 7. In: Biological Effects of Atmospheric Pollutants -- Fluorides. National Academy of Sciences, Washington, DC 1971.

Weinstein, Leonard H., and Delbert C. McCune. Effects of air pollution on vegetation. p. 60-74. In: P. M. Giever (ed.). Air Pollution Manual. Part 1 - Evaluation. 2nd edition, Amer. Ind. Hyg. Assoc., Detroit. 1972.

Jacobson, Jay S., and D. C. McCune. Collaborative study of analytical methods for fluoride in vegetation: effects of individual techniques on results. Appendix. J. Assoc. Official Anal. Chem. 55(5): 991-998. 1972.

Weinstein, L. H., D. C. McCune, Jill F. Mancini, L. J. Colavito, D. H. Silberman, and P. van Leuken. Studies on fluoro-organic compounds in plants. III. Comparisons of the biosynthesis of fluoro-organic acids in *Acacia georginae* with other species. Environ. Res. 5(4): 393-408. 1972.

McCune, D. C. Summary and synthesis of plant toxicology. Advan. Chem. Ser. 122: 48-62. 1973.

Mandl, R. H., L. H. Weinstein, D. C. McCune, and Monica Keveny. A cylindrical open-top chamber for the exposure of plants to air pollutants in the field. J. Environ. Qual. 2(3): 371-376. 1973.

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~~Exhibit 17~~

Exhibit RB-3

LIST OF REVIEW BOARD MEETINGS

Date	Activity
I. February 9, 1983	Dr. Curtis met at Snell & Wilmer to discuss research plans for Palo Verde Power Plant and project implementation plans with University of Arizona (U of A).
II. February 25-26, 1983	Dr. Curtis met with UA staff, Bechtel, NUS and associated personnel to implement research plan; helicopter flight to PVNGS with Dr. K. Foster to survey area and crops for research plan and field study; Dr. McCune contacted and agreed to join team.
III. March 17-18, 1983	*Reviewed Palo Verde Salt Drift monitoring program; reviewed research proposed by U of A; site visits by review panel (Tucson); Mr. Lauver recommended for temporary technical assistance on field and greenhouse studies.
IV. May 16-17, 1983	*Meeting at U of A to review data, progress and site visit to Marana; discussed aerosol spray apparatus, greenhouse site visit.
V. June 20, 1983	Meeting at U of A to review data, progress and simulated drift composition (synthetic blowdown summary).
VI. July 21, 22, 1983	*Reviewed greenhouse research and field data; site visit to greenhouses and Marana research documentation procedures.

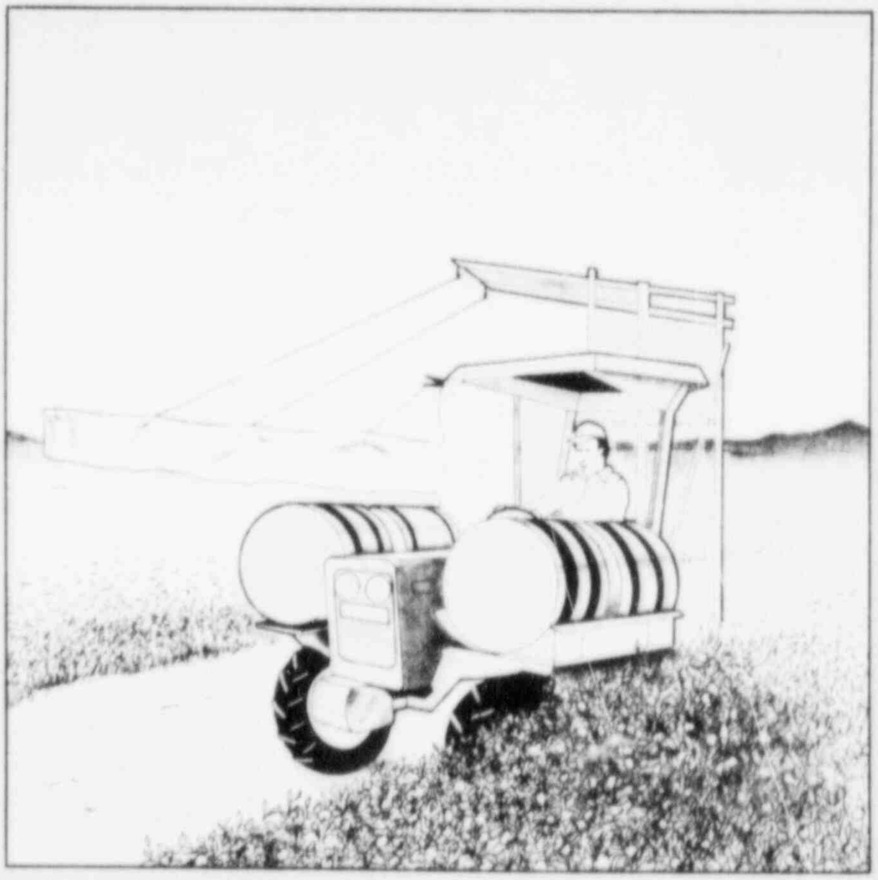
Exhibit RB-3 - con't

VII. October 10-11, 1983	Meeting at U of A to review all research data, presentation and reporting procedures; visits to greenhouses and Marana field site; decision to terminate.
VIII. December 3, 1983	*Meeting in Ontario, CA to review rough draft "An Assessment of Salt Drift on the Productivity of Agricultural Crops in the vicinity of the Palo Verde Nuclear Generating Station" by Foster, et al.
IX. January 16-17, 1984	Report format established, data of report reviewed in detail with U of A staff, rough draft corrected and results discussed, Tucson.
X. April 23-26, 1984	Volume I and Volume II drafts reviewed with U of A staff in Tucson.
XI. July 15-16, 1984	Volume I and Volume II (final drafts) reviewed with U of A staff in Tucson.

* All members of Review Board present

Exhibit RB-4

~~Exhibit [illegible]~~



University of Arizona • College of Agriculture • August 1984

AN ASSESSMENT OF SALT DRIFT ON THE PRODUCTIVITY OF AGRICULTURAL CROPS IN THE VICINITY OF THE PALO VERDE NUCLEAR GENERATING STATION

by

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August 1984

DISCLAIMER

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

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1. EXECUTIVE SUMMARY

1.1. INTRODUCTION

During the operation of the Palo Verde Nuclear Generating Station cooling towers, saline water in the form of droplets (drift) will be emitted in the cooling tower air stream(plume) and transported downwind. The water in the drift is expected to evaporate quickly in the arid Arizona climate resulting in the deposition of dry particles (the solids dissolved in the water droplets prior to evaporation) on plants in surrounding areas. The salinity of the drift can be characterized generally as one-third that of sea water and the particles deposited are predominantly composed of Na^+ and Cl^-, approximately 31.7% and 30.7 % respectively. The quantity of drift that will be emitted and the distribution of the depositions in the area surrounding Palo Verde are not within the scope of this study.

The effects of sea spray and cooling tower saline drift on plants in coastal areas have been the subject of research in recent years. These studies have shown that sensitivity of vegetation to saline drift is a function of plant species, the levels of Cl^- and Na^+ in the droplets, duration of exposure, and the ambient relative humidity. In contrast, little research has focused on this problem in noncoastal arid environments.

The primary objective of this research was to evaluate the effects of foliar salt drift deposition on the productivity of selected crop species. Correlative to this primary objective, the program included observations of phenological and physiological responses, the occurence of foliar injury, and tissue analyses to determine the accumulation of salts.

A simulated saline drift similar in composition to the drift predicted to be emitted from the cooling towers at the Palo Verde Nuclear Generating Station was applied to crops grown under field or greenhouse conditions. These crops were: cotton (greenhouse and field); alfalfa (greenhouse and field); barley (greenhouse only); and cantaloupe (field only). The simulated saline drift was applied to the crops at nominal rates*: control with no spray treatment (field only); 0 (control sprayed with distilled water); 10 lbs/a·yr; 100 lbs/a·yr; 500 lbs/a·yr; and 1,000 lbs/a·yr (not applied in the field to cotton or cantaloupe). The effective deposition rates (based on the total disolved solids in anhydrous form) were approximately 74% of the nominal rates, or 7.4 lbs., 74 lbs., 370 lbs. and 740 lbs/a·yr, respectively.

* For conversion to equivalent metric units, 1 lb/a·yr = 1.12 kg/ha·yr

1.2. RESULTS

Although the same rates of simulated saline drift deposition were used in the greenhouse and field, as noted above, it should be emphasized that because of the differences between the two environments direct comparisons of data cannot be made.

In alfalfa, barley, and cantaloupe, there was no evidence of any impact on yield from foliar deposition of the simulated drift applied at effective rates of 370 lbs/a·yr or less. With respect to field-grown alfalfa there was some evidence (not conclusive) that measurable effects on yield were obtained at a deposition rate of 740 lbs/a·yr.

In the case of cotton, the yield results were more complex. Comparisons among treatments in the greenhouse showed that yields (lint and seed) from cotton plants treated at rates of 7.4, 74, 370 lbs/a·yr, respectively, were all greater than yields from control plants treated with distilled water. At final greenhouse harvest, the controls had about five times more green bolls on a weight basis than the 370 lbs/a·yr treated plants.

With respect to field-grown machine-harvested cotton, the 7.4 lbs/a·yr treatment yield was greater when compared to the no treatment (unsprayed) control yield, but less than the distilled water (sprayed) control treated plants; however, the differential in yields was not statistically significant (Table 1). Among the machine-harvested plants a nonsignificant increase in yield from the 7.4 lbs/a·yr treated plants was observed when compared to both no treatment control plants and the 74 lbs/a·yr treated plants (Table 1). Yields from the no treatment plants and the 74 lbs/a·yr treated plants were basically the same. There was a nonsignificant decrease in yield in the 7.4 lbs/a·yr treated plants as compared to the sprayed control. There were no statistical yield differences in the machine-harvested plots, although there was a trend in the sprayed plots toward reduced yields with increasing treatment levels (Table 1).

In the field, some cotton plants were also harvested by hand as the bolls matured. As in the machine-harvested plots the highest yields were obtained from the control plants treated with distilled water (Table 1). The hand-harvested yields from the 7.4 lbs/a·yr treatment were not statistically different from the sprayed and unsprayed controls. The 74 lbs/a·yr treatment had statistically lower yield than the sprayed control but not the unsprayed or the 7.4 lbs/a·yr treatment. Yield from the 370 lbs/a·yr treatment was significantly lower than the 7.4 lbs/a·yr treatment and the sprayed and unsprayed controls (Table 1).

Table 1.

Effects of Simulated Saline Drift on Yields of Cotton in Field and Greenhouse

Effective Treatment Levels lbs/a·yr	Yields of Seed Cotton[1]		
	Field		Greenhouse
	Hand-Harvested lbs/a	Machine-Harvested lbs/a	Hand Harvested g/plant
No Treatment	2527.2[ab]	2269.6	N/A
0	2734.3[a]	2594.4	63.9[a]
7.4	2356.5[ab]	2316.2	83.3[b]
74	2237.4[bc]	2238.8	81.6[b]
370	1905.2[c]	2124.4	88.9[b]
LSD (.05)	381.6	NS	11.7
Standard Error ($S_{\bar{x}}$)	30.4	133.3	3.7

[1]Means followed by the same letters within a column are not significantly different at the 5% level when using the least significant difference (LSD) test.

In both greenhouse and field, no conclusive changes in cotton fiber quality were measured.

In general, there were no salt induced physiological changes observed in the four crops. However, greenhouse cotton plant heights were reduced in both the 370 and 740 lbs/a·yr treatments. Foliar injury was observed in the greenhouse cotton and barley treated with 370 and 740 lbs/a·yr simulated saline drift only during the latter part of the growing season and in the field grown alfalfa treated with 740 lbs/a·yr simulated saline drift. The form, incidence, and severity of salt-induced foliar injury was conditioned by four factors: species; level of treatment; duration of the exposure period; and conditions of culture and exposure. Tissue analysis indicated that more Na^+ and Cl^- were absorbed by the simulated saline drift treated plants than the control plants.

1.3. CONCLUSIONS

Given the limitations of any one-year study, it appears that a simulated saline drift treatment level of 7.4 lbs/a·yr did not adversely affect the productivity of alfalfa, barley and cantaloupe. In the greenhouse, cotton plants treated with 7.4 lbs/a·yr simulated saline drift yielded significantly more seed cotton. Machine-harvested field-grown cotton productivity was not statistically affected at a simulated saline drift treatment level of 7.4 lbs/a·yr. Although the treatment level of 7.4 lbs/a·yr did not statistically reduce productivity of hand-harvested, field-grown cotton ($p = .05$), the data indicate that this treatment may be near the level where statistically significant reduction could be detected (Table 1).

2. INTRODUCTION

2.1. BACKGROUND

2.1.1. The Palo Verde Nuclear Generating Station

Palo Verde Nuclear Generating Station Units 1, 2, and 3 are located in Maricopa County in southwestern Arizona. The general descriptions of the generating station, the site, and surrounding area, are from the following three documents:

- Final Environmental Statement Related to the Operation of Palo Verde Nuclear Generating Station, Units 1, 2, and 3, Docket Nos. STN 50-528, 529, and 530, Arizona Public Service Company, et al., U.S. Nuclear Regulatory Commission, February 1982. (FES-OL)

- Environmental Report, Operating Licensing Stage, Palo Verde Nuclear Generating Station, Arizona Public Service Company, Supplement 4, December 21, 1981. (ER-OL)

- Final Environmental Statement Related to Construction of Palo Verde Nuclear Generating Station, Units 1, 2, and 3, Docket Nos. STN 50-528, 529, and 530, Arizona Public Service Company, U.S. Nuclear Regulatory Commission, September 1975. (FES-CP)

The FES-OL was used as the primary information source and was supplemented by additional information from the ER-OL and FES-CP.

The general description of Palo Verde Nuclear Generating Station is:

> The facility will employ three pressurized-water reactors (PWRs) producing 3817 megawatts thermal (MWt) each. Steam turbine-generators will use this heat to provide a nominal net electrical output of 1270 megawatts (MWe) per unit. The maximum design thermal output of each unit is 4100 MWt. The exhaust steam will be condensed by cooled water from three circular mechanical-draft cooling towers per

unit. Secondarily treated sewage effluent from a pipeline in the vicinity of the City of Phoenix, Arizona, 91st Avenue sewage treatment plant will be the sole source of cooling water. (FES-OL, pg. iii).

2.1.2. Description of Site and Surrounding Area

The FES-OL identifies several changes in the Palo Verde Nuclear Generating Station area since the FES-CP but does not summarize current land use. These changes are the addition of an interstate highway interchange, extension of Interstate Highway 10, and additional residential development in the region. Accordingly, excerpts from the FES-CP are still valid, and excerpts from the ER-OL generally provide accurate information on the site and the surrounding natural features and land use.

> The site of the Palo Verde Generating Station (PVNGS) is in Maricopa County, Arizona, roughly 15 miles west of Buckeye, and about 50 miles west of downtown Phoenix. An approximately rectangular area, four miles (N-S) by two miles (E-W) in its maximum dimensions, comprises the site property. Its northern edge is just south of the Buckeye-Salome Road and about 1-1/2 miles south of Wintersburg. (FES-CP, pg. 2-1).

The total area of the site is "1640 ha (4050 acres). Of this, 1250 ha (3100 acres) will be occupied by station facilities" (FES-OL, pg. 4-2, 3). This includes an approximately 80-acre makeup water reservoir and "250 acres of evaporation ponds" that could be expanded to no more than "a total of 670 acres" (ER-OL, pg. 3.6-13).

> The terrain in the site area is relatively flat desert with elevations ranging from about 900 to 1000 feet above mean sea level (MSL). Scattered about the vicinity are small hills and buttes.... Northwest of the site are the Palo Verde Hills, rising fairly abruptly to nearly 2200 feet MSL about six miles west-northwest of the reactor locations. Centennial Wash is an intermittent stream about six miles south of the reactor sites, beyond which the land rises gradually, but includes isolated, steeply sloped hills. Buckeye Valley, through which the Gila River flows, is east and southeast of the site. The desert is flat north and northeast of the site and is traversed by many intermittent streams. (FES-CP, pg. 2-1).

"Most of the land within ten miles of the site is open desert. About 10% of it is currently irrigated for agricultural purposes" (FES-CP, pg. 2-5). A 1983 map showing agricultural land and crops is presented in Figure 1 (foldout in pocket).

2.1.3. Cooling Tower System Description

As indicated in the FES-OL, "The design of the cooling towers has been changed to three circular mechanical-draft cooling towers per unit" instead of the rectangular mechanical draft towers originally proposed. "Each of the round towers will be 92 m (300 ft) in diameter at the base and 20 m (64 ft) high, with 16 fans...." (FES-OL, pg. 4-3).

> The total annual makeup water requirement per unit is now estimated...to be 2.6 x 10 m^3/year (21,350 acre-ft/year) per unit. (ER-OL, pg. 3.3-1).
>
> The primary plant water source is waste water effluent from the City of Phoenix 91st Avenue Sewage Treatment Plant and from the City of Tolleson's Sewage Treatment Plant. The processed effluent from these two sources is delivered to the onsite water reclamation plant via pipeline which starts at the 91st Avenue Sewage Treatment Plant. It is further treated and then stored in the 2300 acre-foot onsite reservoir. (ER-OL, pg. 3.3-1).
>
> Each unit's circulating water system removes waste heat resulting from normal operation of the unit and rejects it to the atmosphere via the three cooling towers in each system. Heat rejection is accomplished by the evaporation of a portion of the circulating water flow. To maintain the chemical concentration of circulating water at or below 15 times that of makeup water (15 cycles of concentration), a quantity of water, called blowdown, must be discharged from the system. In addition to evaporation and blowdown losses, a small amount of water in the form of entrained droplets (drift) is carried away in the cooling tower air stream. Makeup water to replace these losses in each unit is drawn from the reservoir. (ER-OL, pg. 3.3-2).

After approximately 15 cycles of concentration, the salt content of the circulating water will be approximately one-third of the salt content of sea water. The salt (species) will be primarily sodium (and) chloride with substantial amounts of magnesium and calcium ... and sulfates. Less than 0.1 percent by weight of the solids will be heavy metals or biocides. Drift from cooling towers is designed to be controlled to 0.0044 percent loss of the circulating water flow" (ER-OL, pg. 5.3-3). This value "is a manufacturer's guarantee and is typical of drift losses from circular mechanical draft cooling towers. (FES-OL, pg. 4-3).

This drift is emitted from the cooling tower stacks and is transported downwind with the plume. As the plume loses buoyancy, the droplets fall out and drift downward by gravity. Because of the arid desert climate, the water in these droplets is expected to evaporate quickly. The resulting solid salt particles will deposit over a wide area on the surrounding soil and plants. The amount of salt drift and the Palo Verde Nuclear Generating Station deposition pattern was predicted in the ER-OL and was reviewed by the Nuclear Regulatory Commission in the FES-OL. Additional studies on drift loss, transport modeling, and monitoring have been commissioned by Arizona Public Service Company. These topics are beyond the scope of this report.

2.1.4. Environmental Impact Statements

As indicated in Section 2.1.1., the Nuclear Regulatory Commission has issued two environmental impact assessments of Palo Verde Nuclear Generating Station, the FES-OL in February 1982 and the FES-CP in September 1975.

The FES-OL concluded that "Station cooling towers will produce no appreciable impacts from fogging and drift deposition; the impacts that do occur will be less than predicted in the FES-CP (Sections 5.4 and 5.5)" (FES-OL, pg. iv). With respect to drift, it was further stated "The maximum offsite deposition rate is now estimated to be 13.4 kg/ha (12 lb/acre) of solids per year, primarily concentrated salts ... Even if all solids from offsite drift deposition accumulated in desert soils over the lifetime of PVNGS, soil salinity would not be altered sufficiently to impact biota (NUREG-0522)" (FES-OL, pg. 5-10).

A more comprehensive discussion of potential salt drift impacts was presented by the NRC in the FES-CP:

> Salt from cooling tower drift could modify floral and faunal species composition on some acreage close to the site boundaries depending upon drift design specification selected for the cooling towers; however, this is not expected to generally affect the population structure and stability of areas further away (Sec. 5.5.2). (FES-CP, pg. i).
>
> Very little information is available in the literature on the effects of aerosol salt applied to soils associated with vegetation, or on the vegetation itself, particularly for the arid southwest. Salts applied directly to the soil may adversely affect vegetation in at least three diverse ways: (1) increase the osmotic potential, thereby making it more difficult for roots to withdraw water from the soil, (2) specific ions contained therein may inhibit plant nutrition, and (3) some specific ions may produce toxic effects. Airborne salts, when directly applied to plant seeds or the foliage, also may have adverse effects. These effects are known to be different for various species and at different life stages within species and are briefly discussed below.
>
> Foliar accumulation of airborne salt on leaf surfaces can cause leaf damage (e.g., necrotic lesions). The staff is unaware of any studies which assess the impact of foliar salt application on desert scrub vegetation. The unique leaf morphology of many desert plants (i.e., thick leaves, heavy cuticle, stomatal distribution, etc.) coupled with the low humidity and sparse rainfall characteristic of the PVNGS region invalidates the use of coastal salt water cooling tower studies for comparison purposes. That (sic) the applicant will monitor for offsite damage to vegetation due to salt deposition and evaluate and transmit such information to the staff. (FES-CP, pg. 5-17, 18).

2.2. LITERATURE REVIEW

2.2.1. Cooling Towers

The natural draft tower and the mechanical draft tower are the two designs most commonly chosen for closed-cycle cooling of the steam condensers in a power plant. The most extensive studies of the effects of saline drift have been conducted for the natural draft cooling towers at the Chalk Point Station in Maryland, which uses brackish water for makeup (Curtis, 1977; Curtis, Lauver and Francis, 1976; Curtis, Lauver and Francis, 1977; Curtis et al., 1977; Curtis, Francis and Lauver, 1978; Lauver et al., 1978; Mulchi, Armbruster and Wolf, 1982). The effects of drift emissions from mechanical draft towers have been investigated at the Palisades Plant in Southwestern Michigan (Rochow, 1978), the P.H. Robinson Generating Station in Galveston County, Texas (Wiedenfeld, Hossmer and McWilliams, 1978), and Turkey Point Station in Florida (Hindawi, Raniere and Rea, 1976).

Design features of the cooling tower such as type of tower, drift eliminator design, and release height, determine the amount of drift and the affected dispersal pattern. The concentration of salts in the drift is determined by the salt content of the makeup water and the number of cycles of concentration, which is an operational parameter. In general, aerosol drift from the taller natural draft towers is dispersed over a greater area (with lower salt deposition per unit area) than the drift dispersed from mechanical draft towers (Chen, 1977). Droplet size, which is dependent on drift eliminator design, also has been identified as a very important factor in determining drift deposition pattern (Webb, Wheeler and Morre, 1978; Policastro, Dunn, and Breig, 1978; Dunn, Boughton and Policastro, 1978; Slinn, 1974).

In addition to cooling tower design and operational parameters, dispersal of the aerosol drift is dependent upon ambient meteorological conditions such as wind velocity, relative humidity, and evaporation rate, which is related to humidity and temperature (Davis, 1979; Israel and Overcamp, 1974). Evaporation is considered of greater importance in neutral atmospheres (Environmental Systems Corporation, 1974), and modellers must alter predictive methods to account for the resultant changes in droplet size and salt concentration (Laskowski, 1975; Hanna, 1974; Roffman and Grimble, 1975). Relative humidity influences what fraction of the droplets size spectrum will become dry prior to deposition. Wind speed has been

identified as influential when the plume reaches its full height and begins to turn horizontal (Argonne National Laboratory, 1981).

Studies of the effects of saline drift emissions from cooling towers generally have been limited in scope and location. As shown by the studies cited above, most studies of drift from cooling towers located at power plants have been conducted in humid coastal climates with moderate rainfall. Because the characteristics of the makeup water at these plants is generally brackish (i.e., seawater diluted with freshwater), the studies of the effects of saline drift at these plants have focused on Na^+ and Cl^- uptake by vegetation.

2.2.2. Salt Dispersion, Deposition, and Accumulation

The concentration of salts in the saline drift from a cooling tower is dependent on salinity of the cooling water, and tower concentration rate (Davis, 1979; Israel and Overcamp, 1974). Dispersal of the aerosol drift is dependent upon wind velocity and relative humidity as well as tower design (Davis, 1979; Israel and Overcamp, 1974). Drift from cooling towers is deposited upon vegetation through sedimentation and impaction of wet and dry particles (Talbot, 1979). Leaves on the windward side suffer significantly more damage than leaves on the leeward side (Hindawi, Raniere and Rea, 1976).

Deposition and accumulation of salts on crop foliage are dependent upon: 1) airborne salt emission rate; 2) wind velocity; 3) surface roughness factors of plant canopy and leaves (Williams and Moser, 1975); 4) settling velocity of the particles; and 5) the distance from the cooling tower (Moser, 1975; Roffman and Roffman, 1973). Heaviest deposits occur downwind from the tower and the amount of salts deposited per unit area decreases as the distance from the tower increases (Israel and Overcamp, 1974). Roffman and Roffman (1973) report that rates of deposition decrease almost exponentially with increasing distance from the source, i.e., the estimated deposition rate decreases at least an order of magnitude with a three-fold increase in radius from the tower. A comprehensive review of and comparisons among the various cooling tower studies was published by Talbot (1979).

2.2.3. Factors Determining Salt Injury

Studies show that foliar injury from saline aerosols is dependent upon the following factors: 1) relative humidity (McCune et al., 1977; Moser, 1975); 2) temperature (Smith and Robinson, 1971); 3) photoperiod (Simini and Leone, 1982); 4) salt particle size and composition (McCune et al., 1977); 5) rainfall after exposure (Silberman and McCune, 1978); and 6) plant species (McCune et al., 1977).

McCune et al. (1977) reports that at equivalent exposures, saline mist with 45% of the particles larger than 150 μm in diameter caused more injury to foliage than a mist in which 95% of the particles were 50 μm to 150 μm in diameter.

Relative humidity is a highly significant factor in foliar injury. Saline aerosols deliquesce when the relative humidity exceeds 75% suggesting that the salts on the surface are absorbed into the leaf only when they are hydrated (Cassidy, 1971). The penetration of the salt from the droplets across the epidermis is proportional to the area of contact between droplet and epidermis and the concentration of salts within the droplet (Logan, 1975). Kannan (1980) reports that substances with high molecular weight penetrate more slowly; ionic radius and degree of hydration also influence the rate of penetration, favoring a lyotropic series (Haile Mariam, 1965). McCune et al. (1977) and Moser (1975) showed that when plants were exposed and maintained at 75% or greater relative humidity for 12 hours per day, the toxicity of saline particles was increased, i.e., it was doubled, as compared to plants exposed to 50% relative humidity. Grattan, Maas and Ogata (1981) demonstrated that foliar accumulation of Na^+ and Cl^- were linear functions of salt deposition levels in pepper (Capsium annum L.), corn (Zea mays L.), soybean (Glycine max L.) and tomato (Lycopersicon lycopersicum L.).

Simini and Leone (1982) studied Cl^- uptake in 11 woody and nonwoody plant species under different conditions of temperature, relative humidity, and photoperiod. In general, most species studied absorbed more Cl^- when exposed to shorter photoperiods, lower temperatures, and higher relative humidities. The authors suggest that increased light and temperature may cause structural changes in the cuticle, leading to decreased permeability. Sargent and Blackman (1970) have shown in young bean (Phaseolus vulgaris L.) leaves that the penetration rate of chloride in the presence of light decreases as pH increases; in the dark, the rate of absorption remains constant throughout the pH range.

Crop salt tolerance is generally expressed as a function of soil salinity. However, Bernstein (1975) and Maas, Grattan and Ogata (1982) demonstrated that the relative tolerance of crop species to saline aerosols and sprinkler irrigation water is not the same as the tolerance of these same crops to soil salinity. Species that do not appear to be specifically sensitive to Cl^- and Na^+ when surfaced irrigated, may be injured by spraying saline irrigation water on the leaf surfaces. Conversely, the response of plants to saline sprays does not necessarily parallel known responses to soil salinity. Busch and Turner (1967) have reported that sprinkling cotton with saline irrigation water caused leaf burn and yield reduction not apparent with surface irrigation. Citrus trees will loose their leaves when sprinkled with saline irrigation water but will not lose their leaves when surface irrigated with the same water (Ehlig and Bernstein, 1959). Because of these differences, soil salinity studies have not proven to be a reliable guide for predicting how saline drift may affect plants.

In general, field tests have shown foliar damage to be dependent on plant species and stage of development. Woody plants tend to be more sensitive to aerosol drift than nonwoody plants (McCune et al., 1977), probably because of continued salt absorption over the longer time period. McCune et al. (1977) studied 11 woody species treated with saline mists and found that the younger leaves of deciduous species were more sensitive than older ones. A greater than 100-fold difference in median effective doses existed among the 11 species examined. Increasing the relative humidity from 50% to 80% doubled the injurious effect as did increasing the particle size of the mist ($> 150\ \mu m$). Francis and Curtis (1979) conducted a 2-year field study using six tree species. Replicated field plots were sprayed with simulated saline cooling tower drift at concentrations ranging from 8685 to 13888 ppm at various spray rates. Injury was noted on tulip poplar stipules (Liriodendron tulipifera L.), slight injury was noted on some white ash leaves (Fraxinus americana L.) and significant injury was noted on flowering dogwood (Cornus florida L.). Francis and Curtis (1979) suggest that dogwood may be a useful bioindicator of saline drift because the intensity of tip and marginal necrosis was related to Na^+ and Cl^- accumulation in leaves.

2.2.4. Plant Injury: Detrimental Concentrations of Airborne and Foliar Salts

Symptoms of plant damage from foliar absorption of saline aerosol drift are characterized as acute and chronic. Acute symptoms include marginal foliar necrosis, lesions, shoot-tip dieback, leaf curl, interveinal necrosis, and molding, a condition of stunted growth on the pollutant source side of the foliage (McCune et al., 1977; Talbot, 1979). Chronic effects, which are less obvious, are characterized by a chlorotic condition in the interveinal regions, lighter leaves, slower growth, and a change in structure and diversity in the plant community over time (McCune et al., 1977). According to Hosker and Lindberg (1982), chronic exposure also may increase susceptibility to disease and insect damage.

Numerous researchers have treated nonwoody plants with a simulated aerosol salt drift. Mulchi and Armbruster (1975) investigated the effects of saline aerosol on soybeans and corn. Severity of injury was directly proportional to the quantity of salt and duration of exposure. In addition, yields of the treated plants were reduced relative to control plants. In a subsequent study, Mulchi and Armbruster (1981) found that application rates of 6.88 and 13.76 kg NaCl/ha·wk* induced foliar injury in soybean seedlings within 1 week. Rates of 13.76 kg NaCl/ha·wk and 6.88 kg NaCl/ha·wk resulted in foliar injury to corn in 3 and 5 weeks, respectively. After 8 weeks, soybean recovered and no injury was observed in the upper canopy; however, corn foliar injury became more pronounced with time. Mulchi and Armbruster (1983) also have studied tobacco (Nicotiana tabacum L.) plants using either NaCl or brackish water at rates of 0.97 to 22.24 kg/ha·wk for 8 weeks. No foliar injury was induced by treatment; however, an application rate of 4.0 kg/ha·wk resulted in a yield increase.

Grattan, Maas and Ogata (1981) treated peppers, tomatoes, and soybeans with saline aerosols in an environmental chamber that simulated morning dew. A total deposition treatment level of 0.4 mg Cl^-/cm^2 resulted in foliar necrosis within 3 to 8 days. No injury symptoms were apparent, however, on any species when relative humidity was maintained at 70% in the absence of the simulated morning dew. McCune et al. (1977) has reported that sensitive plant species (corn, Canadian hemlock [Tsuga canadensis (L.) Carr.], dogwood) show adverse effects from saline aerosols at Cl^- deposition levels ranging from 3 μg to 67 μg Cl^-/cm^2. Susceptible

* For conversion to equivalent english units, 1 kg/ha·wk = 0.891 lb/a·wk

species displayed extensive leaf burn, tip and marginal necrosis, and defoliation following foliar application of saline aerosols.

Hassan (1981) observed that NaCl sprayed on bean plants stimulated vegetative growth but reduced flower, pod, and seed growth. Bernstein and Francois (1975) reported lower yields from bell peppers sprinkled with water containing 1450 mg/l of salts. Bernstein and Francois (1975) also found more leaf burn and lower yields of plants sprinkled at 2.3 day intervals (seasonal average) compared to 3.5 and 4.75 day intervals and attribute the yield reduction primarily to foliar salt absorption. Eisikowitch (1979/1980) reported that an ecotype of the horned poppy (Glaucium flavum, Crantz) has difficulty setting seed in locations exposed to winds carrying sea spray.

In a study of the effect of salt drift from a nuclear generating station at Turkey Point, Florida, Hindawi, Raniere and Rea (1976) found no effects on indigenous vegetation; however, sweet corn and bush bean introduced 215 m from the cooling tower exhibited leaf injury after 3 weeks of exposure. The authors then treated 1-, 3-, and 5-week-old bush beans with a saline aerosol with concentrations of 5, 25, and 75 μg sea salt/m^3. The incipient injury threshold was found to be 5 $\mu g/m^3$ after 100 hours cumulative exposure to saline aerosols over a 4-week period. The leaves from treated plants exhibited random chlorotic and necrotic areas on the adaxial (upper) surfaces.

In controlled environment studies, plant salt tolerance and absorption rates affected the amount of injury from saline spray. Barley (Hordeum vulgare L., 'Gus') treated with saline spray at rates of 15 and 30 meq/l daily (5 days/wk) for seven weeks induced only minor injury even though Na^+ and Cl^- were readily absorbed. Alfalfa (Medicago sativa L.) sprayed at the same rates absorbed less salt but exhibited more foliar damage. Cotton (Gossypium hirsutum L., 'Deltapine 90') sprayed at with 30 meq/l and 60 meq/l absorbed salt very slowly and exhibited little foliar injury (Maas, Grattan and Ogata, 1982).

Rochow (1978) studied the effects of calcium and sulfate deposition on leaves in the vicinity of the Palisades Nuclear Plant in southwestern Michigan. Severe foliar damage was observed on all deciduous and evergreen tree species within 92 m

of the cooling towers and was attributed to the extremely high sulfate deposition rate. Injury was similar to that caused by sulfur oxides.

Some studies show that foliar injury from saline aerosols is dependent not only upon the size and composition of the salt particles deposited on the leaf tissue, but also upon: 1) the nature of the leaf surface; 2) climatic parameters, particularly humidity; 3) plant species and age; and 4) cuticular thickness and composition (Robertson and Kirkwood, 1969; Bukovac, Flore and Baker, 1979; Hull, 1970; Leece, 1976). Most of the research on saline drift effects has focused on climatic conditions similar or equivalent to a coastal climate with high humidity and moderate to high rainfall. A literature search conducted in December 1983 by the University of Arizona's College of Agriculture did not identify any published studies assessing the impact of salt accumulation on native and cultivated plants in noncoastal arid areas. A study of saline drift effects with low humidity and sparse rainfall should provide a better basis for assessment of the physiological and biochemical mechanisms of foliar injury in an arid environment.

3. GENERAL STUDY APPROACH

3.1. SCOPE

This project investigated the effects of foliar deposition of simulated saline drift on crop growth in noncoastal arid environments. Four levels of simulated saline drift were applied to cotton, alfalfa, and barley cultivated in greenhouses, and to cotton, alfalfa, and cantaloupe cultivated in a field near Marana, Arizona. At both sites, evaluations were made of drift deposition, accumulation of foliar salts, foliar injury, and productivity.

The period of cultivation extended from April 1983 to November 1983. Barley is a winter crop and was studied only at the greenhouse site where temperature could be moderated. In contrast, cantaloupe was studied only at the field site because cultivation of a vine crop in a greenhouse presents operational constraints. To conform as closely as possible to agronomic conditions near the Palo Verde Nuclear Generating Station all cultivation practices in the field followed those commonly employed by Arizona growers.

3.2. RATIONALE

Cotton, barley, and alfalfa are three representative crops cultivated near the Palo Verde Nuclear Generating Station (Figure 1 foldout in pocket, Data Summary Volume Section B). Although not extensively grown in that area, cantaloupe is a representative melon crop under consideration for cultivation in the region. The area near Marana, Arizona, was chosen as the agronomic field site because of the proximity to the University of Arizona.

The chemical composition of the simulated saline drift was similar to that expected to be emitted from the cooling towers at the Palo Verde Nuclear Generating Station. Droplet mean diameter was approximately 100 μ. Different rates of application were used to provide a more comprehensive evaluation than could be obtained by using a single application rate. Greenhouses were employed to control variations caused by rain, temperature, wind, humidity, cultivation, soil, irrigation, diseases, etc. The greenhouse study permitted more detailed evaluations

and measurements of individual plants. Three species of crops were evaluated: cotton (Gossypium hirsutum L., 'Deltapine 90'), alfalfa (Medicago sativa L.), and barley (Hordeum vulgare L., 'Gus'). A special greenhouse chamber was designed for the application of measured quantities of simulated saline drift to the plants.

Field studies were conducted on 6 acres of a commercially managed farm near Marana, Arizona. Cotton (Gossypium hirsutum L., 'Deltapine 90'), alfalfa (Medicago sativa L.), and cantaloupe (Cucumis melo L., 'Top Mark') were cultivated. A special tractor mounted sprayer was designed for applying measured quantities of simulated saline drift to the crops.

3.3. OBJECTIVE

The objective of this study was to evaluate the effects of foliar salt drift deposition on the vegetative and reproductive development, and productivity of selected crop species.

4. MATERIALS AND METHODS

4.1. GREENHOUSE - PROJECT DESIGN

4.1.1. Description of the Greenhouses

The study was conducted in two greenhouses designated north and south and located on the University of Arizona Campus Agricultural Center. The north greenhouse was 27 ft-by-72 ft (Figure 2); the south greenhouse was 22 ft-by-72 ft. Drip irrigation systems were used. Plants were grown under sunlight filtered through the clear plastic greenhouse covering. Air temperature was moderated by evaporative coolers and average maximum temperature was approximately 30 C. Relative humidity was increased to 75% or more three times per week by applying water to the greenhouse floor. Temperature and relative humidity were monitored by Omnidata Datapod Digital Recorders located at each end of the north greenhouse (Project Study Plan[PSP] Procedure CA-29).

4.1.2. Experimental Design

Each crop in the north greenhouse was grown in a randomized complete block design with four replications. Each experimental unit consisted of four samples grown in separate pots and separate benches were used for each crop (Figure 3). The experiment was designed to statistically block the variability caused by the temperature gradient from one end of the greenhouse to the other.

Randomized complete block designs were also used in the south greenhouse (Figure 4). All three crops were grown on separate parts of the same bench. The cotton and alfalfa each had three replications and the barley had two replications. Each alfalfa experimental unit had five transplant pots and five seedling pots/unit.

4.1.3. Plant Culture

Cotton (Gossypium hirsutum L. 'Deltapine 90'), alfalfa seedlings and transplants (Medicago sativa L. 'Lew'), and barley (Hordeum vulgare L. 'Gus') were cultivated. Plants were grown in plastic pots filled with Terra-lite potting mix. Cotton was planted in 6-gallon pots; one plant per pot. Barley was planted in

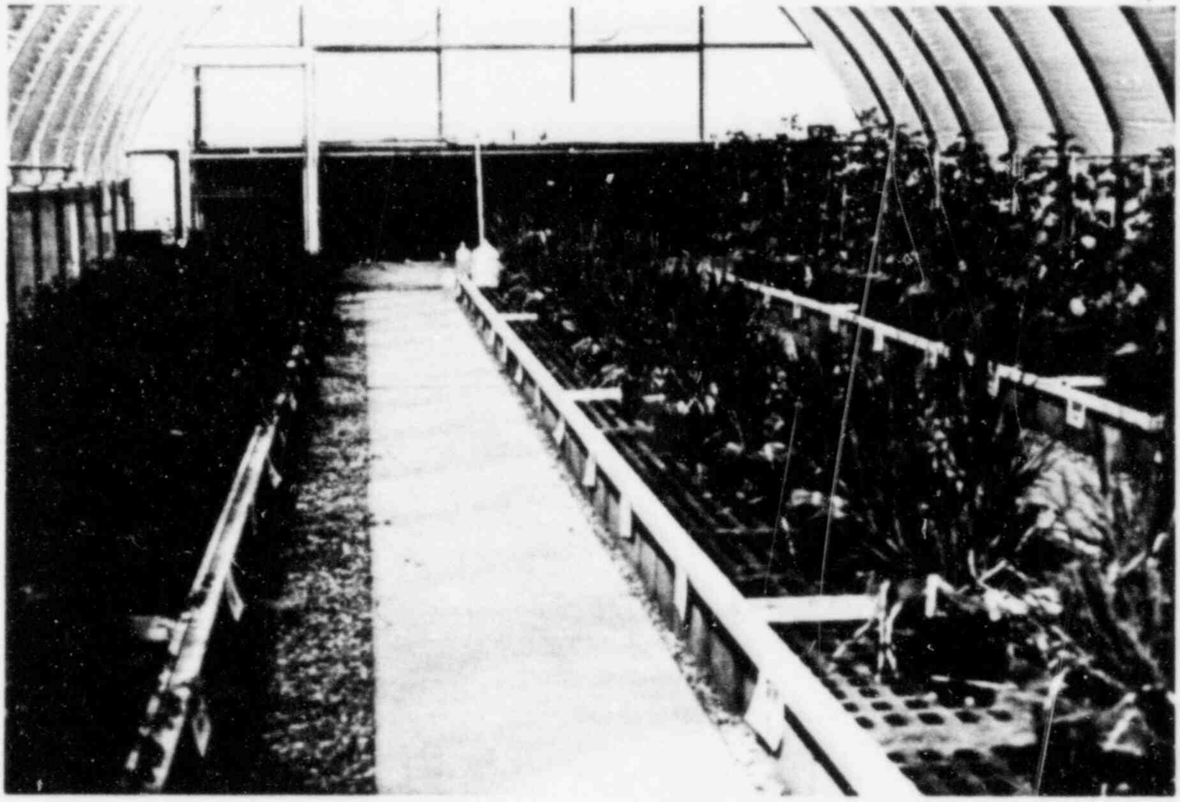


Figure 2. North greenhouse at the University of Arizona Campus Agricultural Center. The crops from left to right are alfalfa, barley and cotton

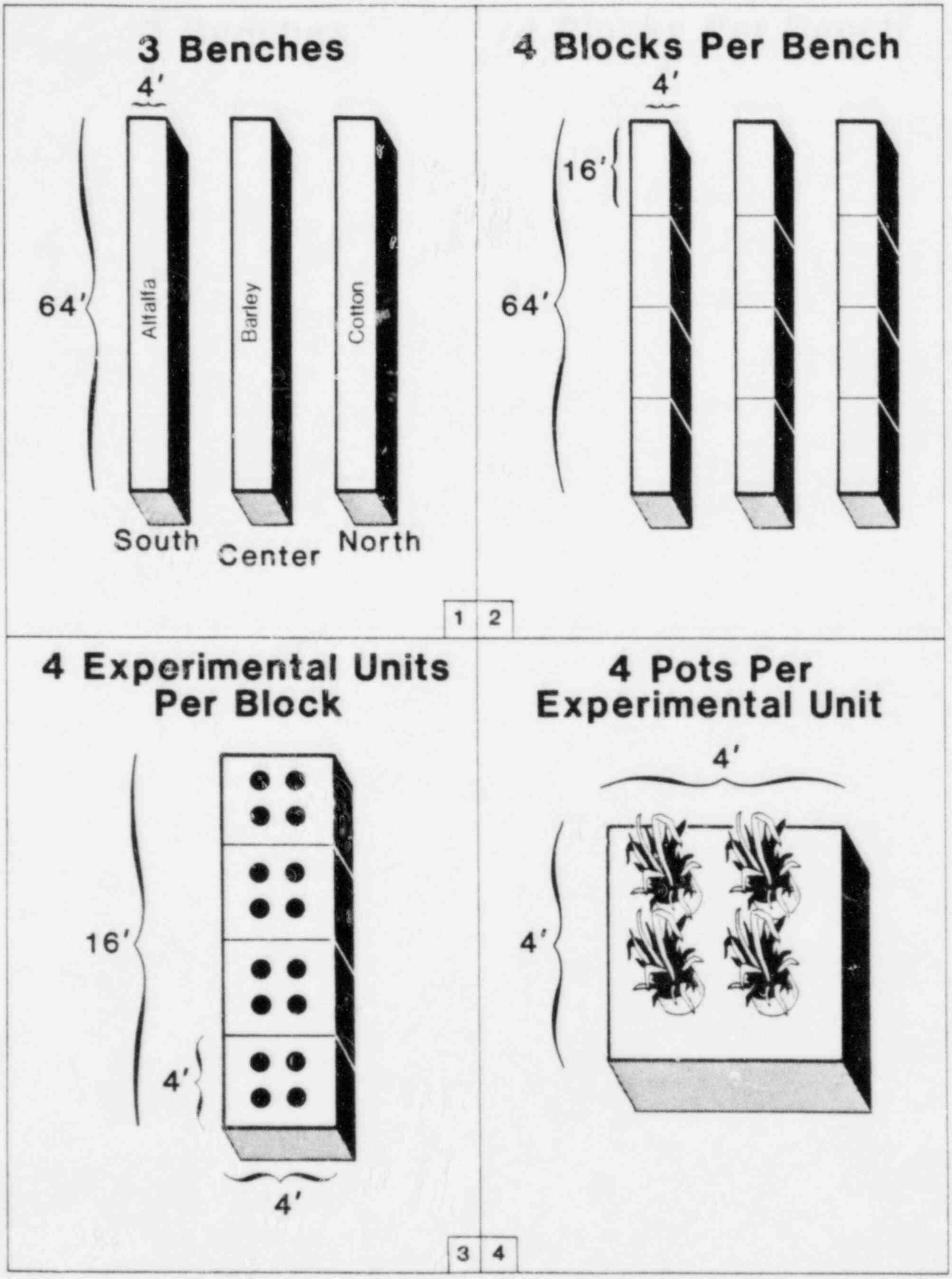


Figure 3. Experimental plan for the north greenhouse

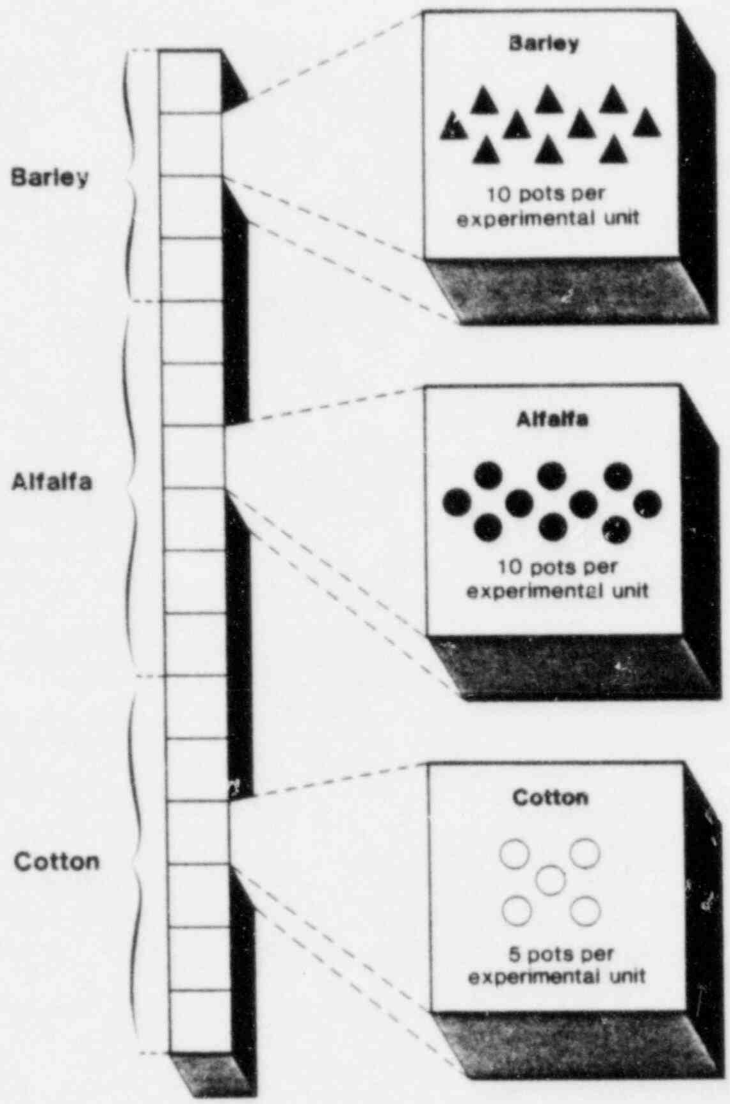


Figure 4. Experimental plan for the south greenhouse

2-gallon pots and was thinned to two plants per pot. Alfalfa seeds were planted in 2-gallon pots and thinned to approximately 10 plants/pot (seedlings). Alfalfa transplants from the United States Department of Agriculture's Plant Materials Center were planted in 2-gallon pots. Clear plastic sheeting with holes cut for the plants to grow through was placed over the pots. To help prevent overheating of the soil the plastic covering was elevated on stakes 5 cm above the rim of the pot.

When required, irrigation was applied to the plants through the 1 gallon/hour drip emitters. Irrigation duration ranged from 20 to 30 minutes, or until the water began to leak from the bottom of the pot (PSP Procedures CA-36, and CA-39).

Fertilizer was added weekly to the irrigation water (fertigation). A Smith Measure Mix Liquid Fertilizer Injector, Model R-3, ensured a uniform and constant rate of application to each pot. Peter's Professional Water Soluble Fertilizer (20-20-20 plus micronutrients) was initially used as the sole nutritional source. The fertilizer injector mixed the weighed quantity of nutrients with irrigation water to deliver a solution with a concentration of 100 ppm nitrogen. The total weekly fertilizer amendment for each pot was 0.5 gallon of water and 100 ppm nitrogen. When required to maintain proper nutrient levels, Hoagland's solution and urea were applied directly to the pots (PSP Procedures CA-35, CA-36, and CA-39).

Lannate, Malathion 50, Thuricide, Fulex DDVP, and Clean Drop Dimethoate 267 EC Systemic Insecticide were used as needed for insect control in both greenhouses (PSP Procedure CA-32).

4.1.4. Treatment

In the north greenhouse crop species were treated with four nominal rates of deposition (0 [distilled water], 10, 100, and 500 lbs/a·yr). Whereas, in the south greenhouse crop species were treated with 0 (distilled water) and a nominal 1000 lbs/a·yr treatment. To apply these levels of treatment, a known volume and composition of simulated saline drift was applied at regular intervals.

4.1.4.1. Preparation of Simulated Saline Drift Treatment Solutions

Three simulated saline drift solution formulations were provided by the Bechtel Power Corporation over the duration of this study (Table 2). Stock solutions of each compound were prepared. Treatment solutions were prepared by combining aliquots of the stock solutions with distilled water. The amount of stock solutions used to prepare the final treatment solutions was based on the hydrated chemical weights (Table 2a).

Salt solutions were applied to the plants in the greenhouses by means of a chain driven spray boom mounted in a specially designed portable plexiglass chamber measuring 4 ft-by-4 ft at the base with a height of 7 ft (Figures 5 and 6). Each spray rig was adjustable and was raised or lowered to approximately 0.5 m above the crop canopy during spraying. A vinyl curtain was attached at the top of the spray chamber on a spring loaded roller to contain the spray within the experimental unit. Velcro was used to ensure a tight curtain seal at the chamber sides. Gutters at each endpoint of boom travel collected excess solution that dripped from the nozzles.

The volume of solution applied to the experimental units was dependent upon nozzle delivery rates and spray boom speed. The speed of the boom was adjusted so that the correct amount of solution could be dispersed over the area of each experimental unit in two passes of the boom. The area of each experimental unit was 1.48 m^2 (16 ft^2). As an example, the concentration of the treatment solution to be applied to the experimental units in the nominal 500 lbs/a·yr treatment group during a 5-day week, were calculated as follows:

treatment solution concentration [TSC] (g/l) =

$$\frac{\text{salt treatment (g/experimental unit area[EUA]·wk)}}{\text{spray volume (l/EUA)}}$$

salt treatment:

$$500 \text{ lbs/a·yr} = 226800\text{g/a·yr} \div 43560 \text{ ft}^2\text{/a} \div 52 \text{ wk/yr} \times 16 \text{ ft}^2\text{/EUA}$$

$$= 1.60 \text{ g/EUA·wk}$$

Table 2.

Simulated Saline Drift Formula
(Provided by Bechtel Power Corporation)

Chemical	Revision 2 7/20 - 12/2	Revision 1[a] —	Revision 0 5/24 - 7/19
	Quantity lbs/1000 gal		
Distilled H_2O	995 (gal)	995 (gal)	995 (gal)
$Na_2SO_4 \cdot 10H_2O$	68.0	68.0	68.0
NaCl	54.0	54.0	54.0
$NaNO_3$	26.6	26.6	26.6
$CaCl_2 \cdot 2H_2O$	10.0	10.0	10.0
$Na_2Si \cdot O_3 \cdot 9H_2O$	3.1	3.1	3.1
KOH	2.5	2.5	--
$MgSO_4 \cdot 7H_2O$	2.0	2.0	2.0
$NaHCO_3$	0.6	0.6	0.6
NALCO 1370[b]	0.21	0.21	0.25 (NALCO 345)[c]
$Na_3PO_4 \cdot 12H_2O$	0.2	0.2	0.2
NH_4Cl	0.05	0.05	0.05
$BeSO_4 \cdot 4H_2O$	0.05	0.05	0.05
$FeCl_3 \cdot 6H_2O$	0.04	0.04	0.04
NaF	0.03	0.03	0.03
H_3BO_3	0.03	0.03	0.03
$MnCl_2 \cdot 4H_2O$	0.022	0.022	0.014 ($MnCl_2$)
$ZnCl_2$	0.02	0.02	0.02
$SrI_2 \cdot 3H_2O$	0.02	0.002 ($SrI_2 \cdot 6H_2O$)	--
$CuCl_2$	0.005	0.005	0.005
Phenol	0.0012	0.0012	--
$AgNO_3$	0.0007	0.0007	0.0007
$Pb(NO_3)_2$	0.0004	0.0004	0.0004
As_2O_3	0.0003	0.0003	0.0003
$Ba(NO_3)_2$	0.0002	0.0002	0.0002
$CdCl_2$	0.0002	0.0002	0.0002
SeO_2	0.0002	0.0002	0.0002
CrO_3	0.0001	0.0001	0.0001
$HgCl_2$	0.00002	0.00002	0.00002

[a] Not applied to plants.
[b] Proprietary water treatment chemical.
[c] NALCO 1370 used to prepare treatment solutions.

Table 2a.

Simulated Saline Drift Anhydrous Formula
(Provided by Bechtel Power Corporation)

Chemical	Quantity lbs/1000 gal	Anhydrous lbs/1000 gal
Distilled H_2O	995 (gal)	
$Na_2SO_4 \cdot 10H_2O$	68.0	29.979
NaCl	54.0	54.0
$NaNO_3$	26.6	26.6
$CaCl_2 \cdot 2H_2O$	10.0	7.550
$Na_2Si \cdot O_3 \cdot 9H_2O$	3.1	1.331
KOH	2.5	2.5
$MgSO_4 \cdot 7H_2O$	2.0	0.977
$NaHCO_3$	0.6	0.6
NALCO 1370[a]	0.21	0.21
$Na_3PO_4 \cdot 12H_2O$	0.2	0.0863
NH_4Cl	0.05	0.05
$BeSO_4 \cdot 4H_2O$	0.05	0.03
$FeCl_3 \cdot 6H_2O$	0.04	0.0235
NaF	0.03	0.03
H_3BO_3	0.03	0.03
$MnCl_2 \cdot 4H_2O$	0.022	0.0137
$ZnCl_2$	0.02	0.02
$SrI_2 \cdot 3H_2O$	0.02	0.0173
$CuCl_2$	0.005	0.005
Phenol	0.0012	0.0012
$AgNO_3$	0.0007	0.0007
$Pb(NO_3)_2$	0.0004	0.0004
As_2O_3	0.0003	0.0003
$Ba(NO_3)_2$	0.0002	0.0002
$CdCl_2$	0.0002	0.0002
SeO_2	0.0002	0.0002
CrO_3	0.0001	0.0001
$HgCl_2$	0.00002	0.00002
TOTAL	167.48032	124.05612

[a] Proprietary water treatment chemical.

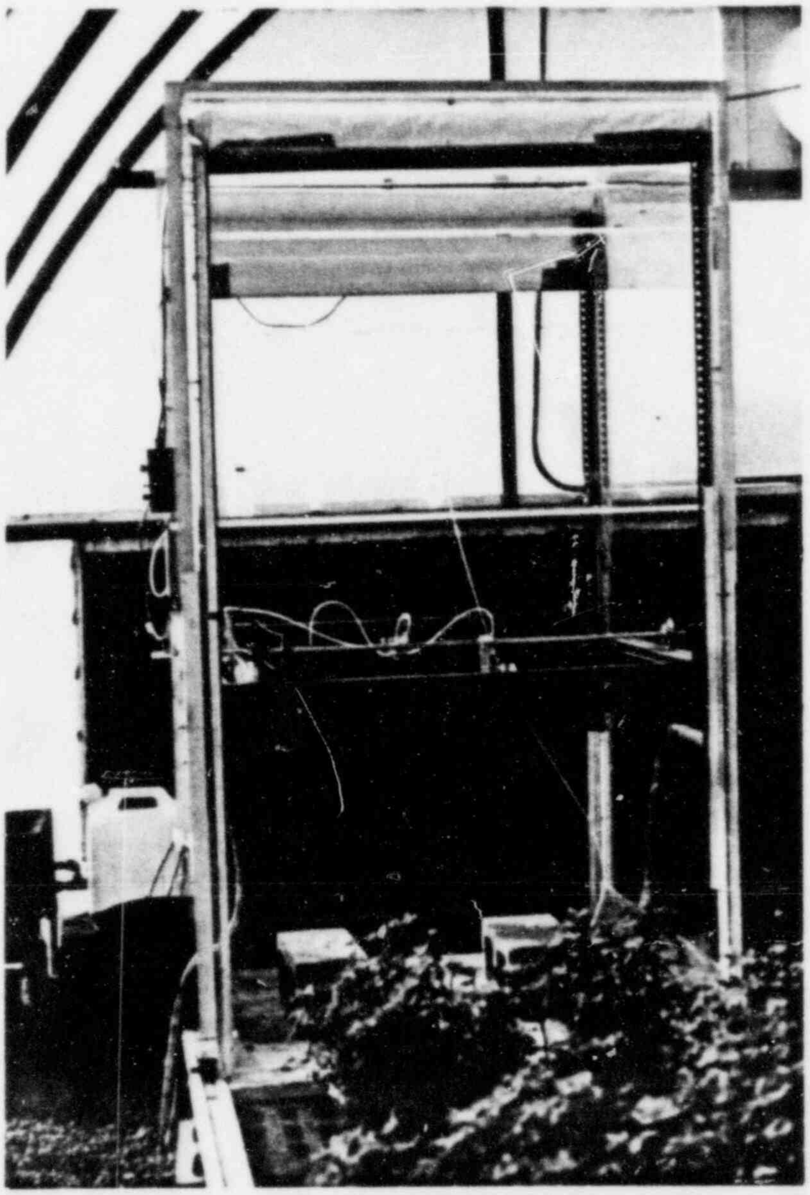
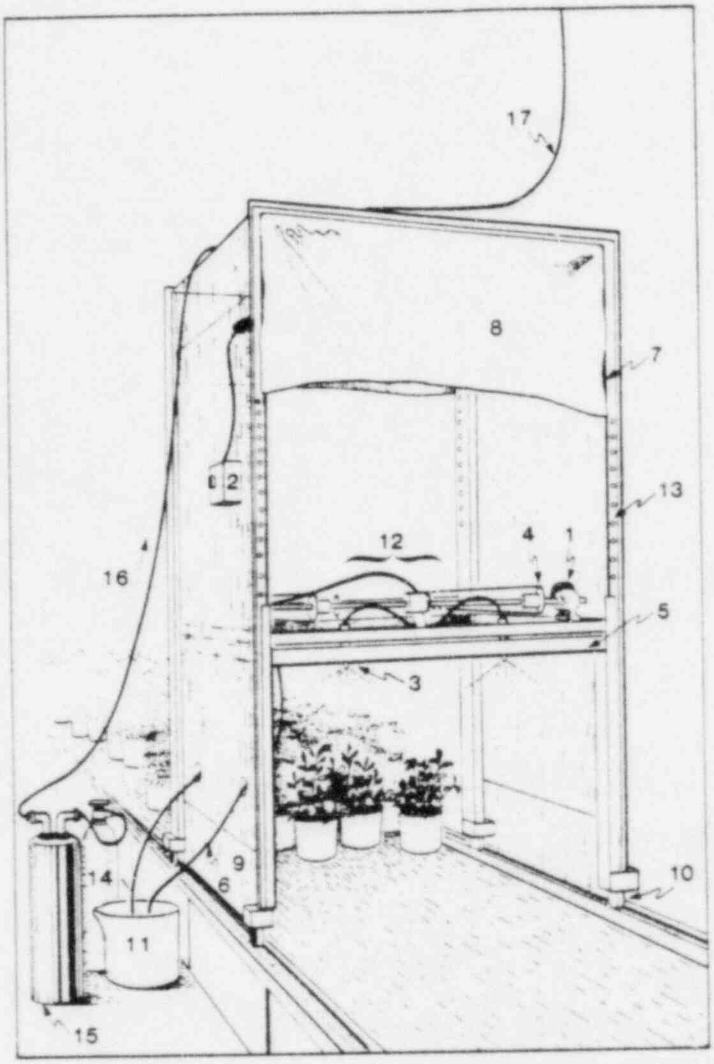


Figure 5. Spray boom rig used to apply simulated saline drift to greenhouse plants



1 drive motor
2 control box
3 spray nozzle
4 chain drive
5 gutter
6 gutter hoses
7 Velcro strips on edges of curtains
8 vinyl curtains
9 skirts on bottom of chamber
10 wheels
11 drain bucket
12 spray boom rig
13 height adjustment angle iron
14 compressed nitrogen tank
15 salt solution tank
16 salt solution under pressure
17 power supply line

Figure 6. Plexiglass chamber and spray boom rig

spray volume:

2 nozzles = 0.017 l/EUA·day

TSC = 1.60g/EUA·wk ÷ (0.017 l/EUA·day x 5 day/wk)

= 1.60g/EUA·wk ÷ 0.085 l/EUA·wk

= 18.82g/l

Application rates and solution concentrations are shown in Table 3. The nominal 100 lbs/a·yr treatment solution was prepared by diluting an aliquot of the nominal 500 lbs/a·yr treatment solution. The nominal 10 lbs/a·yr treatment solution was prepared by diluting an aliquot of the nominal 100 lbs/a·yr treatment solution. The pH of each of the final solutions was adjusted to 6.8-7.0 using sulfuric acid (H_2SO_4). The calculations for the nominal 1000 lbs/a·yr solution differed somewhat from the nominal 500 lbs/a·yr solution because the spray boom delivered only 15 ml with two passes of the boom, requiring a treatment solution concentration of 42.67 g/l (PSP Procedures CA-25 and CA-33).

4.1.4.2. Application of Simulated Saline Drift Treatment Solutions

Treatment was accomplished as follows: a stainless steel tank was pressurized to 80 pounds per square inch (psi) ± 5 psi using nitrogen gas and connected to the Spraying Systems Model SF-2 (hollow cone) spray nozzles located on the bottom of the spray boom. The volume of solution delivered was monitored each spraying day in both greenhouses by holding a Nalgene graduated cylinder beneath a moving nozzle, thus measuring the amount of liquid sprayed by each nozzle during two passess of the boom. Delivery rates were adjusted to the 15 ml or 17 ml standard by adjusting the boom velocity. Boom travel was then timed with a stopwatch in order to check and adjust boom speed as the day progressed (PSP Procedure CA-22).

Spraying was done in increasing order of concentration, beginning with the distilled water controls. After each spraying, the vinyl curtains were raised and the outside of the gutters were wiped off to prevent excess solution from dripping on the plants. The chamber then was moved to the next experimental unit to be sprayed.

Table 3.

Greenhouse Treatment Rates and Solution Concentrations

Treatment Number	Nominal Treatment Rates (lbs/a·yr)	Treatment Solution Concentration (mg/l)	Treatment Solution Volume (ml)
1	0[a]	0	17 or 15[b]
2	10	376.3	17
3	100	3763	17
4	500	18815	17
5	1000	42667	15

[a] Distilled water.

[b] The treatment solution volumes in the north and south greenhouses were 17 and 15 ml, respectively.

After the final spraying at each concentration level, 500 ml samples of each treatment solution were collected from the nozzles. Analyses of the concentrations were run on weekly (5 day/wk) composites of these 500 ml samples. The University Analytical Center, Department of Chemistry, University of Arizona, analyzed samples of the distilled water and simulated saline drift solutions collected from the spray nozzles during spraying at the greenhouse. Total dissolved salts (TDS), pH, and ionic concentrations of major species (sodium, chloride, sulfates, calcium, magnesium, potassium, and nitrates) and minor species were determined according to standard procedures (Methods for APS Salt Drift Project).

Following completion of spraying, the chamber was placed on a cart for cleanup. The nozzles were flushed with distilled water for 6 minutes, were removed from the spray rig, and were dried with compressed air. The nozzles were not replaced in the spray rig until the next application day to ensure that they remained dry and unclogged. The inside of the chamber was thoroughly cleaned and dried after completion of the spraying (PSP Procedure CA-22).

The salt delivery of the spray boom was evaluated using parafilm covered petri dishes (McCune et al., 1977). Two petri dishes covered with parafilm were placed at the plant canopy height. The two-nozzle spray boom rig was operated in the same manner as in the treatments. After exposure to the spray, the petri dishes were covered, marked, and returned to the laboratory for conductivity measurements.

In the laboratory, the parafilm was removed from the petri dishes, and the salt exposed side of parafilm was placed face down for 5 minutes in 6 ml of distilled water to dissolve the salts on the parafilm surface. Electrical conductivity measurements then were taken of the 6 ml solution with a Model 4503 Selectro Mark Analyzer. The quantity of salts deposited was estimated from a standard curve (PSP Procedures CA-13 and CA-14).

Droplet size measurements were taken once a week using a photographic paper technique (Farlow, 1954; Stainer and Stow, 1976). A piece of predeveloped paper (Iford-Ilfobrom 4.24K semi-mat, double weight, developed in Kodak Dektol developer, air dried in darkness) was placed under a nozzle at

the same height as the plant canopy. The spray boom was passed over the paper once, covering it with droplets. The paper was exposed to bright light to intensify the droplet marks, then placed in Kodak Fixer General Purpose (10 minutes), rinsed in water (10 minutes), and air dried. The droplets were measured using an ocular micrometer (20 mm diameter disc with 5 mm length line divided into 50 units) installed in a Bausch and Lomb Compound Microscope (PSP Procedure CA-9).

A Sierra Instruments Model 244 Dichotomous Virtual Impactor was used in the north greenhouse to monitor for background salts (PSP Procedure CA-43).

Table 4 presents a schedule for planting, harvesting, and treatment for the greenhouse experiments.

4.1.5. Evaluation of Plant Response

4.1.5.1. Selection of Plants for Evaluation

One plant from each experimental unit was used for repeated measurements using the porometer and psychrometer throughout the growing season and was not included in the final harvest. Visual evaluations were performed on the remaining plants of each experimental unit.

4.1.5.2. Visual Observations

Plants in the controls and the nominal 500 lbs/a·yr or nominal 1000 lbs/a·yr treatments were evaluated weekly. Observations were recorded and photographs were taken of the plants. Plants were evaluated for insect and fungal damage, necrosis, chlorosis, leaf deformity, plant height, turgidity, epinasty, and the number of flowers and/or fruit estimated. Cotton flowers were tagged as they appeared and the number of flowers were recorded (PSP Procedures CA-24, CA-31, and CA-40).

Table 4.

Planting, Harvesting and Treatment Schedule for the Greenhouse, 1983

Crop	Planting Date	Start of Treatment	End of Treatment	Spray Days Potential[a]	Spray Days Applied	Date of Harvest
North Greenhouse						
Cotton	5-27	6-3	10-12	94	92	10-13 to 10-17[b]
Alfalfa transplants	5-12	6-3	12-2 11-2[c]	101[cd]	99[cd]	6-24, 7-11, 8-1, 8-24 9-12, 9-28, 10-25
seedlings	6-28	7-14	12-2 11-2[c]	75[cd]	74[cd]	8-12, 9-12, 9-30, 10-25
Barley	7-18	8-8	10-19	53	51	10-20
South Greenhouse						
Cotton	6-29	7-13	11-11	88	86	11-14[b]
Alfalfa transplants	6-23	7-13	12-2 11-2[e] 11-23[f]	77[de]	76[de]	8-10, 9-6, 9-27, 10-24
seedlings	6-29	7-13	12-2 11-2[e] 11-23[f]	77[de]	76[de]	8-10, 9-6, 9-27, 10-24
Barley	6-29	7-13	10-06	62	61	10-7

[a] Potential spray days are 5 days/wk Monday through Friday.
[b] Dates of biomass harvest, seed cotton harvested as it matured.
[c] Last day of any data collection, plants not sprayed on 2 November 1983.
[d] Plants not sprayed on date of harvest.
[e] Last day of any data collection 2 November 1983, plants sprayed.
[f] Plants moved to north greenhouse.

4.1.5.3. Resident Surface Salts on Plants

The quantity of resident surface salts was estimated by measuring the area of the leaves and washing the leaves to remove the accumulated salts from the surface of the leaves.

After biomass harvesting, all crop species were washed to remove the resident salts from the surface of the plants. The plastic bags in which the plants were stored were rinsed with distilled water and the rinse water was combined with the plant wash solution. Each plant was dipped once in a beaker containing 2000 ml distilled water for 15 seconds and then was dipped in a second beaker containing 2000 ml distilled water for another 15 seconds. The water in the two beakers was then combined and a sample was reserved in a 2-oz plastic bottle. Electrical conductivity readings were made on the reserved sample. The concentration of the salt was determined from a standard curve. Plastic gloves were worn at all times to prevent contamination (PSP Procedures CA-3, CA-13, CA-27, and CA-28).

4.1.5.4. Steady-State Porometer Measurements

Transpiration, diffusive resistance, relative humidity, leaf temperature, and cuvette temperature measurements were taken weekly from each plot on the abaxial surface of the youngest fully expanded cotton leaf, the abaxial surface of a barley leaf blade, and the fourth leaf down from an apex of an alfalfa plant. All measurements were taken with a LI-COR LI-1600 Steady-State Porometer. Measurements were taken from a 2.0 cm^2 leaf area for cotton and 0.6 cm^2 leaf area for barley and alfalfa (Beardsell, Jarvis and Davidson, 1972) (PSP Procedure CA-42).

4.1.5.5. Leaf Area Measurements

Leaf area measurements were taken with the LI-COR LI-3000 Portable Area Meter in the greenhouse and the LI-COR 3100 in the laboratory. One plant was selected from each experimental unit for measurement at the time of harvest. Approximately 20% to 25% of each representative alfalfa and barley plant was removed from the plastic bag. All leaves were removed from

this sample and were run through the leaf area meter, and then dried. After drying, the leaf area of the whole plant was estimated by comparing the dry weight of the sample to the dry weight of the entire plant. Cotton leaves were separated into several pieces in order to fit into the transparent sheath (PSP Procedures CA-1, and CA-2).

4.1.5.6. Leaf Water Potential Measurements

Leaf water potential measurements were taken with a Wescor HP-115 Water Potential data system according to the method of Walker, Oosterhuis and Savage (1983). Attached leaves were washed by dipping them in 500 ml of distilled water for 30 seconds and allowing them to dry at room temperature. Two 6-mm diameter leaf disks were taken from the fully expanded leaves of cotton and barley. The two leaf disks were placed in a sample chamber, abaxial side up, approximately 2 mm below the psychrometer (PSP Procedure CA-26).

4.1.5.7. General Harvest and Yield Procedures

4.1.5.7.1. Alfalfa

Alfalfa plants were harvested when approximately 50% of the plants in all experimental units were at 10% bloom (approximately one inflorescence/plant). The plants were cut approximately 2.5 cm above the soil medium, immediately placed into labelled plastic bags, and stored in an ice cooler until transfer to the main campus of the University of Arizona for storage in a refrigerator. Fresh weights of alfalfa were taken as soon as the plants were brought to the laboratory. In the north greenhouse, the transplants were harvested seven times, and the seedlings were harvested four times. In the south greenhouse, the transplants and seedlings were harvested four times (Table 4) (PSP Procedure CA-3).

Leaf area measurements were made at harvest on one representative alfalfa plant from each experimental unit. A LI-COR LI-3000 leaf area meter was used as previously described (cf. 4.1.5.5).

The harvested alfalfa tissue was placed in paper bags and was dried in a General Signal "Stabil-Therm" forced draft oven at 80 C for at least 36 hours. Dry weights of each plant were then taken. The plants were then ground in a UDY Cyclone Sample Mill (Model MS), and the ground samples were stored in labelled envelopes. These samples were sent to the University of Arizona's Soils, Water, and Plant Testing Laboratory for analysis of 13 essential elements (nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, boron, copper, chlorine, iron, manganese, molybdenum, zinc) and sodium. Twelve plants from the control and the nominal 500 lbs/a·yr simulated saline drift treatment were analyzed from six harvests (PSP Procedures CA-3, and CA-23).

4.1.5.7.2. Cotton

Seed cotton and bracts were harvested from each plant and weighed as the bolls matured. The bracts were dried at 80 C for at least 36 hours in a General Signal "Stabil-Therm" constant temperature oven and dry weights were obtained. Lint samples were sent to the United States Department of Agriculture Marketing Service Cotton Laboratory at Memphis, Tennessee, for quality analysis (PSP Procedures CA-28, and CA-41).

Cotton leaves with attached petioles, green bolls, squares, and flowers (including entire pedicels), stems, and all axillary branches were placed in plastic bags. Fresh weights were obtained using a Mettler balance and the samples were stored in a refrigerator. Plastic gloves were worn at all times while harvesting the plant material.

The detached plant parts were rinsed in distilled water and electrical conductivity readings were taken of the salt solution as previously described (cf. 4.1.5.3.). Leaf area measurements were taken from 25% to 35% of the leaves of one plant randomly selected from each plot. Dry weights of the leaf samples were obtained and total leaf areas were estimated by comparing the dry weight of each measured leaf area portion with the dry weight of the entire plant. The plants were dried and ground as described above. Twelve control plants and an equal number of plants treated with nominal 500 lbs/a·yr simulated saline drift were analyzed for 13 essential elements and Na^+ (PSP Procedures CA-28, and CA-13).

4.1.5.7.3. Barley

The heads of each barley plant were removed and placed in a labelled plastic bag. The remaining above ground portion of each plant (stems, leaf blades) was placed in another labelled plastic bag. Fresh weights were taken using a Mettler balance and the plants stored in a refrigerator (PSP Procedure CA-27).

Salts residing on the plant surfaces were washed off the plant with distilled water as described above and electrical conductivity readings were taken of the salt solutions (PSP Procedures CA-27, and CA-13).

The plants were dried as described above in Section 4.1.5.7.1. The dry barley heads and florets were counted for each plant. The heads were threshed to dislodge the seeds and winnowed to remove the chaff. Seeds were counted and weighed and the percentage seed set for each plant was determined. Dried plant material was ground using a UDY Cyclone Sample Mill (Model MS) as described in section 4.1.5.7.1. Vegetative tissue from twelve plants from the control and nominal 500 lbs/a·yr simulated saline drift treatment were analyzed for 13 essential elements and Na^+ (PSP Procedures CA-27, and CA-23).

4.2. FIELD PROJECT DESIGN

4.2.1. Experimental Design

The experimental plan for each crop in the field study consisted of a randomized complete block design with eight replications of each treatment. Cotton (Gossypium hirsutum L. 'Deltapine 90'), alfalfa (Medicago sativa), and Cantaloupe (Cucumes melo L. 'Top Mark') were cultivated.

4.2.1.1. Cotton

The cotton was grown in eight blocks arranged in two 985 ft-by-38 ft strips. Each strip contained 20 plots. Each plot consisted of 12 rows 35 ft in

length with 38 in. row spacing. Fifteen ft alleys were established between plots. The 40 plots were numbered in sequence from 41 to 80. Two rows on each side (east and west) of a plot served as border rows; the plants in these rows were not analyzed. The two rows (rows 3 and 4) adjacent to the two border rows on the eastern side (rows 1 and 2) were machine harvested at the end of the season (Figure 7). Flower tagging and hand harvesting was conducted in the third row from the western edge of each plot (row 10). Visual observations were taken from the fourth row from the western edge of each plot (row 9). Random selection of plants was accomplished by tossing a stick. Additional measurements such as porometer and water potential readings were taken in rows 9 and 10 (Figure 7). Data were not collected from the center four rows (rows 5-8). Field roads measuring 13 ft wide were established on each side of the two blocks to permit spraying with the tractor spray boom rig. Four additional border rows were planted on the west and east side of the experiment to act as buffers.

4.2.1.2. Alfalfa

Alfalfa was cultivated in four borders running north and south in an established field of 3-year-old alfalfa. Each of the four borders consisted of 12 plots, numbered in sequence from 81 to 128. Each plot measured 35 ft-by-18 ft and was separated from adjoining plots by 15 ft alleys (Figure 8). Plants in the alfalfa plots used for observations and measurements were randomly selected.

4.2.1.3. Cantaloupe

The cantaloupe was grown in eight experimental blocks grouped into two strips measuring 985 ft-by-20 ft. The two strips were separated by a 10-ft alley. Forty plots were used, each measuring 35 ft by 20 ft and separated from adjoining plots by 15-ft alleys. The plots were numbered in sequence from 1 to 40. Each plot contained three rows (north and south) spaced 80 in. apart. The center row of each plot was used for plant and fruit evaluation (Figure 9). Random selection of plants for visual evaluation was accomplished by tossing a 55 cm-by-25 cm frame into the middle row (PSP Procedure CA-18).

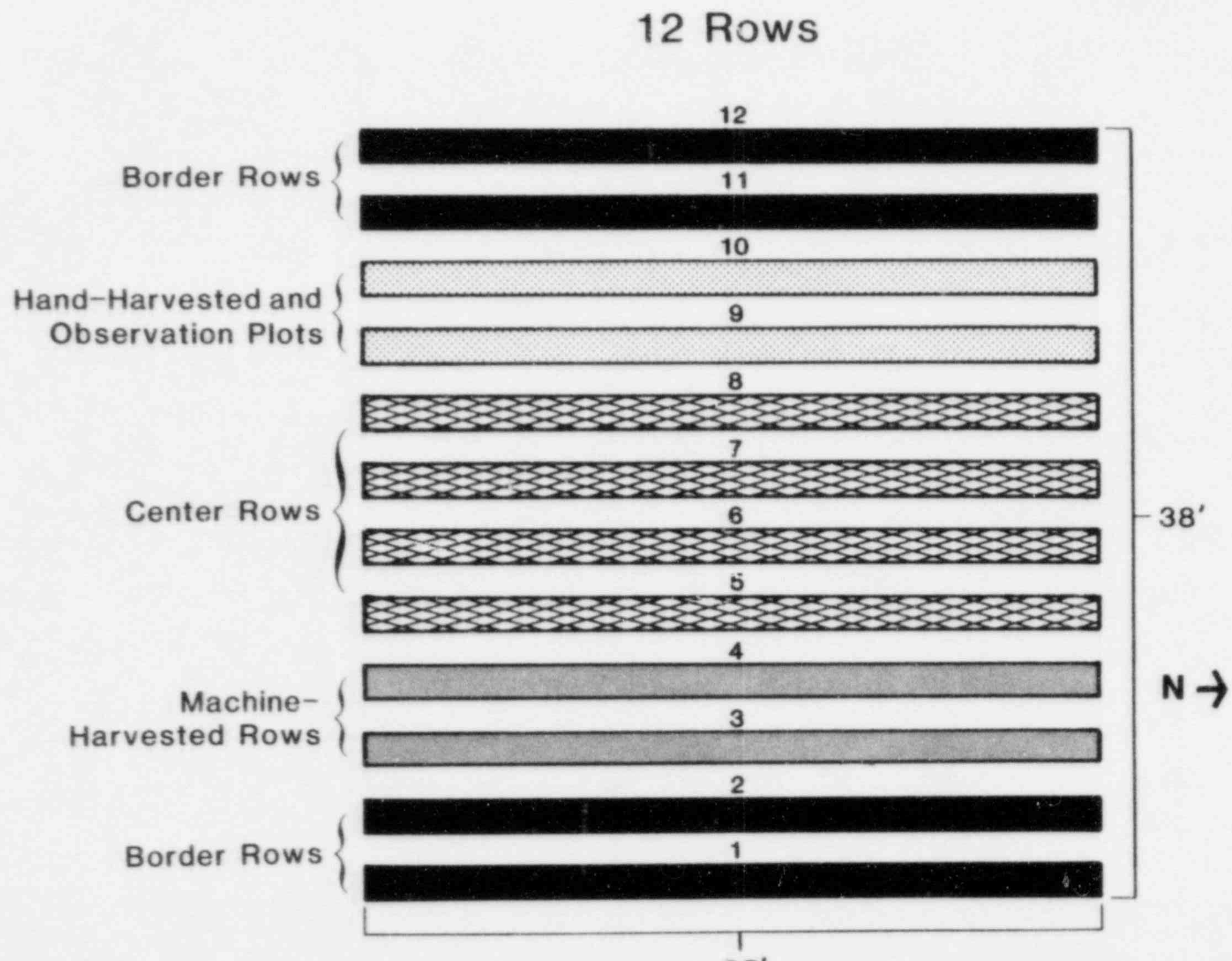


Figure 7. Cotton plots at the Marana field site

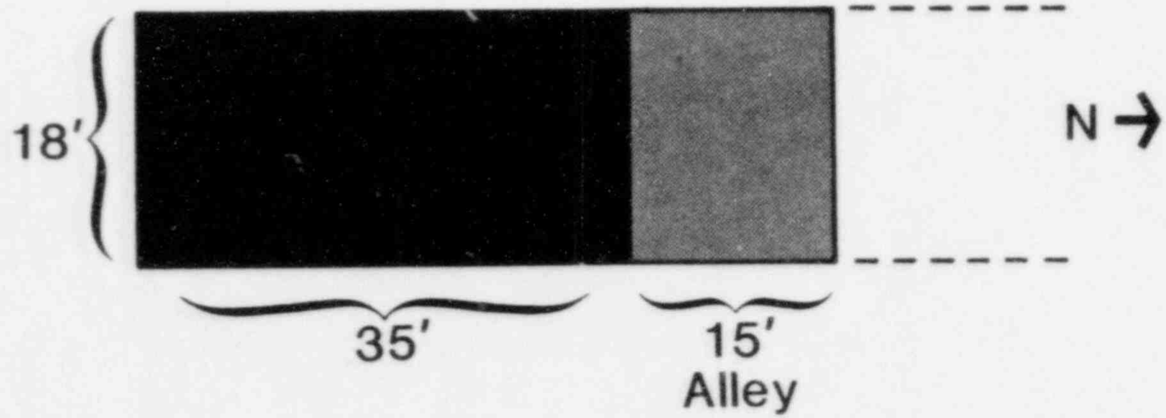


Figure 8. Alfalfa plots at the Marana field site showing alley between plots

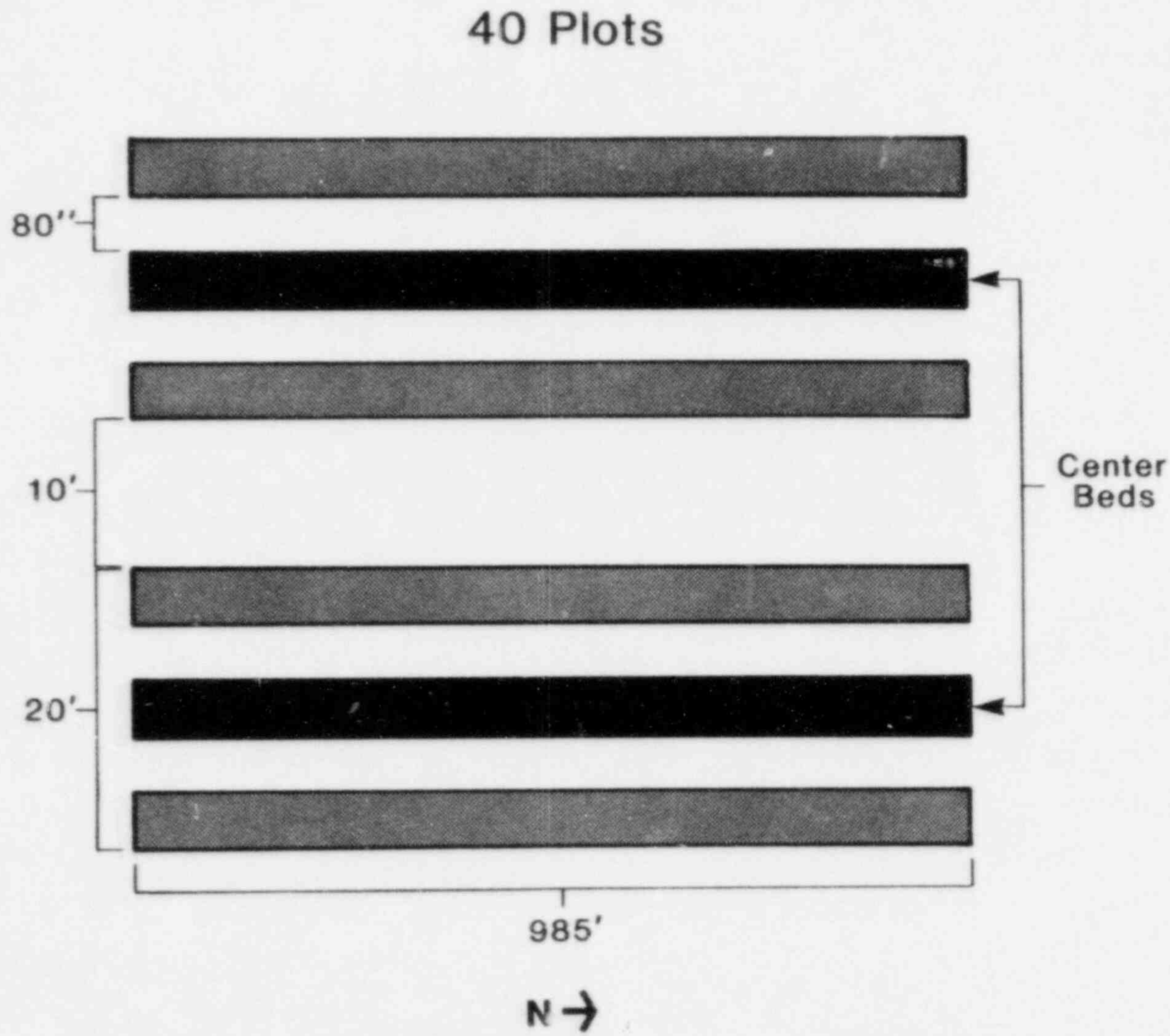


Figure 9. Cantaloupe strips at the Marana field site

4.2.2. Plant Culture

The alfalfa plots were established in a 3-year-old stand of alfalfa. The cotton and cantaloupe were planted for this study. Cultural practices including the amount and timing of irrigation for these crops were conducted by the farm operator, using practices in general use for proper farm management, except for the application of Benlate 50WP fungicide on the cantaloupe to control powdery mildew. Alfalfa was commercially harvested with a swather and was baled before the first treatment and following each sample harvest (PSP Procedures CA-17, and CA-19).

4.2.3. Treatment

Four nominal rates of deposition (0 [distilled water], 10, 100, and 500 lbs/a·yr) and an unsprayed control were selected to evaluate the effects of foliar deposition and accumulation on the selected species. In addition, a nominal 1000 lbs/a·yr treatment was included for alfalfa.

4.2.3.1. Preparation of Simulated Saline Drift Treatment Solutions

The composition of the simulated saline drift solution (Table 2) was provided by the Bechtel Power Corporation and was the same as that used in the greenhouse studies (cf. 4.1.4.1). The treatment solutions were prepared from stock solutions (PSP Procedures CA-25, and CA-33).

The salt solution was applied to the plots by a modified tobacco sprayer boom mounted on a Ford 1500 tractor. The sprayer had a 21 ft long spray boom on one side that was vertically adjustable from 2 ft to 8 ft above the ground. The boom was shrouded in a polyethylene curtain measuring 30 in. across the top and 15 in. on the sides (Figures 10, 11, and 11a). The boom carried four independent spray lines, each with 13 nozzles placed 19 in. apart, and had an effective spray width of 20.58 ft. Four tanks were mounted on the tractor. Each tank was connected to its own corrosion resistent roller pump, pressure regulator, and spray line, thus avoiding the possibility of contamination from other solutions (PSP Procedures CA-6, CA-16, and CA-21).

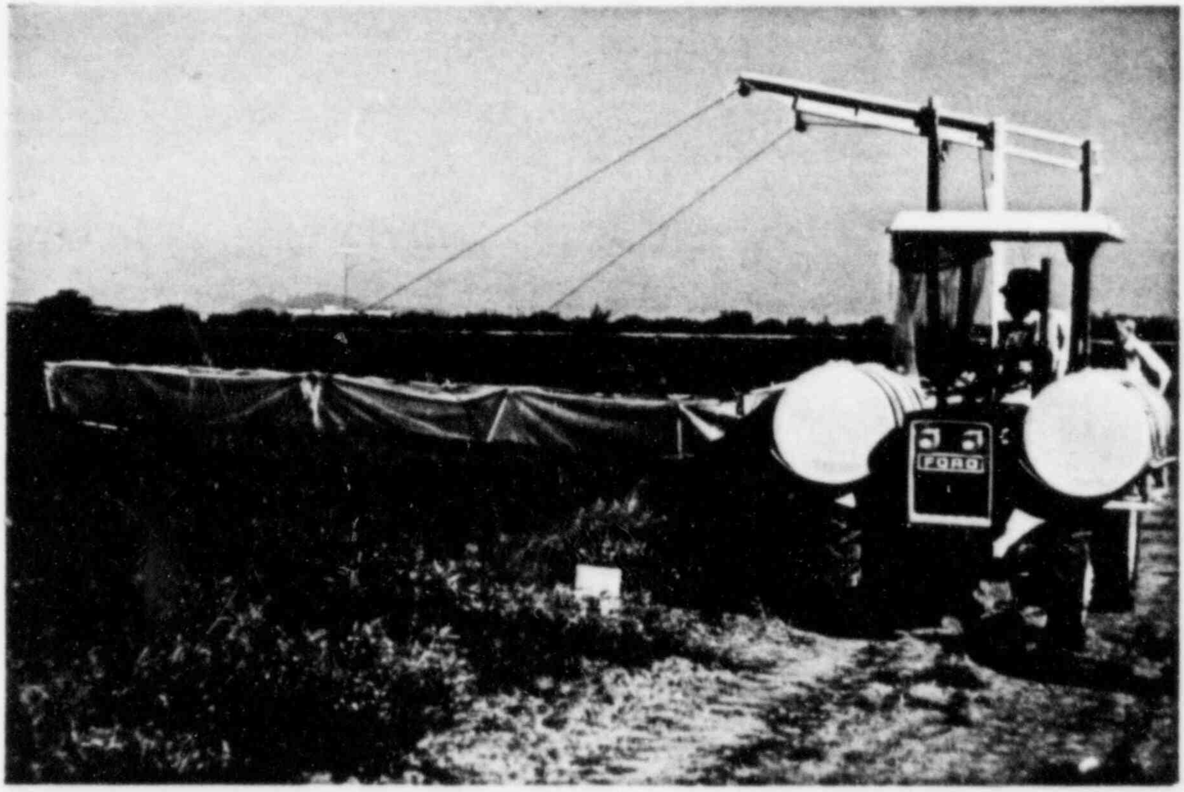
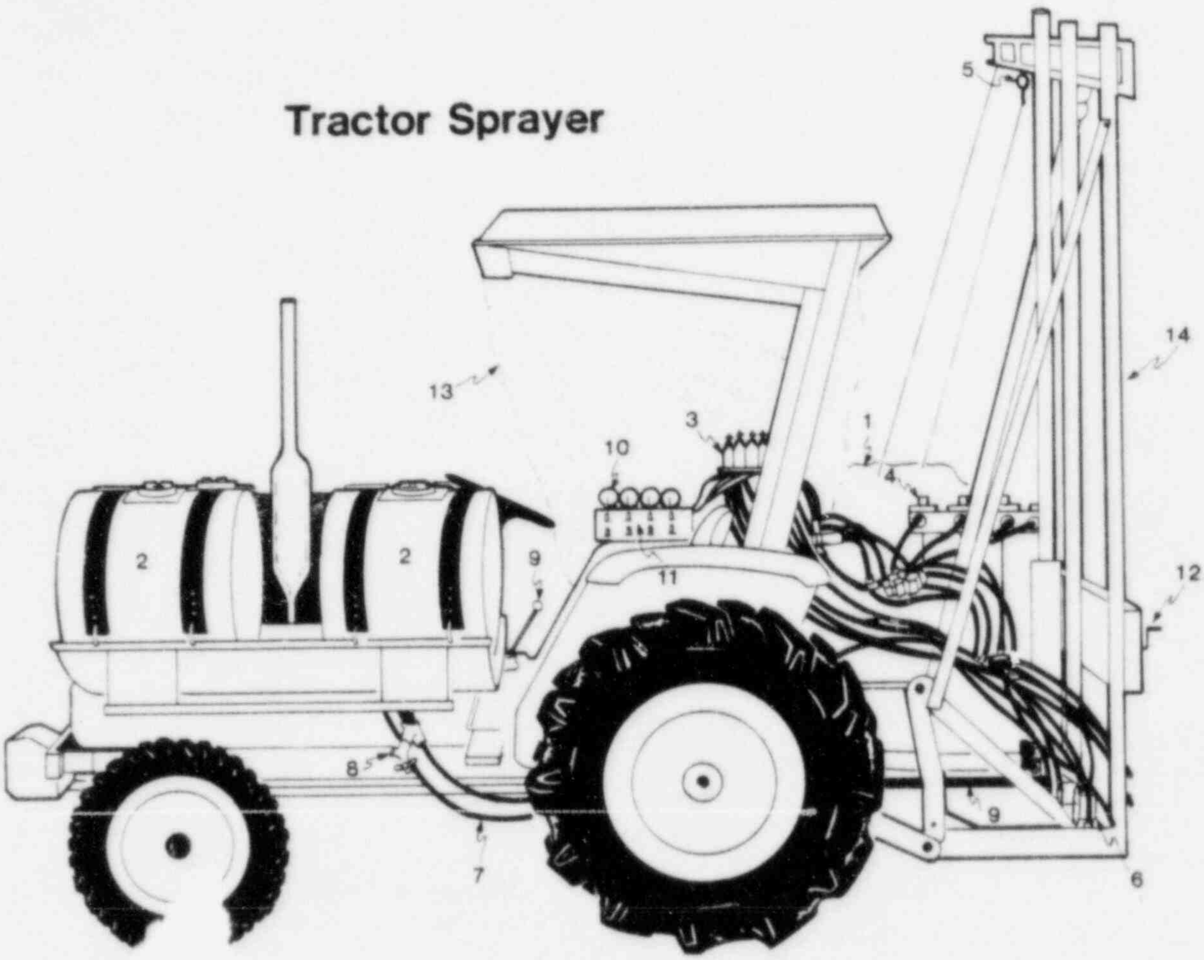
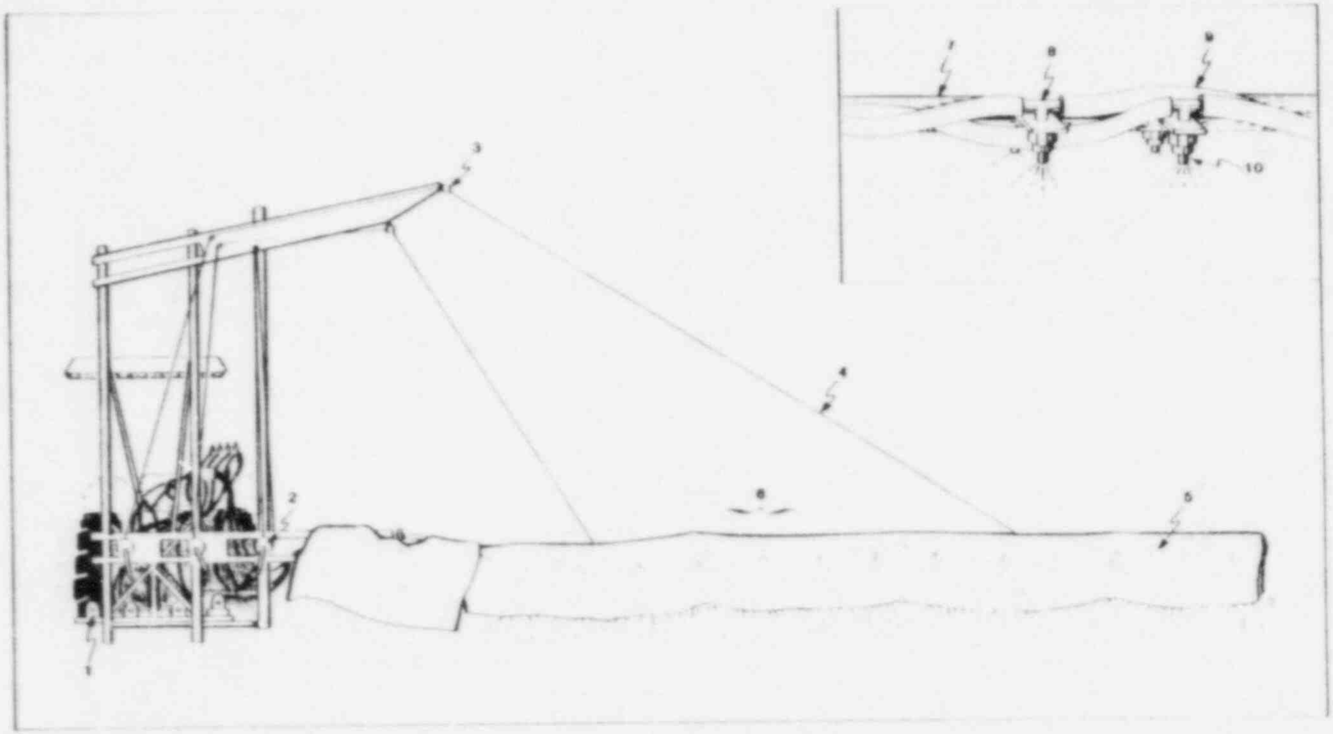


Figure 10. Tractor sprayer applying simulated saline drift to alfalfa at the Marana field site



1 spray boom
2 tanks
3 pressure regulators
4 solenoid valves
5 pulleys for adjusting height
6 pumps
7 hoses from tank to boom
8 drain spigot on tanks
9 PTO shaft
10 pressure gauges
11 switches (boom switches and regulator bypass switches)
12 boom adjustment winches
13 tractor curtain
14 boom stabilizer

Figure 11. Detailed diagram of the tractor sprayer



1 pump
2 boom adjustment winches
3 pulley
4 lift cable
5 curtain
6 boom
7 metal boom arm
8 fitting
9 spray line
10 spray nozzle

Figure 11a. Rear view diagram of tractor boom and spray distribution

The concentration of the treatment solutions applied to the crops was determined by nozzle delivery rates and tractor speed. The tractor speed was established with the engine running at 1650 RPM ± 50 RPM using a tachometer. At 1650 rpm, the tractor was run in ninth gear to apply the 0, nominal 10, and 100 lbs/a·yr treatments, and in third gear to apply the nominal 500 and 1000 lbs/a·yr treatments. Using a pressure of 90 psi the nozzle delivery rate of each nozzle was approximately 98.4 ml/min with a mass mean droplet diameter of 100 μ.

The plots for the three crops measured 35 ft in length. For calculations of treatment solution concentrations, plot width was established at 20.58 ft which is the total effective width of the spray boom. The transit time of the tractor in third gear along the length of a plot was 33.5 seconds, and in ninth gear, the transit time was 6.8 seconds. The concentration of treatment solution applied to the plots in the nominal 100 lbs/a·yr treatment group was calculated as follows:

treatment solution concentration [TSC] (g/l) =

$$\frac{\text{salt treatment (g/experimental unit area[EUA]·wk)}}{\text{spray volume (l/EUA)}}$$

where EUA = plot

salt treatment:

100 lbs/a·yr = 45360g/a·yr ÷ 52 wk/yr x 0.0165 a/EUA

= 14.393g/EUA·wk

spray volume:

13 nozzles = 0.1451 l/EUA·day

TSC = 14.393g/EUA·wk ÷ (0.1451 l/EUA·day x 5 day/wk)

= 14.393 g/EUA·wk ÷ 0.726 l/EUA·wk

= 19.84g/l

4.2.3.2. Application of Simulated Saline Drift Treatment Solutions

Each individual experimental plot was sprayed with one of the following nominal treatments: no spray; 0 lbs/a·yr (distilled water); 10 lbs/a·yr; 100 lbs/a·yr; and 500 lbs/a·yr (Table 5). Each alfalfa block also included a plot sprayed with a nominal 1000 lbs/a·yr treatment. In addition to the plot number, each plot was also labelled with a treatment number (Figure 12).

Treatments 5 and 6 were sprayed using the nominal 100 lbs/a·yr solution as follows: for treatment 5, the tractor was slowed to one-fifth the speed at which treatment 4 was sprayed, thus delivering 725 ml (5 x 145 ml) of the nominal 100 lbs/a·yr solution to the treatment 5 plots. Treatment 6 was sprayed in two passes of the tractor boom at the same speed as in treatment 5. Thus 1450 ml (2 passes x 5 x 145 ml) of the nominal 100 lbs/a·yr solution was applied to the treatment 6 plots.

The cotton plots were less than twice the width of the spray boom, and the salt solutions were applied from each side of the plots. The center four rows received more simulated saline drift, and were not used for data collection.

Aliquots of solutions were collected from the spray boom nozzles and were composited weekly; they then were analyzed at the University Analytical Center to confirm treatment solution concentrations (cf. 4.1.4.2.).

In addition, deposition of salts was measured weekly (or as conditions permitted) by placing three parafilm-covered petri dishes at the top of the plant canopy (McCune et al., 1977). One dish was placed in each of three plots at distances of approximately 5, 10, and 15 ft from the edge of the plot. The tractor spray boom then was driven across each of the three plots under the same operating conditions used for the treatments. After spraying, the dishes were covered and labelled. The dishes then were returned to the laboratory and electrical conductivity measurements were taken as described above in Section 4.1.4.2. (PSP Procedure CA-14).

Table 5.

Field Treatment Rates and Solution Concentrations

Treatment Number	Nominal Treatment Rates (lbs/a·yr)	Treatment Solution Concentration (mg/l)	Treatment Solution Volume (ml)
1	no treatment	0	0
2	0[a]	0	145
3	10	1.98	145
4	100	19.839	145
5	500	19.839	725
6	1000	19.839	1450

[a] Distilled water.

Figure 12. Alfalfa plot number 114 exposed to simulated saline drift treatment 6 (nominal 1000 lbs/a·yr)

Droplet sizes were measured weekly as conditions permitted using the procedure described above in Section 4.1.4.2. (PSP Procedure CA-9).

Table 6 presents a schedule for planting, harvesting, and treatment for the field study.

4.2.4. Evaluation of Plant Response

4.2.4.1. Visual Observations

Visual observations followed the procedure described in Section 4.1.5.2. (PSP Procedure CA-18).

4.2.4.2. Various Measurements

Suface salt deposition, steady-state porometer, leaf area, and leaf water potential measurements were made as described above in Section 4.1.5. (PSP Procedures CA-8, CA-11, CA-12, CA-4, CA-29, CA-1, CA-2, and CA-26).

4.2.4.3. General Harvest and Yield Procedures

4.2.4.3.1. Cotton

Cotton was harvested by a two-row cotton picker from the third and fourth rows (Figure 7). These rows were not used for any observations, measurements, or other procedures. Cotton from each plot was kept separate and the seed cotton yields weighed. The harvested cotton was ginned at the University of Arizona Cotton Research Center. Lint samples were sent to the United States Department of Agriculture Agricultural Marketing Service Cotton Division Laboratory at Memphis, Tennessee, to determine fiber quality (PSP Procedure CA-12).

Hand-harvested cotton was picked as it matured from a 7-ft section of the tenth row of each plot as shown in Figure 7 (PSP Procedure CA-12 and CA-15).

Table 6.

Planting, Harvesting and Treatment Schedule for the Marana Field Site, 1983

Crop	Planting Date	Start of Treatment	End of Treatment	Spray Days		Date of Harvest
				Potential	Applied	
Cotton	5-2	5-24	12-1	137	137	11-1 machine 12-1 machine
Alfalfa	Established plants	7-19	7-25	4[a]	3	7-25
		7-25	9-1	28	31	9-1
		9-1	11-3	45	43	11-3
Cantaloupe	5-24	6-6	9-28	83	83	8-19
						8-29
						9-9
						10-11

[a] Spray application on harvest dates not counted. Treatment ended on day prior to harvest.

Cotton leaves were dried and ground as described in Section 4.1.5.7.2. Samples from each sprayed control plot and the nominal 500 lbs/a·yr simulated saline drift treatment were analyzed by the University of Arizona's Soils, Water, and Plant Testing Laboratory, for 13 essential elements and Na^+ (PSP Procedure CA-23)

4.2.4.3.2. Alfalfa

Alfalfa plants were harvested when at least 50% of the plants in all plots were at 10% bloom (approximately one inflorescence/plant). A 20 ft-by-30 in. strip of alfalfa beginning approximately 5 ft to 6 ft into the plot was cut at a height of about 1 in. with a Jari "Chief" Model "K" Sickle Bar Mower. The cut alfalfa was raked and placed on a tarpaulin attached to a Pelouze Spring Balance. A sample of the freshly cut alfalfa was retained for additional analysis, e.g. leaf areas and moisture determinations. The field alfalfa was sampled on 25 July, 1 September and 3 November (Table 6).

Surface salt deposition, leaf areas, drying and grinding of alfalfa were conducted according to procedures described in section 4.1.5.7.1. Samples from the untreated control plots and the nominal 1000 lbs/a·yr plots were analyzed by the University of Arizona's Soils, Water, and Plant Testing Laboratory for 13 essential elements and Na^+ (PSP Procedures CA-11, CA-14, CA-1, CA-2, and CA-23).

4.2.4.3.3. Cantaloupe

A 30-ft section in the center bed of each plot was staked to designate the area to be harvested and weighed (Figure 9). Cantaloupe were considered ripe when the color of the melon was light tan. Harvested cantaloupe were weighed and counted and the average weight/plot was recorded. (PSP Procedure CA-8)

Harvested cantaloupe were surface washed with tap water. The cantaloupe fruit exclusive of the seed and rind was cut into 2.5-cm cubes, and stored in a freezer. The fruit samples from the unsprayed control and the

nominal 500 lbs/a·yr treatment were later freeze dried and stored until chemical analysis by the University of Arizona's Soils, Water, and Plant Testing Laboratory. Samples were analyzed for 13 essential elements and Na^+, arsenic, barium, cadmium, chromium, lead, mercury, strontium, and selenium. (PSP Procedure CA-38).

4.3. CLIMATIC CONDITIONS

Omnidata Datapod Digital Recorders were installed in the cotton field at Marana approximately 7 m south of the experimental plots and in a cotton field approximately 2 km northwest of the Palo Verde Nuclear Generating Station. Rainfall, temperature, and relative humidity, were monitored and recorded throughout the growing season (May through November). Omnidata Datapod Digital Recorders were set up at a desert site approximately 100 m north of the northwest corner of the Marana field site. Rainfall, temperature, and relative humidity were recorded throughout the growing season (May through November). Two Omnidata Datapod Digital Recorders were installed in the north greenhouse to measure relative humidity and temperature throughout the growing season (May through November) (PSP Procedure CA-29).

4.4. STATISTICAL ANALYSIS METHODOLOGY

The north and south greenhouses were separate experiments; therefore, no statistical comparisons were made.

In the observations that were recorded as a "1" for condition present or "0" for condition absent, a chi-square test was used to determine if the fraction of population affected was different between treatments.

4.4.1. One-time Measurements

Since all field and greenhouse experiments were conducted in randomized complete blocks designs, each of the variables that were measured only once during the experiment were subjected to an analysis of variance for the randomized complete blocks design (Steel and Torrie, 1980). An overall test of treatment differences was conducted with the F ratio, F = mean square treatments/mean

square error. If the F ratio test was declared significant (at the 5% level), then the Least Significant Difference test was used to make comparisons among the treatment means. When appropriate, a linear regression was computed with salt treatment level as the independent variable and the measurement of interest as the dependent variable (Procedure CA-34).

4.4.2. Repeated Measurements

Those variables that were measured repeatedly over time on each of the experimental units also were subjected to an analysis of variance. However, measures repeated over time on the same experimental units are multivariate observations, and often the repeated measures are intercorrelated. A standard procedure for repeated measures data is to test initially for the existence of the correlation structure among orthogonal contrasts (a method of separating variability due to treatment effects into component parts) of the repeated measures (Bock, 1975). In these analyses, the chosen contrasts represent terms of a polynomial that expresses the trend over time (i.e., linear, quadratic, etc.). If the contrasts have independent errors (i.e., if they are uncorrelated and have equal variances) and the error variances are not different statistically, then the data may be analyzed with a split plot analysis of variance using treatments as the main plot unit factor and time (occasions of measurement) as the subplot unit factor. If the contrasts are different (statistically different), and differences existed among the variances of the contrasts, then a separate analysis of variance was conducted on each contrast. In this latter case, the analysis was that for a randomized complete blocks analysis of variance, and the F ratio test for treatments was a test for differences among treatments in the trend over time and in treatment averages over time.

If the contrasts had intercorrelated errors (the error terms are not independent), a multivariate analysis of variance was used to analyze the variability among the treatments. Again the analysis of variance was a randomized blocks analysis of variance, but it was for the multivariate observation of contrasts.

Any trends over time in the characteristics were estimated for each of the treatments. If the characteristics changed over time, then the differences in those trends among the treatments were tested for statistical significance. The 5% level was used to determine significance unless otherwise stated (Procedure CA-34).

Standard errors reported in this study were calculated by taking the square root of the quotient resulting from the division of the mean square error by the number of observations.

4.5. PROJECT STUDY PLANS, QUALITY ASSURANCE PROTOCOLS, AND GREENHOUSE, FIELD, AND LABORATORY METHODS AND PROCEDURES

The following documents provide detailed descriptions of the materials and methods used during this study:

An Assessment of Salt Drift on the Productivity of Agricultural Crops in the Vicinity of the Palo Verde Nuclear Generating Plant: 17 November 1983. The Project Study Plan includes 42 procedures describing the laboratory and field methods and related procedures used by personnel directly engaged in this study. Refer to Table 7 for a complete listing of all field, greenhouse, and laboratory procedures and methods.

Project for an Assessment of Salt Drift on the Productivity of Agricultural Crops in the Vicinity of the Palo Verde Nuclear Generating Station: 24 June 1983. The Quality Assurance Plan and protocol for this study.

Methods for APS Salt Drift Project: 15 November 1983. The laboratory procedures used by personnel at the University Analytical Center for analysis of stock solutions, and composited treatment solutions.

Quality Assurance Plan for the Analysis of Salt Drift Deposition on Soil and Vegetation Adjacent to the Palo Verde Nuclear Generating Station: 5 October 1983. The Quality Assurance Plan and laboratory procedures used by personnel at the Soils, Water, and Plant Testing Laboraty for the analysis of plant tissue.

Table 7.

List of Greenhouse, Field and Laboratory Methods and Procedures
Used and Contained in Project Study Plan

Procedure	Title
CA-1	Procedure for Measurement of Leaf Area with LI-COR LI-3000 Portable Area Meter
CA-2	Procedure for Measurement of Leaf Area with LI-COR LI-3100 Area Meter
CA-3	Procedure for Greenhouse Alfalfa Harvest
CA-4	Procedure for Use of the LI-COR LI-1600 Porometer at the APS Project Field Site
CA-5	Procedure for Collecting Soil Samples
CA-6	Procedure for Calibration of the Tractor-Sprayer Spray Nozzles
CA-7	Procedure for Use of Datamyte 1001 Data Recorder
CA-8	Procedure for Harvesting Cantaloupe at the APS Project Field Site
CA-9	Procedure for Droplet Size Measurements
CA-10	Procedure for Calibration of Mettler Balance AC 100
CA-11	Procedure for Harvesting Alfalfa at the APS Project Marana Field Site
CA-12	Procedure for Harvesting Cotton at the APS Project Marana Field Site
CA-13	Procedure for Electrical Conductivity Measurements of Salt Solutions
CA-14	Procedure for Salt Deposition Measurement in Spray Chamber and Field Plots
CA-15	Procedure for Tagging Cotton Blooms at the APS Project Field Site
CA-16	Procedure for Spraying Salt Solution on Field Study Plots
CA-17	Procedure for Applying Benlate 50WP Fungicide to the Cantaloupe at the APS Field Site
CA-18	Procedure for Making Field Site Plant Observations (Field Evaluation Form V-3)
CA-19	Procedure for Field Cultural Practices
CA-20	Procedure for Calibration of Mettler Balance PC 2200

Table 7 (cont.)

CA-21	Procedure for the Pre-Treatment and Post-Treatment Checks of the Tractor-Sprayer
CA-22	Procedure for Use of Greenhouse Spray Chamber
CA-23	Procedure for Grinding Plant Tissue Samples with the UDY Cyclone Sample Mill (Model MS)
CA-24	Procedure for Performing Greenhouse Site Plant Observations
CA-25	Procedure for Preparation of Synthetic Blowdown Solutions for Field and Greenhouse Application
CA-26	Procedure for Use and Calibration of the Wescor HP-115 Psychrometer
CA-27	Procedure for Greenhouse Barley Harvest
CA-28	Procedure for Greenhouse Cotton Biomass Harvest
CA-29	Procedure for Use of Environmental Data Recorders
CA-30	Procedure for Maintaining Laboratory Notebooks
CA-31	Procedure for Photographic Documentation
CA-32	Procedure for Application of Pesticides in the Greenhouse During the APS Study
CA-33	Procedure for Use of the Cole-Parmer Model 5994 pH Meter
CA-34	Procedure for Data Reduction
CA-35	Procedure for Use of the Smith Fertilizer Injector
CA-36	Procedure for Fertilizing and Watering Plants in the Greenhouse
CA-37	Procedure for Chain-of-Custody and Document Control
CA-38	Procedure for Preparation of Cantaloupe for Chemical Analysis
CA-39	Procedure for Indoor Drip Irrigation
CA-40	Procedure for Tagging Blooms in the Greenhouse for the APS Project
CA-41	Procedure for Greenhouse Cotton Boll Harvest
CA-42	Procedure for Use of the LI-COR LI-1600 Porometer in the Greenhouse During the APS Study
CA-43	Procedure for Use of the Sierra Series 244 Dichotomous Sampler (Virtual Impactor)

5. RESULTS

5.1. MONITORING THE DELIVERY OF THE SIMULATED SALINE DRIFT

Concentrations of the salts in the simulated saline drift were monitored to verify the levels of salts applied to the plots. Two different methods were used to monitor these treatment levels. Daily samples of simulated saline drift treatment solutions were collected directly from the spray nozzles, were composited weekly, and were analyzed by the University Analytical Center; and electrical conductivity measurements of salts deposited on parafilm covered petri dishes were taken as described in Section 4.1.4.2.

The amounts of salts applied to the greenhouse and field experimental plots were based on the total chemical weights (Table 8). To adjust for the weight of water in the hydrated salts, it was concluded that TDS better represented the anhydrous salts in the solution (Table 2). Based on TDS the effective solution levels were 74.1% of the nominal concentrations (Table 8).

5.1.1. Analytical Laboratory Analyses of Treatment Solutions

Analyses by the University Analytical Center of weekly composited treatment solutions collected from the spray nozzles in the greenhouse indicated that TDS concentrations ranged from 102% to 133% of the calculated effective treatment solutions concentrations (Table 9). Treatment solutions were within 10% of calculated rates except for the nominal 10 lbs/a·yr treatment level which was 133%.

Weekly treatment solutions composites collected from the tractor sprayer ranged from 101% to 107% of the calculated effective TDS concentrations (Table 10). These percentages are greater than the targeted amounts and may be partially attributed to: 1) slight variations in the concentrations of stock solutions used to prepare treatment solutions; 2) slight variations in the aliquots of stock solution used to prepare treatment solutions; 3) experimental error during analytical determinations of the concentrations of stock solutions; and 4) analytical error in the determinations of TDS concentrations of the treatment solutions.

Table 8.

Nominal and Effective Treatment Rates
(NTR and ETR)

Nominal TDS Treatment Rate[a]		Effective TDS Treatment Rate[b]	
lbs/a·yr	$mg/m^2·day$[c]	lbs/a·yr	$mg/m^2·day$[c]
0	0	0	0
10	4.3	7.4	3.2
100	43.0	74.1	31.9
500	215.1	371	159.4
1000	430.2	741	318.8

[a] Treatment assuming hydrated (formula weight) composition from Table 2.
[b] Treatment assuming anhydrous (ionic) composition from Table 2.
[c] Daily treatment rate based on 5 applications per week.

Table 9.

Comparison of Calculated and Measured TDS in Simulated Saline Drift Solutions (Greenhouse)[a]

Nominal Treatment Levels (lbs/a·yr)	Effective Treatment Levels (lbs/a·yr)	Calculated Effective TDS of Treatment Solutions (mg/l)	Average TDS of Sampled Treatment Solutions (mg/l)	Percent of Effective TDS Treatment Rate
North House				
0	0	0	20.8	--
10	7.4	279	371	133
100	74.1	2790	2840	102
500	371.0	13900	14570	105
South House				
0	0	0	54.4	--
1000	741	31600	34740	110

[a] Based on analyses of solutions used from 25 July to 28 November 1983 Data Summary Volume Section C.

Table 10.

Comparison of Calculated and Measured TDS in Simulated Saline Drift Solutions (Field)[a]

Nominal Treatment Levels (lbs/a·yr)	Effective Treatment Levels (lbs/a·yr)	Calculated Effective TDS of Treatment Solutions (mg/l)	Average TDS of Sampled Treatment Solutions (mg/l)	Percent of Effective TDS Treatment Rate
0	0	0	34.3	--
10	7.4	1469	1483	101
100	74.1	14690	15770	107

[a] Based on analyses of solutions used from 25 July to 28 November 1983, Data Summary Volume Section C.

The ionic composition of these weekly composited samples of the simulated saline drift solutions collected at the greenhouse and the field are in Tables 11 and 12. Trace amounts of salts also were found in the distilled water used at both the greenhouse and the field sites (Data Summary Volume Section C).

5.1.2. Nozzle Delivery Rates

The delivery rate of all nozzles used in the field study was checked weekly (approximately every five spraying days). A delivery rate of 49.2 ml/30 sec per nozzle was used as the standard for calculating the concentration of salt solutions to be sprayed in the field studies (cf. 4.1.4.). The results of these measurements are graphed in Figure 13 and recorded in the Data Summary Volume Table F-I. The individual nozzles were consistent in their delivery rate.

Prior to the 13 September installation of new nozzles with stainless steel cores there was a very gradual increase in the delivery rates. The greatest increase (3.4%) occurred in the distilled water treatment line. The line used to apply the nominal 100 lbs/a·yr and the nominal 500 lbs/a·yr treatment solution increased 1.4%. The line used for the nominal 10 lbs/a·yr fluctuated only slightly, delivering 3.4% less. Following the replacement of the nozzles the delivery rate increased by 6.7%. During the field study, the measured delivery rates for the different lines based on the standard of 49.2 ml/30 sec were 5.4% greater, 0.9% less, and 4.8% greater for the 0, nominal 10 and nominal 100 lbs/a·yr treatment solutions, respectively (Figure 13). The delivery of the spray nozzles positioned directly over the mechanically and hand-harvested cotton rows were within 3% of the measured delivery rates.

5.1.3. Petri Dish Measurements of Salt Deposition

The deposition of simulated saline drift in the greenhouses as measured by the petri dish method exceeded the calculated effective treatment rate for all treatment levels. The averages for all greenhouse treatments and crops are summarized from the Data Summary Volume Section D in Table 13.

Table 11.

Comparison of the Ionic Concentrations of the Simulated Saline Drift Treatment Solutions Used in the Greenhouse Study. (Data Based on Results from the University Analytical Center Analyses from 25 July 1983 to 14 November 1983.)[a]

Ion	Nominal 10 lbs/a-yr Treatment Calculated (mg/l)	Analytical Center Analyses, Aver. (mg/l)	Std. Dev.[b]	Nominal 100 lbs/a-yr Treatment Calculated (mg/l)	Analytical Center Analyses, Aver. (mg/l)	Std. Dev.[b]	Nominal 500 lbs/a-yr Treatment Calculated (mg/l)	Analytical Center Analyses, Aver. (mg/l)	Std. Dev.[b]	Nominal 1000 lbs/a-yr Treatment Calculated (mg/l)	Analytical Center Analyses, Aver. (mg/l)	Std. Dev.[b]
Ca	6.106	7.59	± 0.96	61.06	72.0	± 9.2	305.3	364.5	± 41.6	692.3	870.5	± 71.2
Mg	0.442	0.44	± 0.02	4.42	4.1	± 0.3	22.1	19.8	± 1.5	50.3	47.3	± 2.8
Na	87.07	114.2	± 25.1	870.7	836.1	± 69	4353.8	3923.0	± 465.5	9872.6	9339.0	± 1118.2
K	3.912	4.12	± 0.31	39.12	38.4	± 3.7	195.6	186.3	± 6.7	443.3	428.5	± 12.1
Cl	84.30	119.3	± 21.2	843.0	877.1	± 97.9	4215.1	4492.0	± 295.2	9553.9	10406.0	± 883.8
SO_4	47.27	65.5	± 59.6	472.7	586.4	± 59.2	2363.3	2772.0	± 220.5	5356.8	6289.0	± 545.9
NO_3	43.48	65.1	± 7.2	434.8	484.2	± 44	2173.9	2351.0	± 419.6	4927.6	5581.0	± 782.6
NH_4	0.038	0.079		0.377	0.2		1.886	2.10		4.275	5.52	
Be	0.0057	0.0		0.057	0.0		0.286	0.0		0.646	0.064	
Fe	0.002	0.0		0.020	0.0		0.101	0.10		2.095	0.50	
F	0.030	0.0		0.304	0.37		1.521	1.45		3.446	2.65	
BO_3	0.064	0.096		0.638	1.53		3.188	6.99		7.225	13.49	
Mn	0.014	0.0		0.136	0.12		0.678	0.55		1.550	1.262	
Zn	0.022	0.058		0.216	0.22		1.078	0.86		2.442	1.41	
Sr	0.010	0.0		0.099	0.09		0.496	0.5		1.124	0.998	
Cu	0.005	0.0		0.053	0.04		0.265	0.15		0.599	0.32	
Ag	0.001	0.0		0.010	0.0		0.050	0.027		0.113	0.075	
Pb	0.0006	0.0		0.0056	0.0		0.028	0.0		0.064	0.312	
As	0.0005	0.0		0.005	0.003		0.025	0.015		0.058	0.043	
I	0.029	0.0		0.287	0.0		1.4364	0.0		3.255	0.0	
Si	0.685	0.0		6.849	7.2		34.244	35.18		77.619	81.7	
Ba	0.0002	0.0		0.0024	0.0		0.012	0.07		0.027	0.824	
Cd	0.0003	0.0		0.0028	0.0		0.014	0.042		0.031	0.094	
Se	0.0003	0.0		0.0032	0.002		0.016	0.014		0.036	0.034	
Cr	0.0001	0.0		0.0012	0.0		0.006	0.0		0.013	0.049	
Hg	0.00004	0.0		0.0004	0.0		0.002	0.0		0.004	0.0	
HCO_3	0.976	0.0		9.764	1.73		48.818	26.86		110.653	63.75	
PO_4	0.112	0.018		1.120	0.69		5.602	3.13		12.698	6.45	
IONIC SUM	274.6	376.6	± 82.0	2746	2909	± 223	13729	14188	± 1264	31125	33141	± 2369

[a] Individual ions may not be detectable in treatment solutions.

[b] Standard deviations were calculated only for Ca, Mg, Na, K, Cl, SO_4, NO_3 and ionic sums of individual samples of treatment solutions.

Table 12.

Comparison of the Ionic Concentrations of the Simulated Saline Drift Treatment Solutions Used in the Field Study.
(Data Based on Results from the University Analytical Center Analysis
from 25 July 1983 to 28 November 1983.)[a]

Ion	Nominal 10 lbs/a-yr Treatment			Nominal 100 lbs/a-yr Treatment		
	Calculated (mg/l)	Analytic Center Analyses, Aver. (mg/l)	Std. Dev.[b]	Calculated (mg/l)	Analytic Center Analyses, Aver. (mg/l)	Std. Dev.[b]
Ca	32.3	40.7	± 6.1	322.9	418.4	± 43.2
Mg	2.3	2.2	± 0.2	23.4	21.7	± 1
Na	460.4	431.1	± 59.6	4603.5	4353.3	± 341.9
K	20.7	19.1	± 0.9	206.8	192.3	± 15.4
Cl	455.7	481.1	± 107.4	4556.8	4823.3	± 576.5
SO_4	249.9	280.1	± 20.2	2498.6	2890.0	± 368.6
NO_3	229.8	213.6	± 42	2298.4	2272.7	± 470.1
NH_4	0.2	0.18		1.994	2.39	
Be	0.03	0.0		0.301	0.04	
Fe	0.098	0.0		0.977	0.33	
F	0.161	0.2		1.608	1.84	
BO_3	0.337	0.95		3.37	7.01	
Mn	0.072	0.032		0.723	0.79	
Zn	0.114	0.14		1.139	0.82	
Sr	0.052	0.017		0.524	0.52	
Cu	0.028	0.0		0.280	0.16	
Ag	0.005	0.0		0.053	0.044	
Pb	0.003	0.0		0.030	0.0	
As	0.0027	0.0003		0.027	0.015	
I	0.152	0.0		1.519	0.0	
Si	3.620	0.0		36.204	41.31	
Ba	0.0012	0.0		0.012	0.0	
Cd	0.0015	0.0		0.015	0.047	
Se	0.0017	0.0		0.017	0.018	
Cr	0.0006	0.0		0.006	0.0	
Hg	0.0002	0.0		0.002	0.0	
HCO_3	5.161	1.97		51.613	25.87	
PO_4	0.592	0.052		5.923	3.02	
IONIC SUM	1462	1471	± 195	14617	15060	± 1307

[a] Individual ions may not be detectable in treatment solution.

[b] Standard deviations were calculated only for Ca, Mg, Na, K, Cl, SO_4, NO_3 and ionic sums of individual samples of treatment solutions.

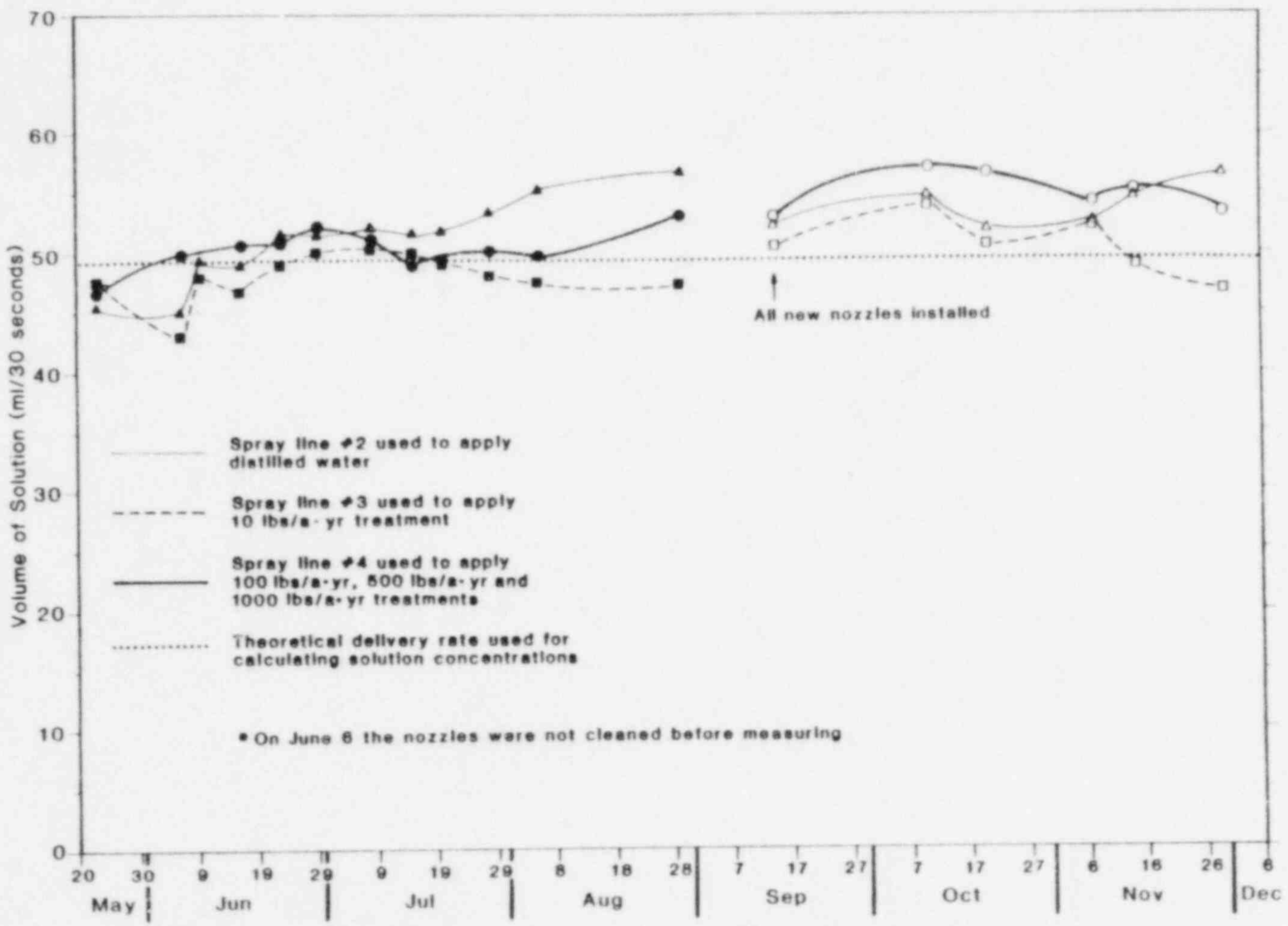


Figure 13. Nozzle delivery rates (field)

Table 13.

Petri Dish Determinations of
Simulated Saline Drift Deposition (Greenhouse)

Effective Treatment Level[a] (lbs/a·yr)	TDS Deposition Petri Dish Measurements[b] (lbs/a·yr)	Effective Treatment Levels[c]
0	6.1	-
7.4	17.3	2.34
74.0	112.0	1.51
371.0	518.0	1.40
741.0	909.0	1.23

[a] Based on actual treatment solution analyses.

[b] Calculations based on multiplying average daily deposition rate x 260 application days.

[c] Ratio of TDS data to effective treatment level.

The average amount of TDS found on the petri dishes sampled in the field ranged from 80% to 200% of the calculated effective treatment levels. The averages for each field treatment level are summarized from Data Summary Volume Section E in Table 14.

5.1.4. Calculated and Measured Delivery of Simulated Saline Drift

5.1.4.1. Greenhouse

Calculated effective treatment levels are compared with measured delivery rates for greenhouse cotton, as an example, in Figures 14 to 16. Detailed tabular data and similar comparisons for greenhouse barley and alfalfa are presented in Data Summary Volume Section D.

5.1.4.2. Field

A comparison of calculated and measured delivery rates are presented as an example, for the field alfalfa plots in Figures 17 to 20. Additional data and similar comparisons for the other field crops are presented in Data Summary Volume Section E.

Petri dish deposition measurements of the simulated saline drift solutions applied to the plots showed variability (Data Summary Volume Section E). Variation in measurements may be attributed to sampling, analytical and experimental error, and fluctuations in environmental conditions.

5.1.5. Droplet Size

5.1.5.1. Greenhouse

The mass mean diameter of simulated saline drift droplets is shown in Table 15. The overall mean was 105 μ, 5 μ greater than the expected 100 μ size. The size of the droplets in the simulated saline drift during June declined to about 80 μ, at which time the old nozzles were replaced (Data Summary Volume Tables G-1 and G-2).

Table 14.

Petri Dish Determinations of
Simulated Saline Drift Deposition (Field)

Effective Treatment Level[a] (lbs/a·yr)	TDS Deposition Petri Dish Measurements[b] (lbs/a·yr)	Effective Treatment Levels[c]
0	6.7	
7.4	14.7	1.99
74	69.5	0.94
371	296.6	0.80
741	852.1	1.15

[a] Based on actual treatment solution analyses.

[b] Calculations based on multiplying average daily deposition rate x 260 application days.

[c] Ratio of TDS data to effective treatment level.

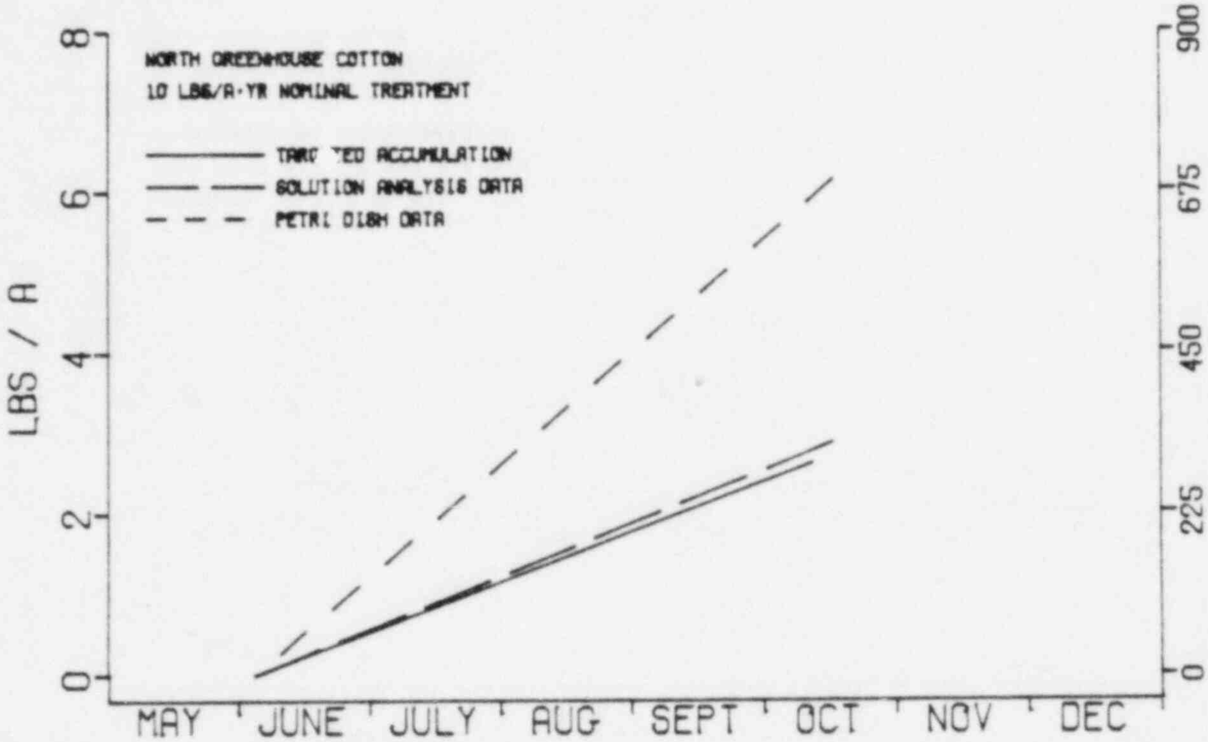


Figure 14. Simulated saline drift deposition levels for the nominal 10 lbs/a • yr treated greenhouse cotton. The calculated effective treatment level (targeted accumulation) is compared with measured delivery (solution analysis data [volume concentration data] and petri dish data).

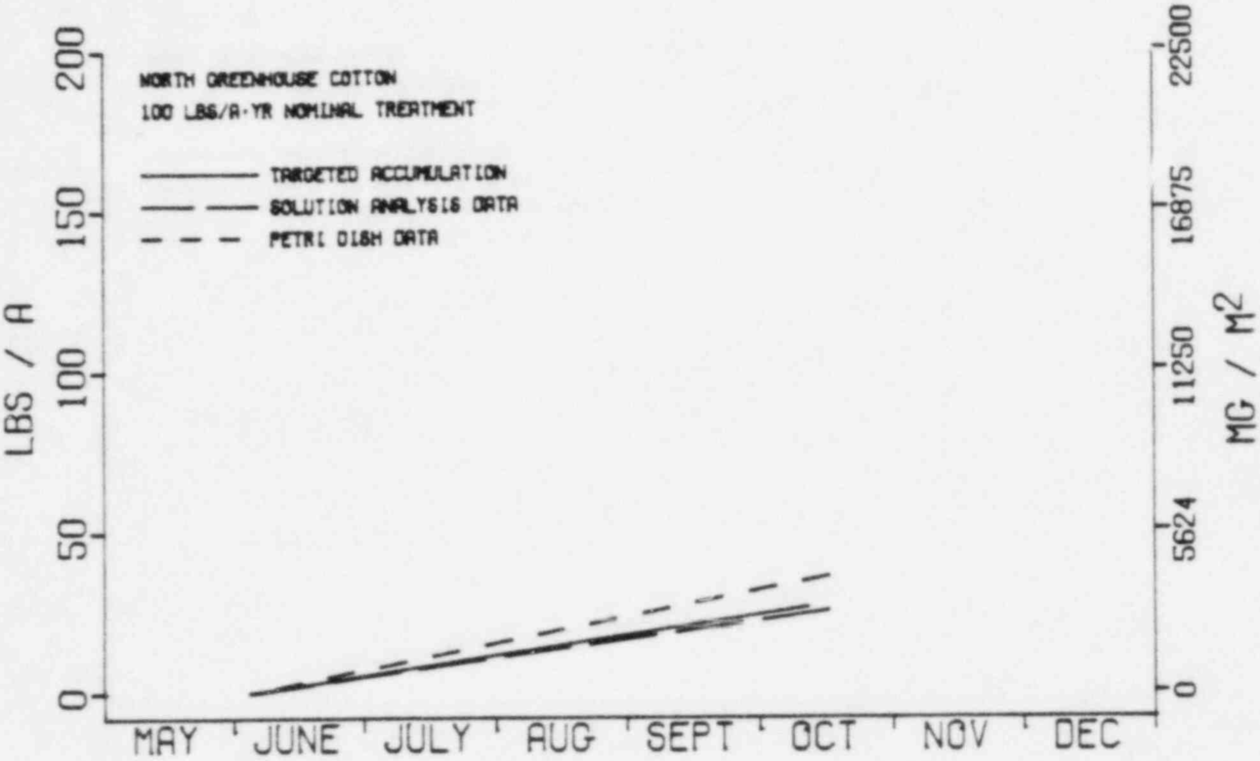


Figure 15. Simulated saline drift deposition levels for the nominal 100 lbs/a • yr treated greenhouse cotton. The calculated effective treatment level (targeted accumulation) is compared with measured delivery (solution analysis data [volume concentration data] and petri dish data).

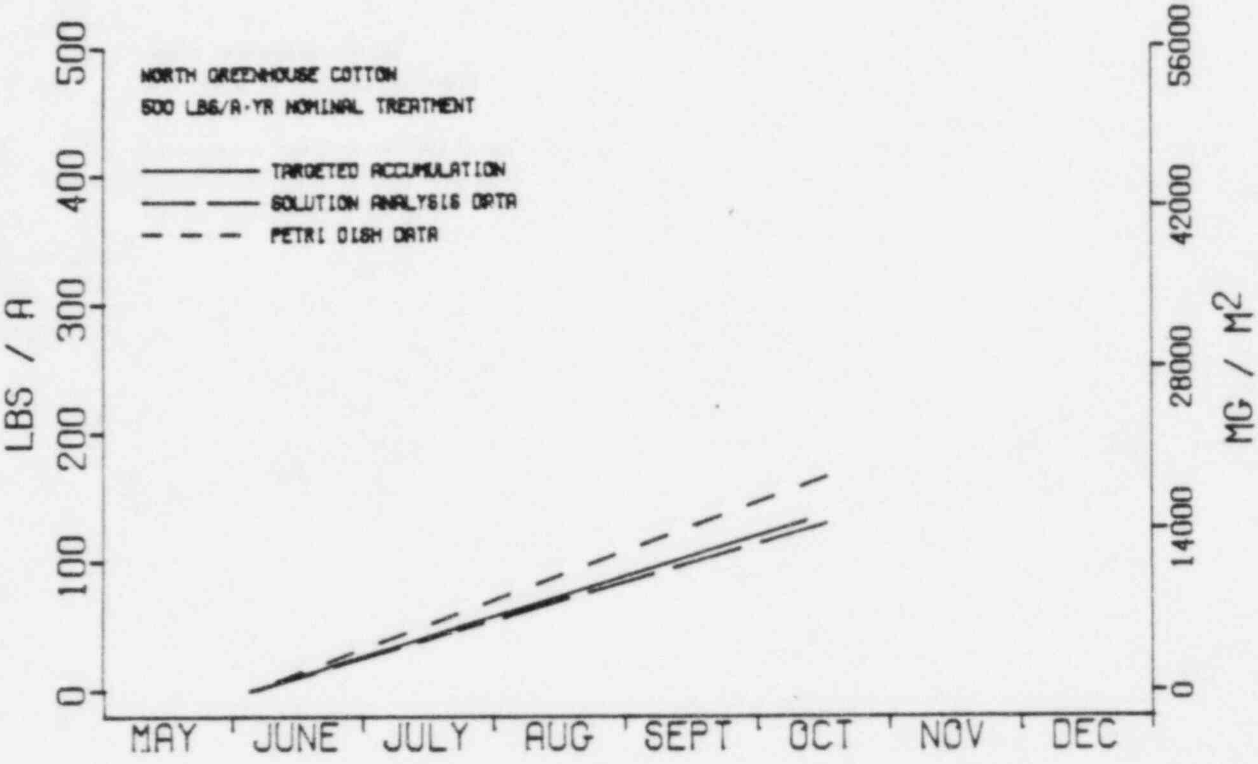


Figure 16. Simulated saline drift deposition levels for the nominal 500 lbs/a • yr treated greenhouse cotton. The calculated effective treatment level (targeted accumulation) is compared with measured delivery (solution analysis data [volume concentration data] and petri dish data).

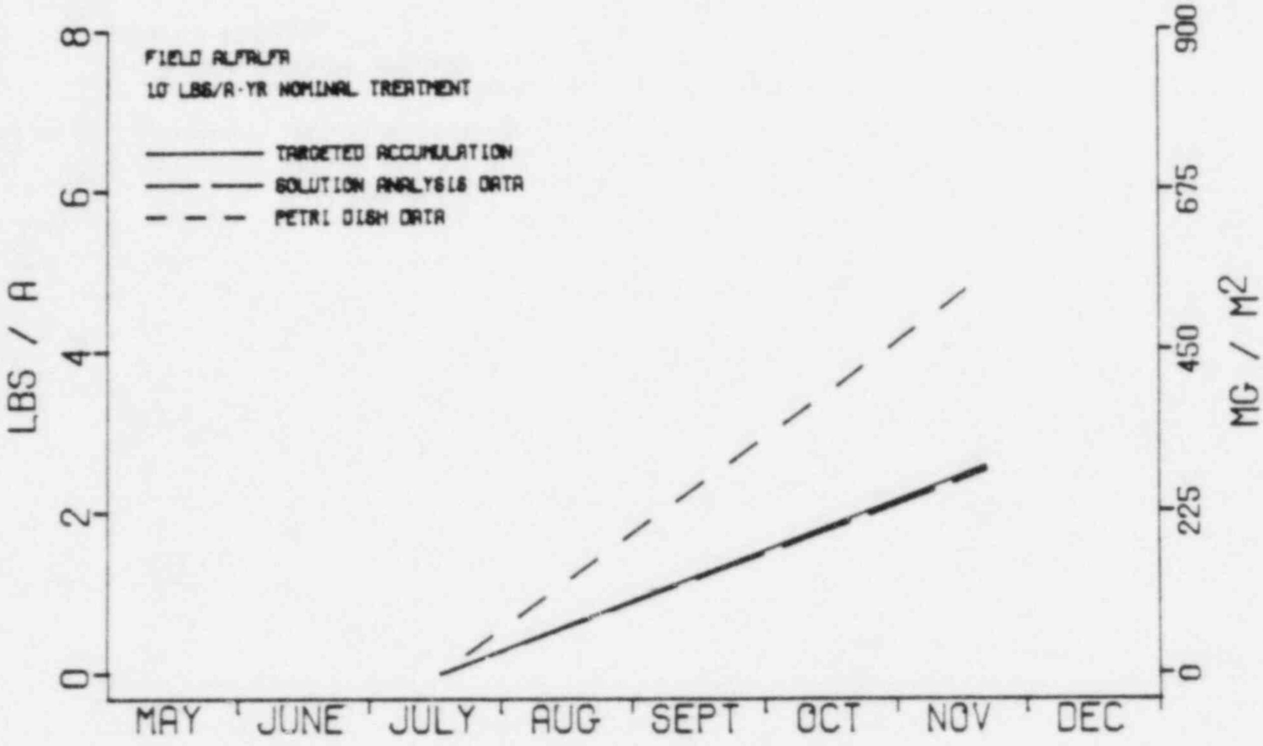


Figure 17. Simulated saline drift deposition levels for the nominal 10 lbs/a • yr treated field alfalfa. The calculated effective treatment level (targeted accumulation) is compared with measured delivery (solution analysis data [volume concentration data] and petri dish data).

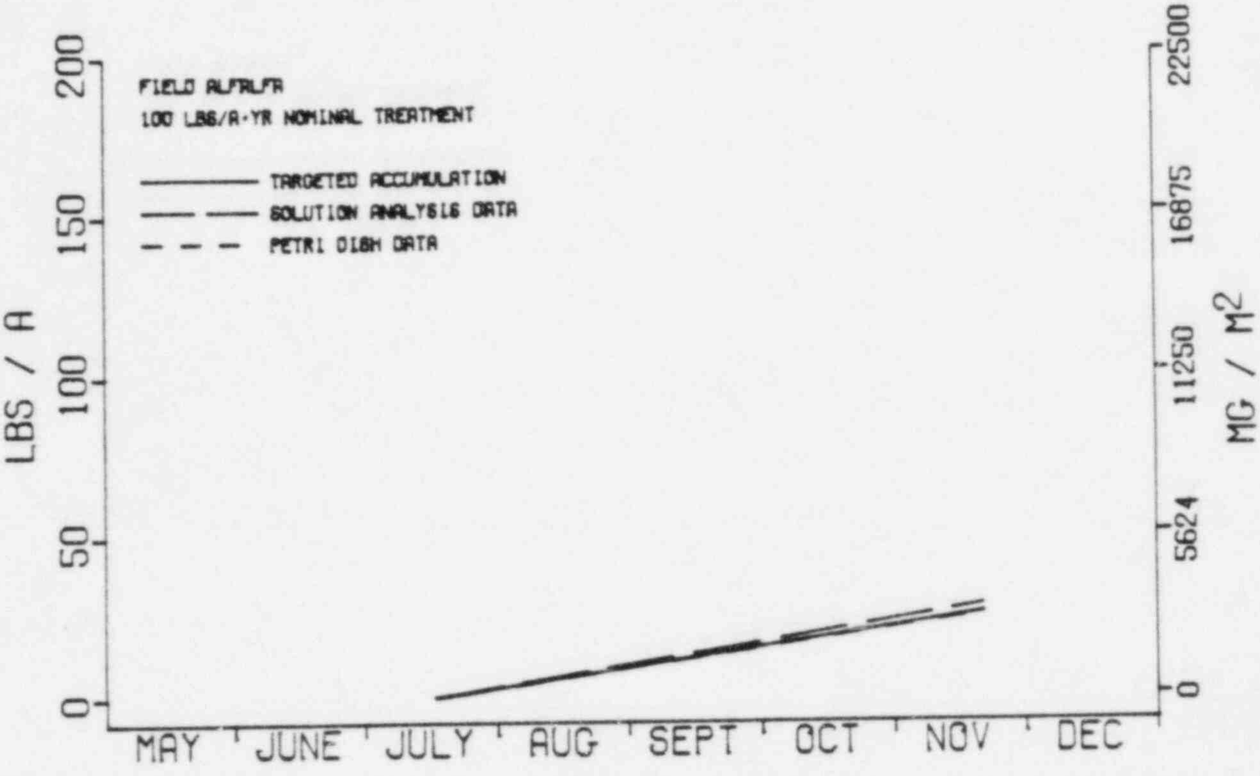


Figure 18. Simulated saline drift deposition levels for the nominal 100 lbs/a • yr treated field alfalfa. The calculated effective treatment level (targeted accumulation) is compared with measured delivery (solution analysis data [volume concentration data] and petri dish data).

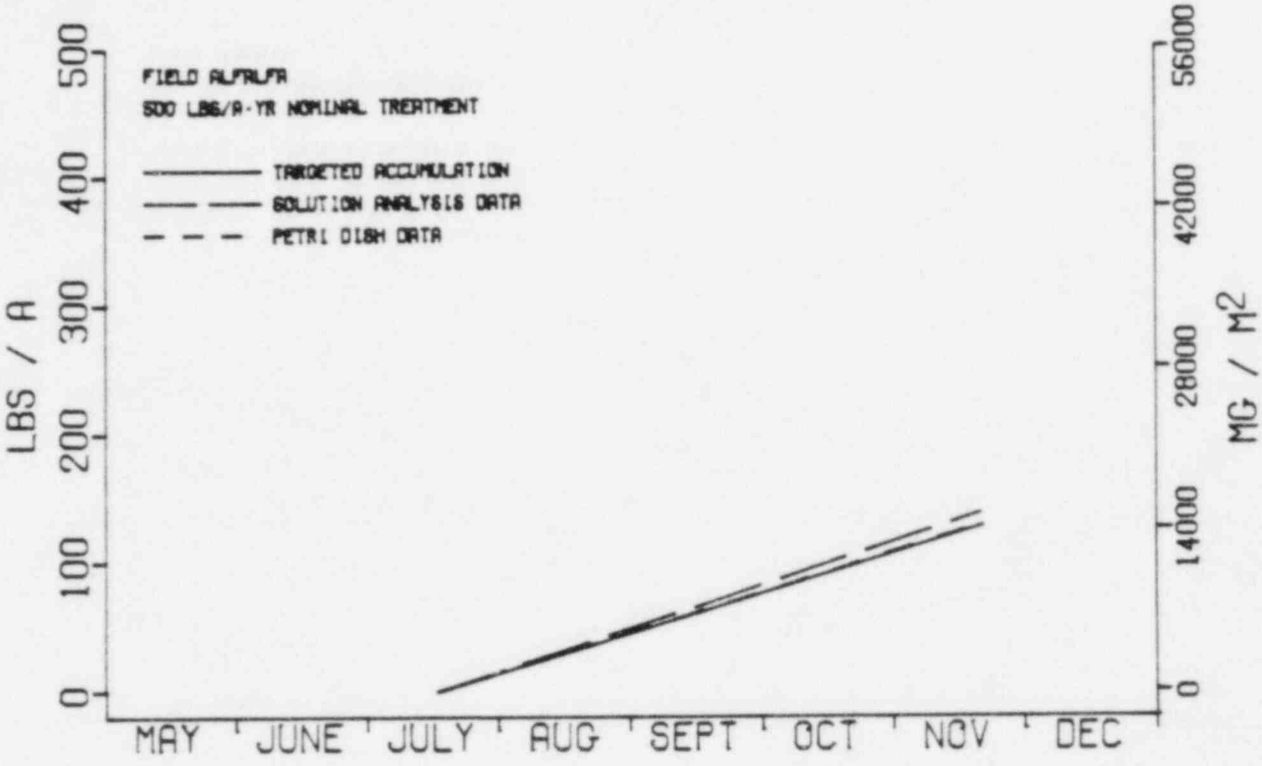


Figure 19. Simulated saline drift deposition levels for the nominal 500 lbs/a • yr treated field alfalfa. The calculated effective treatment level (targeted accumulation) is compared with measured delivery (solution analysis data [volume concentration data] and petri dish data).

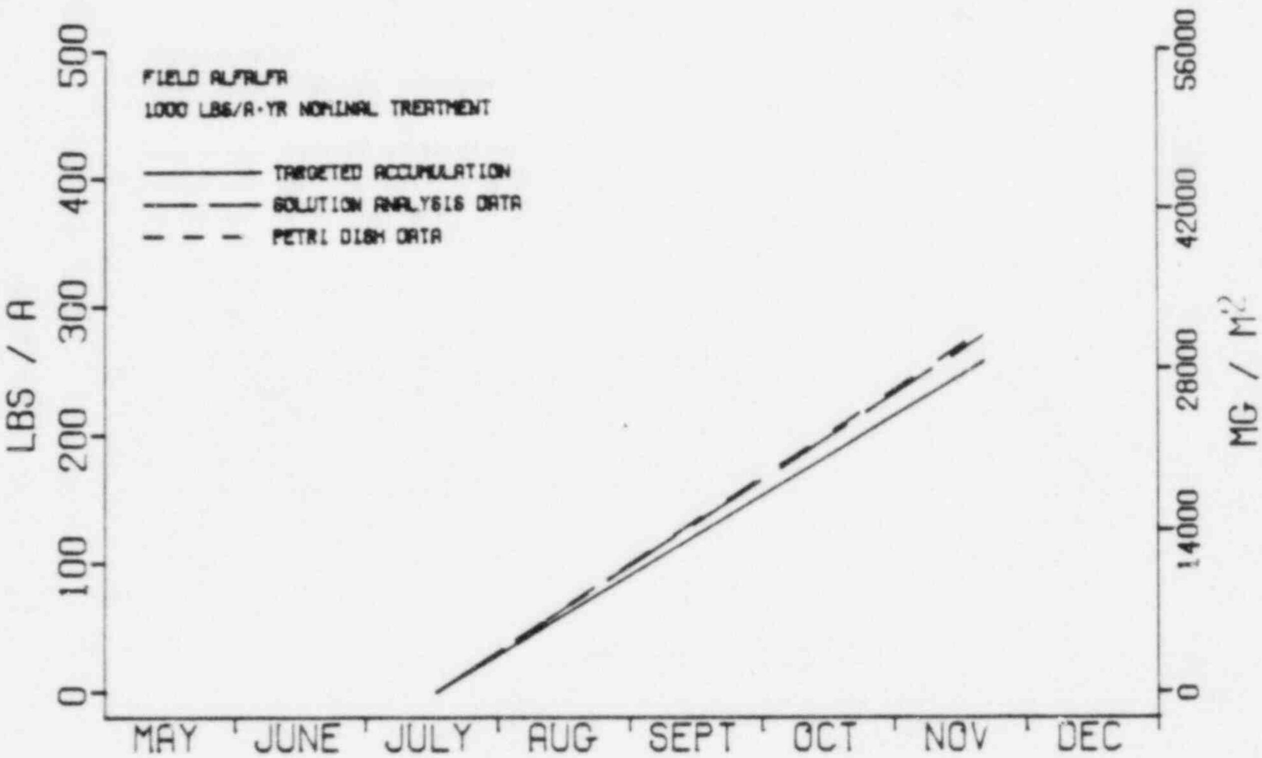


Figure 20. Simulated saline drift deposition levels for the nominal 1000 lbs/a • yr treated field alfalfa. The calculated effective treatment level (targeted accumulation) is compared with measured delivery (solution analysis data [volume concentration data] and petri dish data).

Table 15.

Greenhouse Droplet Size Measurements[a]

Nominal Treatment Levels (lbs/a·yr)	Seasonal Mass Mean Diameter (μ)	Pooled Standard Deviations[b]
0	106.2	40.8
10	103.1	39.4
100	106.9	40.7
500	104.7	39.7

[a] Data abstracted from Data Summary Volume Section G.

[b] Square root of the mean of individual variances.

5.1.5.2. Field

The mass mean diameter of the droplets sprayed in the field study is shown in Table 16 (Data Summary Volume Table G-3).

5.2. CLIMATIC COMPARISONS

5.2.1. The Palo Verde Nuclear Generating Station Field Site and Marana

The maximum temperature in a cotton field near the Palo Verde Nuclear Generating Station was consistently higher than that at Marana field site except for the weeks of 15 July and 11 November (Table 17; Figures 21a, 21b, 21c). The difference in the weekly mean maximum temperatures between the two sites was very small in June but increased gradually in July and August, reaching a peak difference of 7.2 C during the first week of September. The difference in weekly mean maximum temperatures between the two sites decreased gradually to less than 1 C difference in November (Table 17). The weather instruments at the Marana field site and the Palo Verde field site were located in cotton fields. The temperatures may have been affected by irrigation practices and microclimates within the plant canopy. The weekly mean maximum temperatures for both field sites were consistently lower than the weekly mean maximum temperatures for the Marana desert site. This difference persisted until October when irrigation was discontinued.

The weekly mean minimum temperatures at the two field sites were similar. The mean minimum temperature at the Palo Verde field site was within 2.5 C of the mean minimum temperatures at the Marana field site. The seasonal mean minimum temperature was less than 0.1 C higher at the Palo Verde field site than at the Marana field site.

The weekly means for maximum and minimum relative humidity were consistently higher at the Marana field site than at the Palo Verde field site (Table 17). The maximum seasonal mean relative humidity was 5.4% higher and the minimum seasonal mean relative humidity 17.8% higher at the Marana field site (Table 17: Figure 22a, 22b). The maximum and minimum means at both the Palo Verde field site and the Marana field site were greater than those recorded at the

Table 16.

Field Droplet Size Measurements[a]

Nominal Treatment Levels (lbs/a·yr)	Seasonal Mass Mean Diameter (μ)	Pooled Standard Deviations[c]
0	97.0	36.2
10	97.7	35.6
100	96.0	35.4[b]
500	96.0	35.4[b]

[a] Data abstracted from Data Summary Volume Section G.

[b] Same spray line used for these treatments.

[c] Square root of the mean of individual variances.

Table 17.

Weekly Temperature and Relative Humidity Means for the Field Study[a]

		Temperature (C) - Weekly Average						Relative Humidity (%) - Weekly Average					
		Maximum			Minimum			Maximum			Minimum		
		Desert site	Marana site	Palo Verde site	Desert site	Marana site	Palo Verde site	Desert site	Marana site	Palo Verde site	Desert site	Marana site	Palo Verde site
June	3	-	37.1[b]	-	-	14.0[b]	-	-	30.0[b]	-	-	-	-
	10	-	37.6	38.1	-	15.1	16.3	-	39.4	44.9	-	7.8	-
	17	-	39.4	40.2	-	16.6	16.5	-	33.0	36.1	-	-	-
	24	-	37.6	37.9	-	15.4	14.9	-	39.4	49.7	-	-	-
July	1	-	38.8	39.1	-	18.4	19.6	-	55.6	50.4	-	12.7	16.0
	8	-	37.7	40.1	-	22.7	23.4		75.4	61.3	-	33.1	23.9
	15	39.1	37.4	36.1	22.3	20.7	20.6	53.4	68.3	69.3	-	27.7	28.1
	22	-	34.1	36.6	-	22.5	22.5	-	84.4	82.6	-	52.3	42.7
	29	-	34.5	38.1	-	22.9	23.9	-	85.9	82.9	-	53.3	43.0
Aug	5	-	32.6	36.8	-	21.5	23.8	-	90.3	83.9	-	58.4	49.9
	12	-	30.9	35.1	-	20.8	22.5	-	91.7	87.9	-	76.7	57.1
	19	-	29.9[b]	34.2	-	18.6[b]	18.3	-	89.3[b]	89.4	-	66.0[b]	44.6
	26	39.7	31.5	38.4	22.5	21.1	21.8	75.9	90.1	84.0	21.6	74.7	39.9
Sept	2	39.8	30.4	37.6	22.4	20.5	21.6	77.1	90.0	87.0	21.6	76.0	38.0
	9	38.9	29.9	35.6	23.4	21.2	22.7	70.9	87.7	84.3	24.0	72.3	42.7
	16	36.0	28.6	33.3	21.4	20.3	20.9	86.3	90.9	87.4	33.0	78.3	55.1
	23	31.9	26.3	29.9	18.6	17.9	17.6	89.3	92.7	90.7	40.6	79.0	52.9
	30	25.1	23.1	27.4	16.0	16.4	15.1	91.6	93.6	91.9	67.0	85.6	62.7
Oct	7	29.8	27.7	33.3	14.6	14.3	12.6	86.7	91.7	89.1	32.0	63.1	27.7
	14	27.4	30.2	31.6	12.8	11.6	11.3	83.9	91.9	81.9	37.0	44.0	25.7
	21	28.1	30.4	32.1	13.9	12.8	11.1	82.9	86.1	71.9	33.9	37.7	22.7
	28	27.9	30.6	31.1	12.8	12.0	10.4	88.6	90.4	78.0	36.9	38.6	27.1
Nov	4	25.1	27.8	28.5	10.2	9.4	7.8	90.1	92.4	69.9	41.1	42.9	20.7
	11	25.0	28.8	27.8	7.7	6.8	5.6	85.6	89.4	67.9	29.3	29.0	17.9
	18	17.1	19.7	20.1	2.1	1.0	2.1	84.9	89.1	81.1	31.4	33.9	19.1
	25	13.3[b]	16.0[b]	17.4	-0.8[b]	-0.9[b]	-1.1	92.6[b]	94.2[b]	82.3	41.4[b]	42.0[b]	29.0
Seasonal $\bar{x}$[c]			30.86	33.46		15.98	16.07		80.92	75.43		53.51	35.75

[a] The maximum or minimum temperatures or relative humidities recorded each day were averaged, every 7 days, to determine the weekly mean maximums or minimums.
[b] Mean based on less than 7 days because of missing data.
[c] Only for dates with paired data.

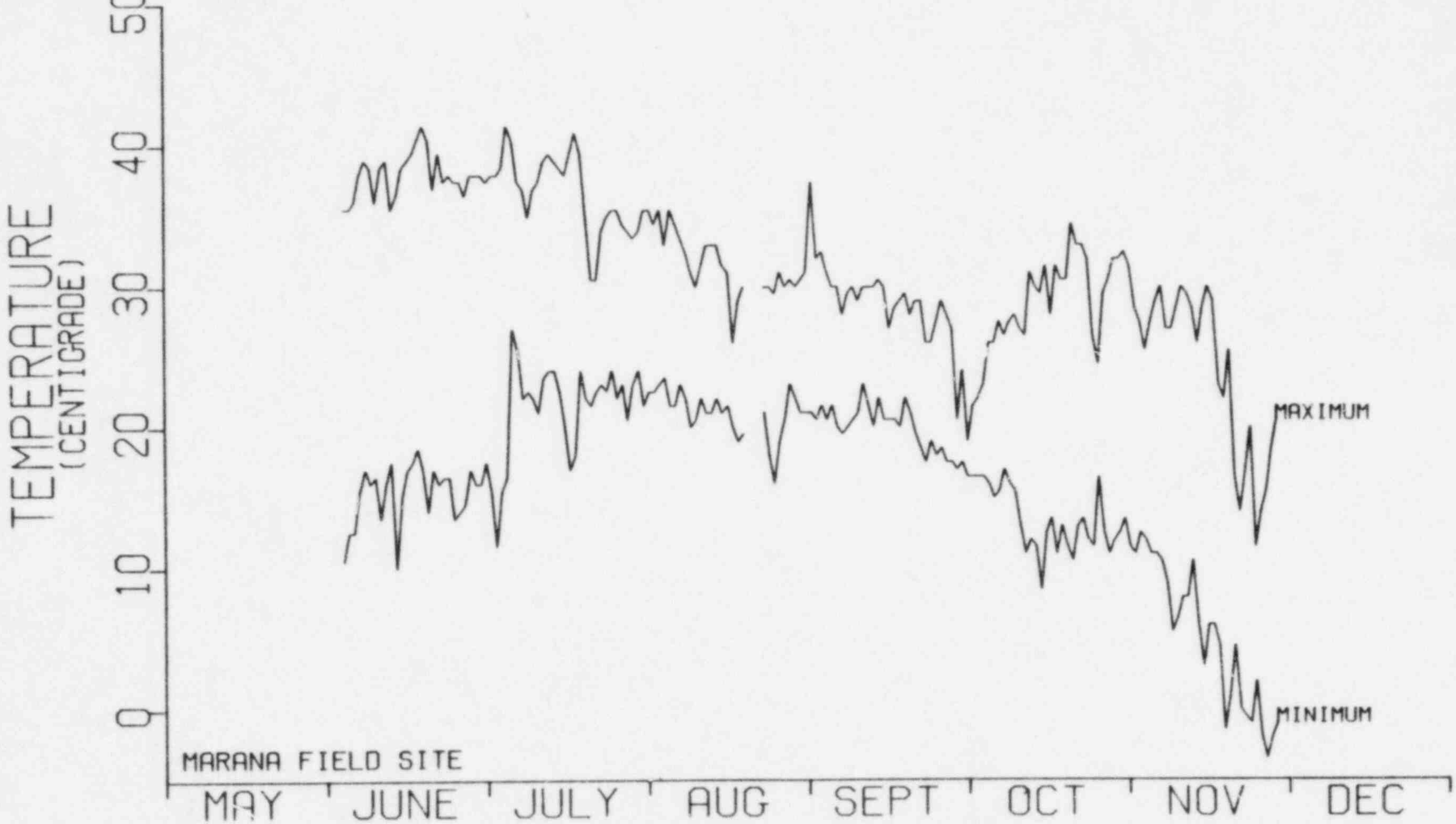


Figure 21a. Maximum and minimum temperatures recorded during the growing season at the Marana field site

Gaps indicate missing data.

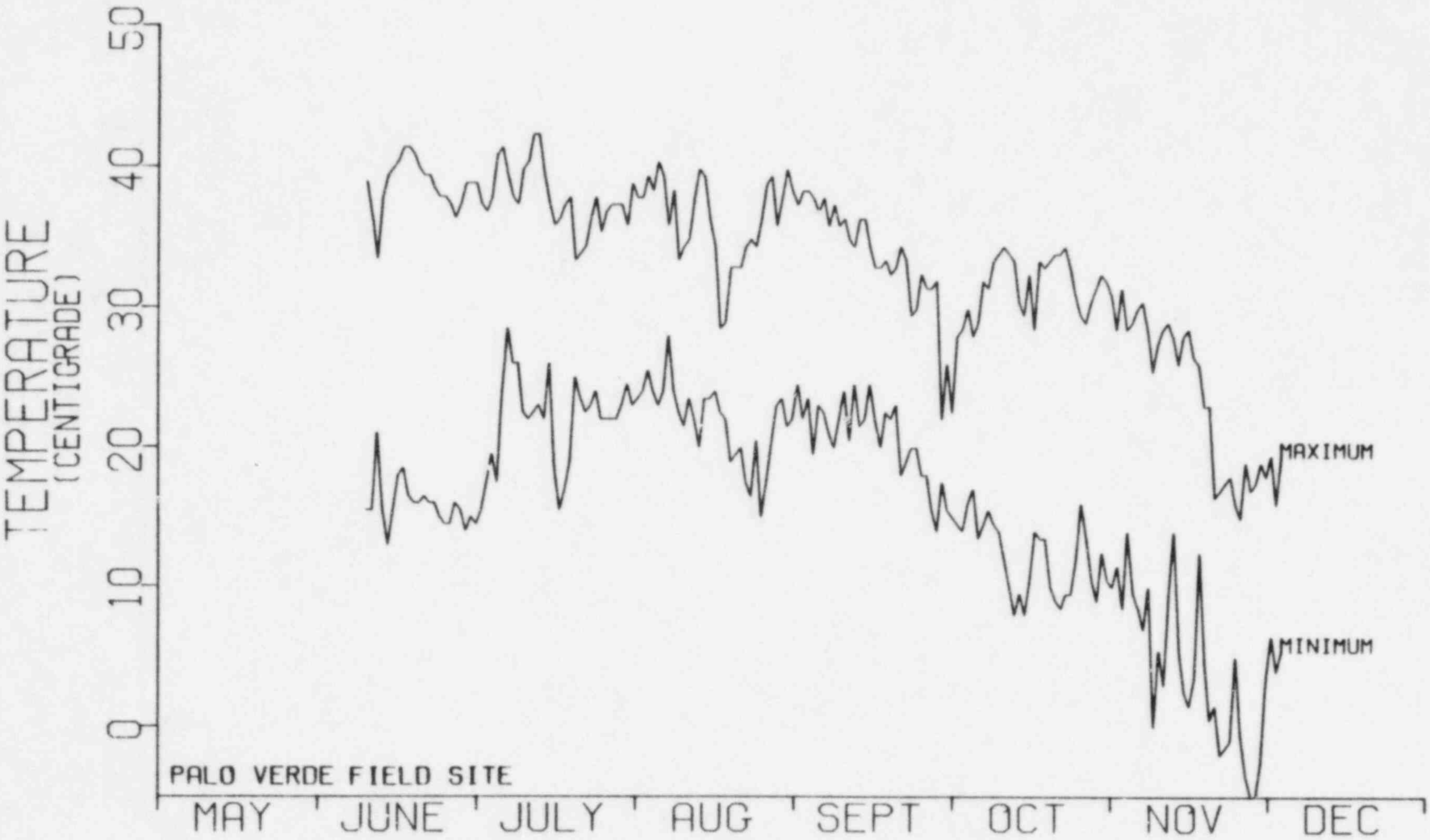


Figure 21b. Maximum and minimum temperatures recorded during the growing season at the Palo Verde field site

Gaps indicate missing data.

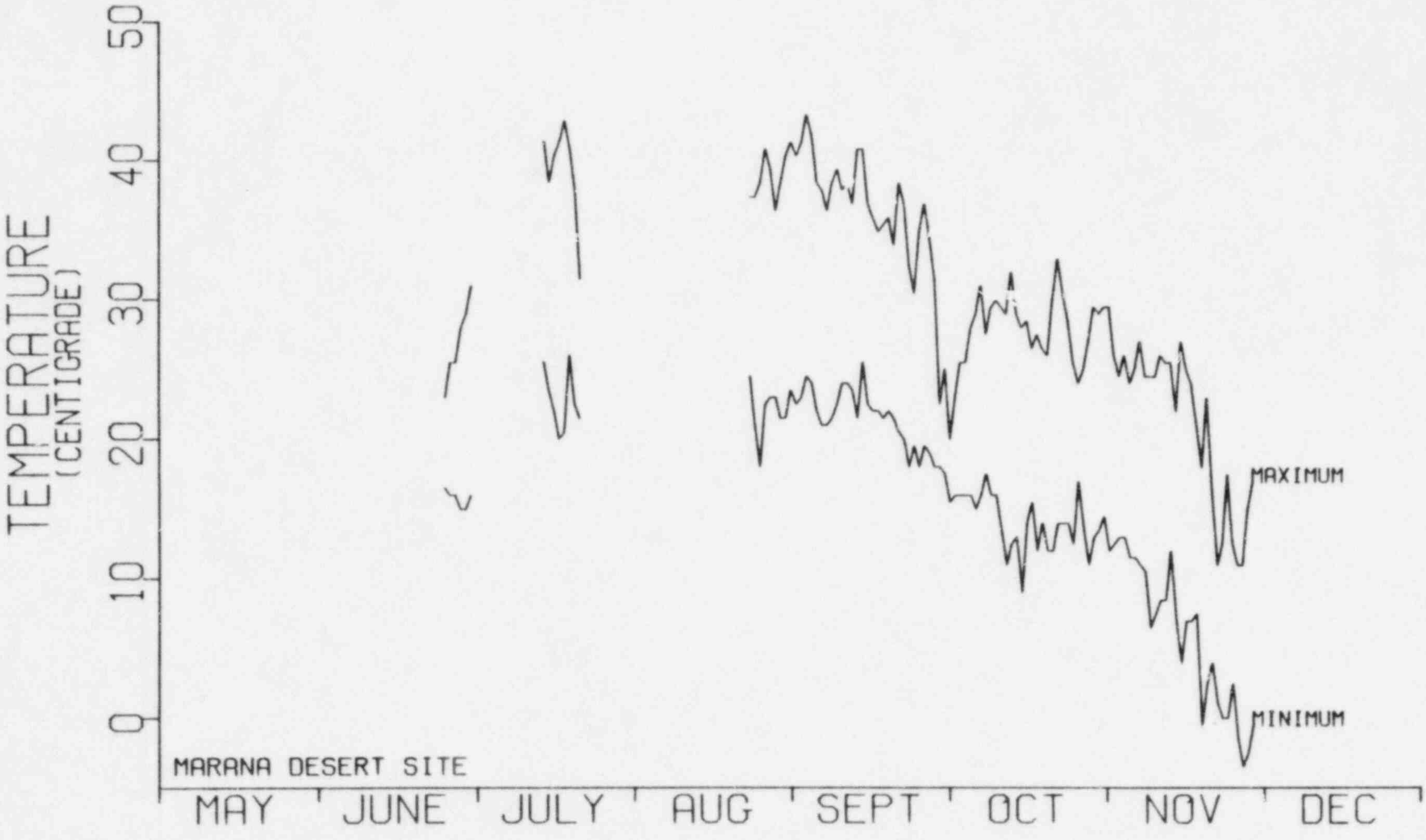


Figure 21c. Maximum and minimum temperatures recorded during the growing season at the Marana desert site

Gaps indicate missing data.

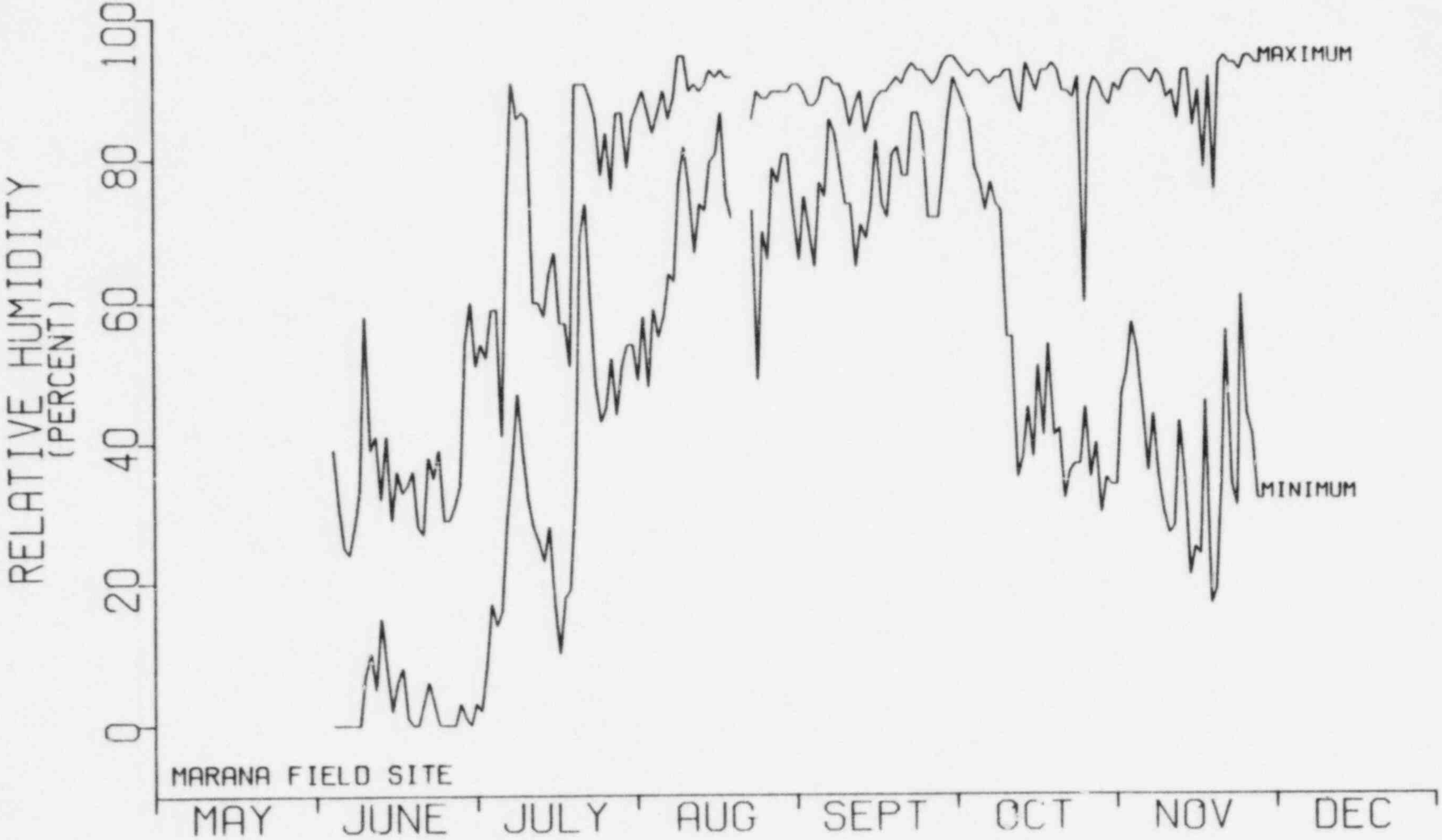


Figure 22a. Maximum and minimum relative humidities recorded during the growing season at the Marana field site

Gaps indicate missing data.

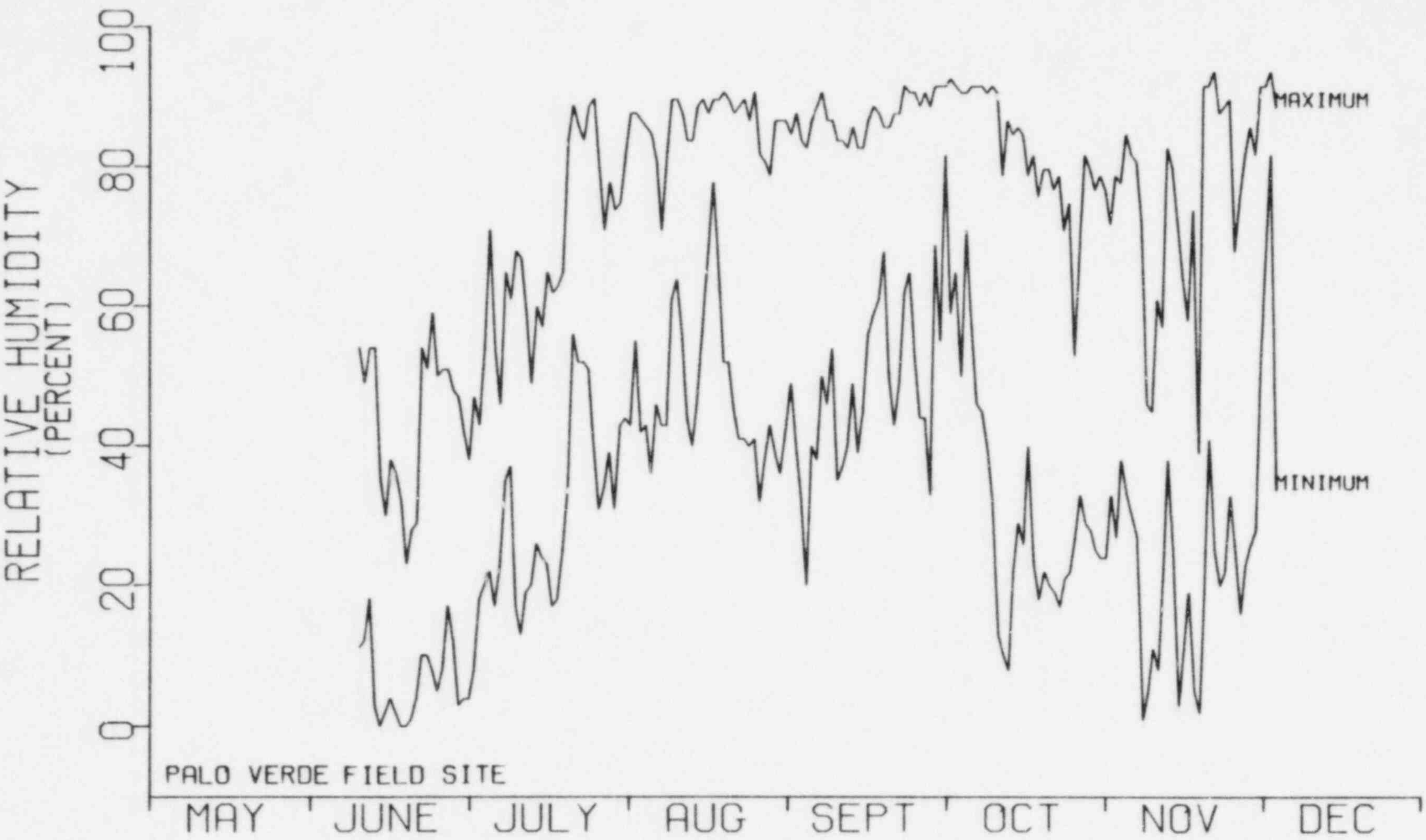


Figure 22b. Maximum and minimum relative humidities recorded during the growing season at the Palo Verde field site

Gaps indicate missing data.

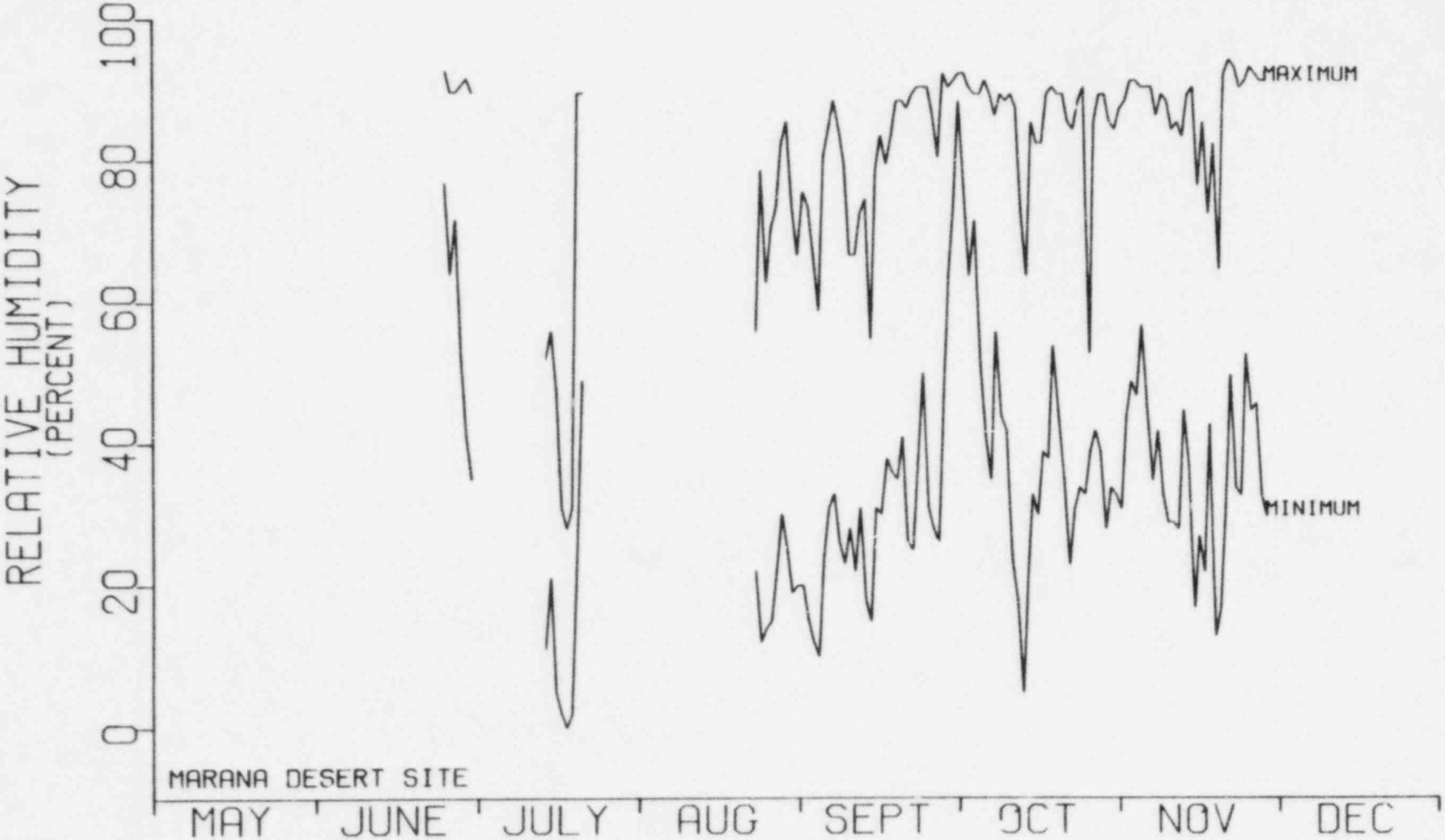


Figure 22c. Maximum and minimum relative humidities recorded during the growing season at the Marana desert site

Gaps indicate missing data.

desert site until October (Figure 22c). In October and November, however, higher means were recorded at the desert site than at the Palo Verde field site, in part due to the excessive precipitation received in the Marana region from an unusually large storm in late September and early October.

The amounts of precipitation received at Marana and the Palo Verde field site were nearly equal until 18 August. Marana received 2 in. of rain during this period, and the Palo Verde field site received 2.03 in. During late August and early September, Marana received more than 1.25 in. more precipitation than the Palo Verde field site. An unusually large storm in late September and early October left 5.5 in. of rain at Marana site. The Palo Verde field site received less than 0.75 in. of rain from this storm (Figure 23). Total rainfall was 10.58 in. at Marana and 4.16 in. at the Palo Verde field site, for the duration of this study.

5.2.2. Greenhouse

The daily maximum temperatures in the north greenhouse ranged from 25 C to 45 C. Maximum temperatures were higher at the east end of the greenhouse, except in November. These variations in temperature can be attributed to the evaporative coolers located at the west end and the exhaust fans located at the east end of the greenhouse. Minimum temperatures at both ends of the greenhouse did not vary by more than 2 C (Figures 24a, 24b).

Recording of the relative humidity in the greenhouse during May 1983 to October 1983 shows that the relative humidity reached 75% or greater each day for approximately 6 hr, 12 hr, 17 hr, 20 hr, and 12 hr, during the months of June, July, August, September, and October, respectively (Figure 25a, 25b, Data Summary Volume Tables H-1, H-2).

Analysis of the air quality in the north greenhouse showed that there were no significant difference in ionic species concentration between days on which spraying with the simulated saline drift took place and nonspraying days (Data Summary Volume Section C).

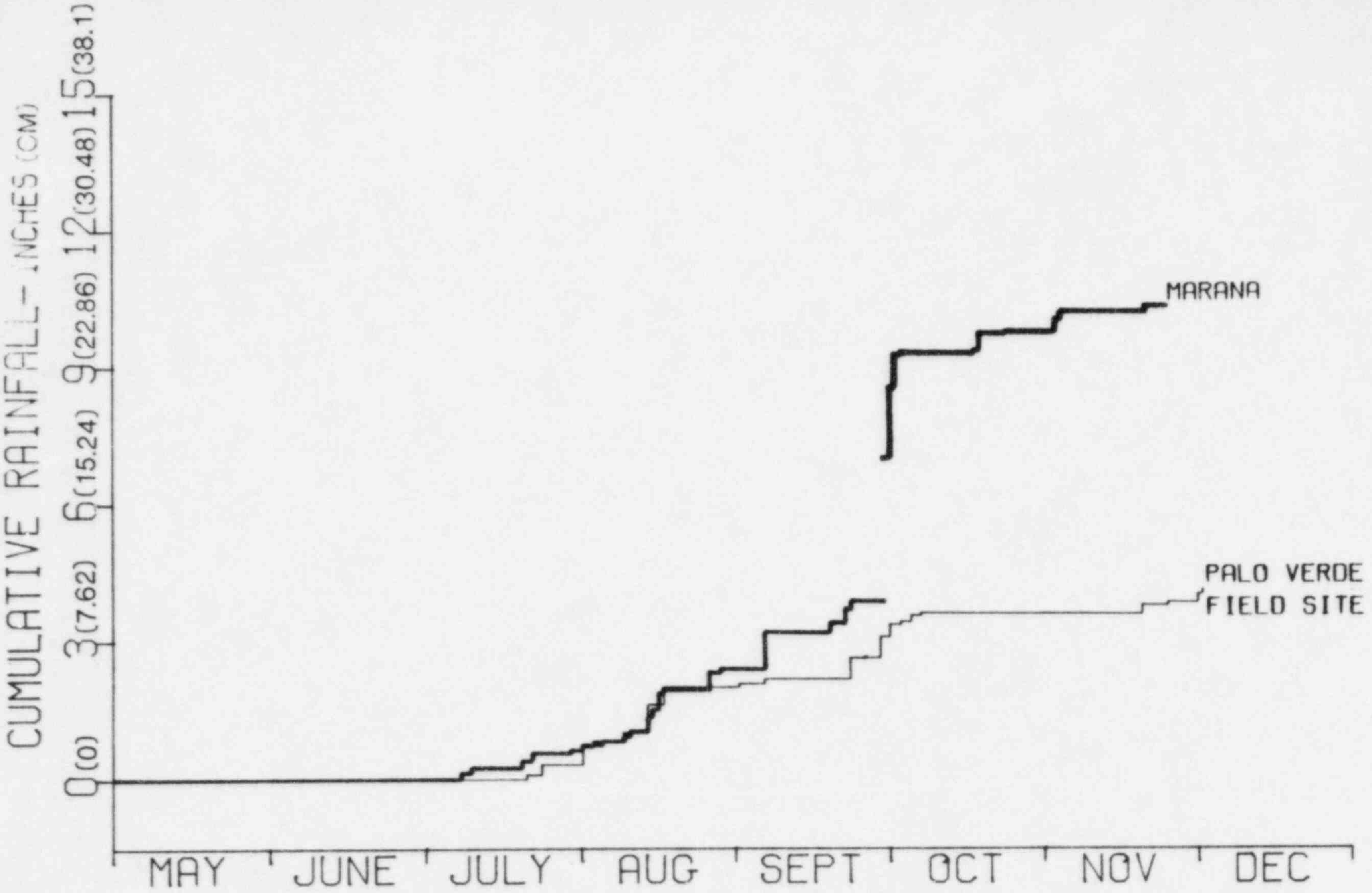


Figure 23. Rainfall comparison: Marana and the Palo Verde field site

Gaps indicate missing data.

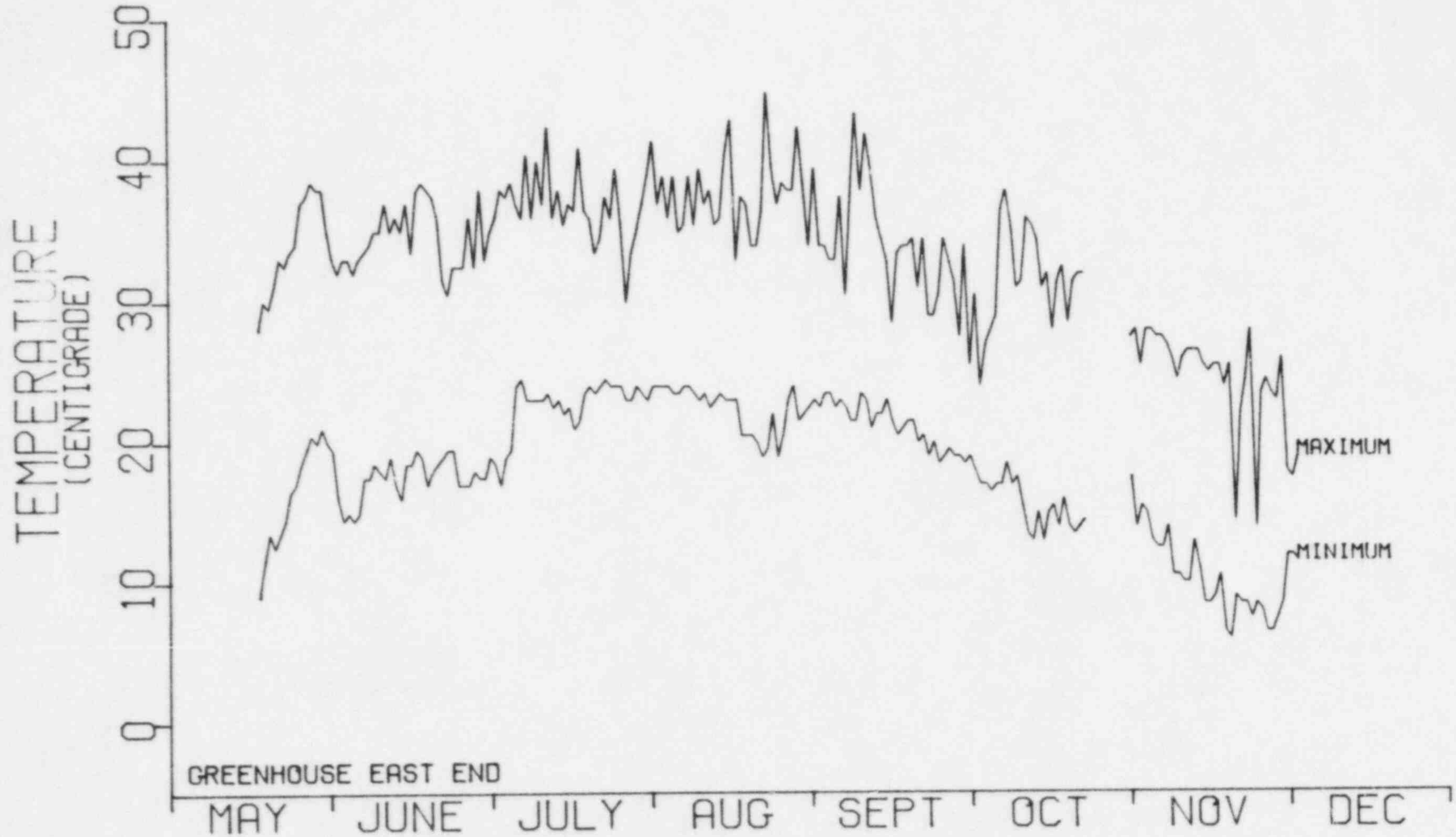


Figure 24a. Maximum and minimum temperatures recorded during the growing season at the east end of the north greenhouse

Gaps indicate missing data.

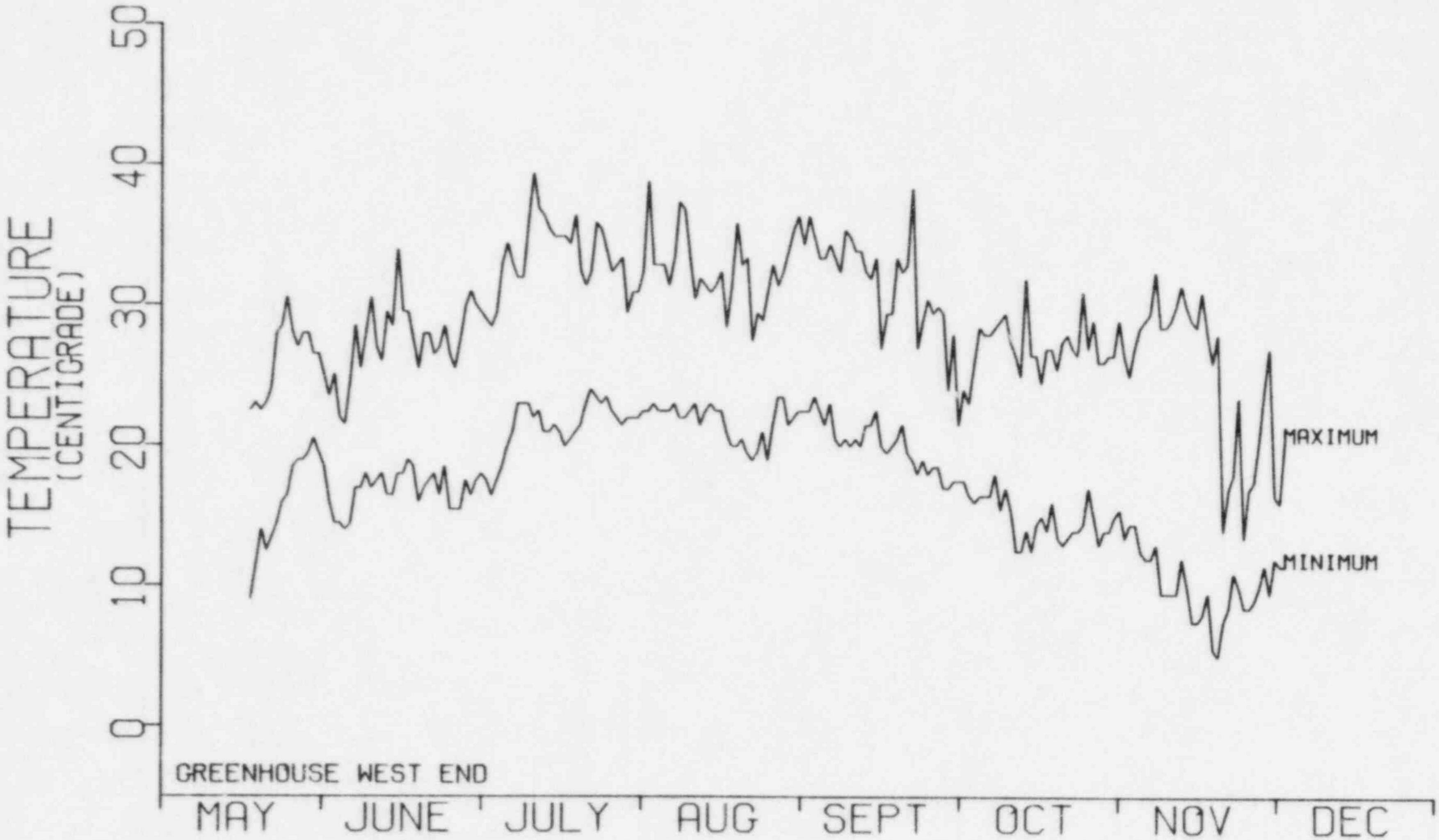


Figure 24b. Maximum and minimum temperatures recorded during the growing season at the west end of the north greenhouse

Gaps indicate missing data.

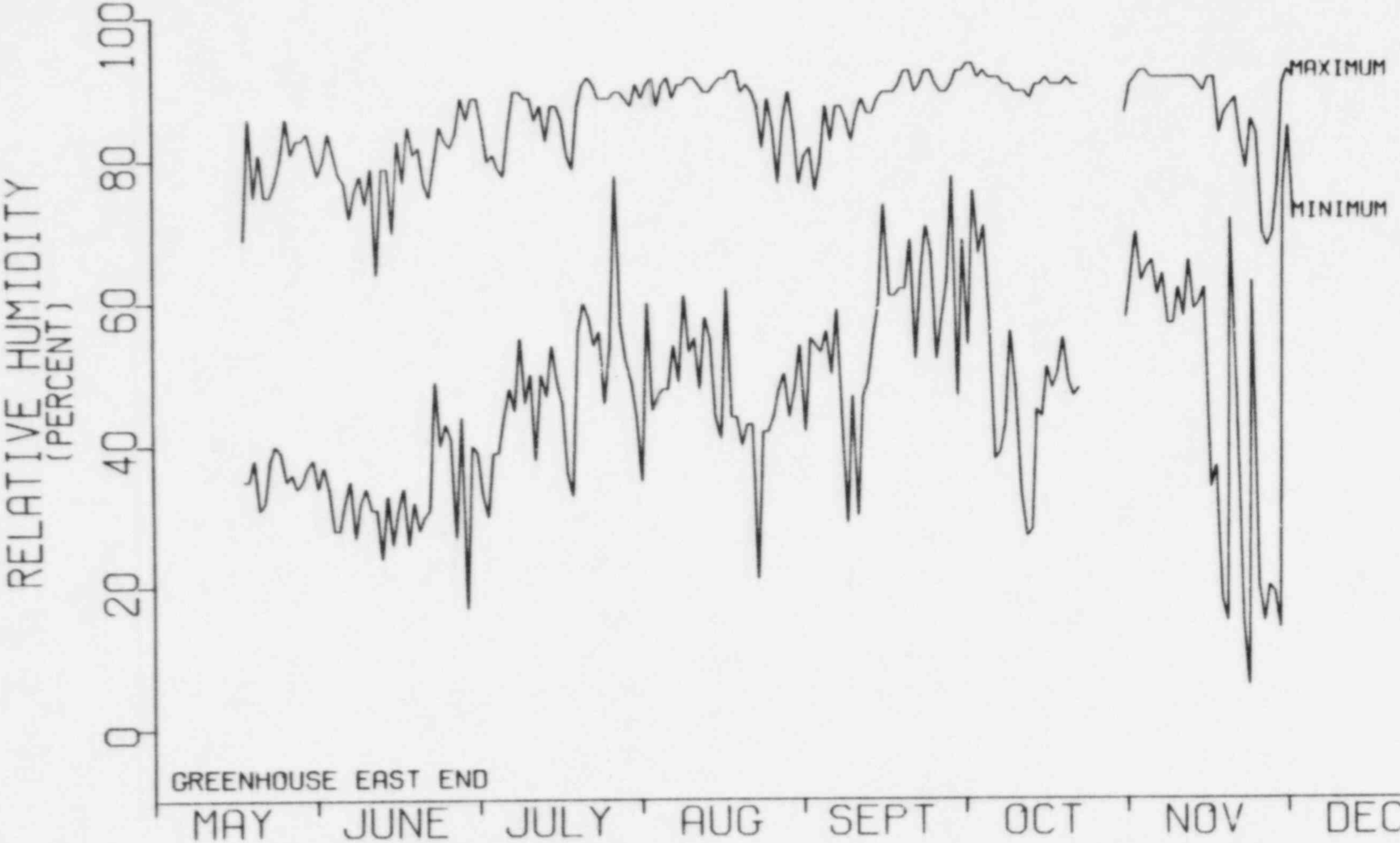


Figure 25a. Maximum and minimum relative humidities recorded during the growing season at the east end of the north greenhouse

Gaps indicate missing data.

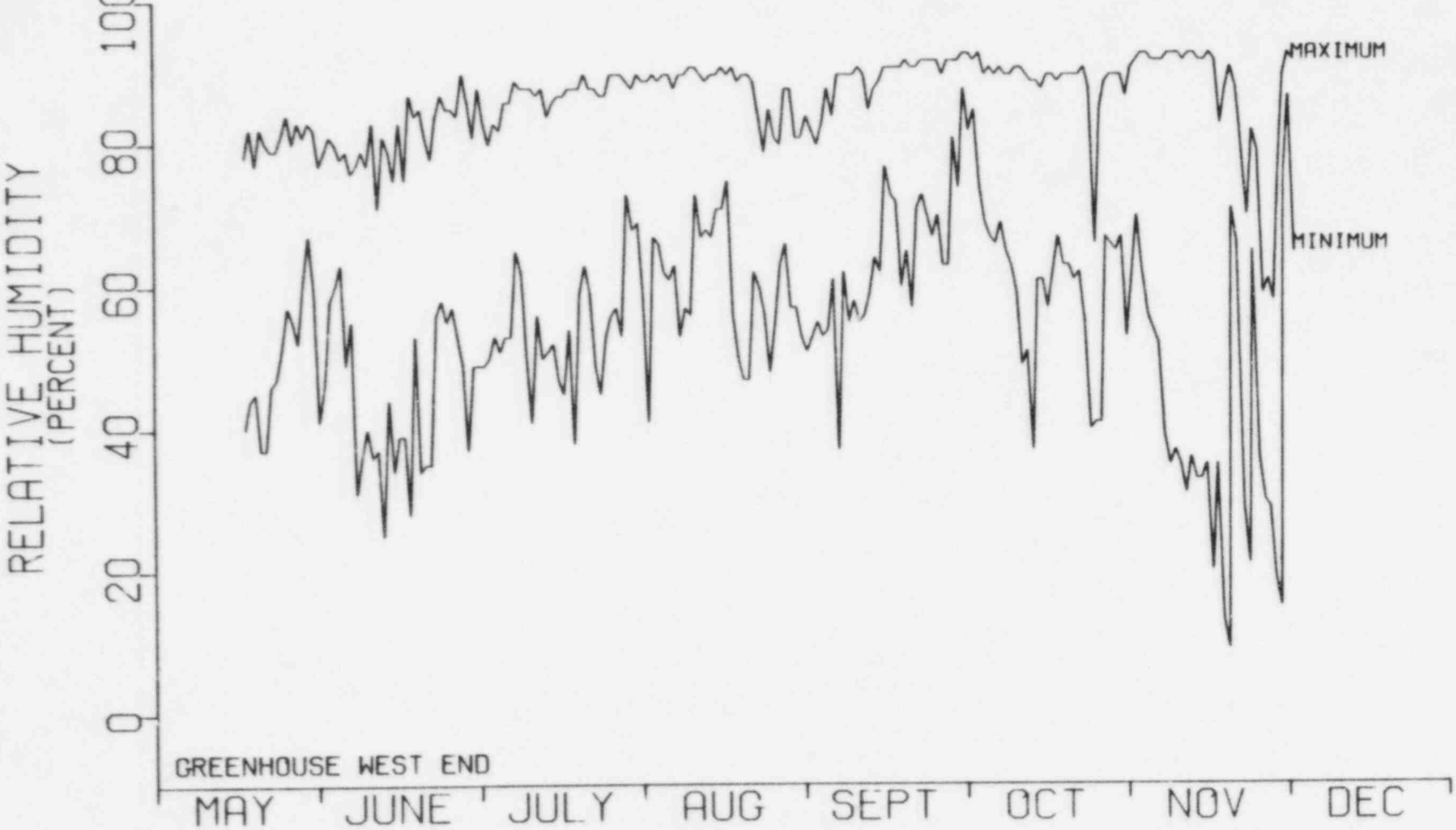


Figure 25b. Maximum and minimum relative humidities recorded over the growing season at the west end of the north greenhouse

Gaps indicate missing data.

5.3. GREENHOUSE EXPERIMENTAL RESULTS

5.3.1. Cotton

5.3.1.1. Resident Salts on Cotton Leaf Surfaces

There were no significant differences among the treatments in the north greenhouse for resident surface salts. The mean concentrations of resident surface salts were 0.045, 0.059, 0.048, 0.047 mg/cm^2 of leaf area and 10.2, 9.4, 10.6, and 9.2 mg/g leaf dry weight for the 0, 10, 100, and 500 lbs/a·yr nominal treatments, respectively (Data Summary Volume Table I-7).

In the south greenhouse, cotton plants treated with nominal 1000 lbs/a·yr simulated saline drift accumulated approximately 23 percent more surface salts/g dry weight of leaves than the controls (Table 18, Data Summary Volume Table I-7). These values were statistically different. The mean concentrations of resident surface salts were 22.3 and 29.2 mg/g leaf dry weight for the 0 and nominal 1000 lbs/a·yr treatment, respectively. On a leaf area basis, the resident salts on the control and treated plants are both 0.13 mg/cm^2.

5.3.1.2. Cotton Leaf Tissue Analysis

Tissue analysis showed that salts accumulated within cotton leaf tissue (Data Summary Volume Tables M-1 to M-4). At harvest, the average Na^+ concentration in the leaves of the nominal 500 lbs/a·yr treated cotton plants (4187 ppm) was approximately six times that of the control plants (662 ppm). The average Cl^- concentration in the treated plants (9901 ppm) was approximately twice that in the controls (5301 ppm). Only the Na^+ and Cl^- concentrations were statistically different (Table 18).

5.3.1.3. Phenological Responses

The plants in the nominal 1000 lbs/a·yr treatment group in the south greenhouse on the average were 19 cm shorter than the controls. This 15% reduction was consistent from 9 September to biomass harvest and was

Table 18.

Significant Differences

Visual Evaluations

Crop	Variable[a]	Harvest	Nominal Treatment Level (lbs/a·yr) 0	500	1000	Standard Error
Cotton North Greenhouse	Height/Plant (cm)					Trend difference
	No. Nodes/Plant					Trend difference
	No. Bolls/Plant 7/27, 8/4, 8/9, 8/15, 8/23, 8/30, 9/8, 9/13, 9/29, 10/5		10.27	12.22	*	0.78
	Tip Necrosis (% leaves/plant) 8/30, 9/8, 9/13, 9/29, 10/5		4.08	7.33	*	0.89
	Margin Necrosis (% area/leaf) 7/6, 7/11, 7/18, 7/27, 8/4, 8/9, 8/15, 8/23, 8/30, 9/8, 9/13, 9/29, 10/5		0.7	3.23	*	0.16
	General Chlorosis (% leaves/plant) 8/30, 9/8, 9/13, 9/29, 10/5		37.50	45.80	*	0.86
	Leafshed/plant[b] 7/27, 8/4, 8/9, 8/15, 8/23, 8/30, 9/8, 9/13, 9/29, 10/5		3.42	3.93	*	0.09
	Deformity - Margin Curl[c] 8/9, 8/15, 8/23, 8/30, 9/8, 9/13, 9/29, 10/5		0.69	0.80	*	0.10

Table 18 (cont.)

Crop	Variable	Harvest	Nominal Treatment Level (lbs/a·yr) 0	500	1000	Standard Error
Cotton North Greenhouse	Square shed/plant[b] 8/9, 8/15, 8/23, 8/30, 9/8		0.53	1.27	*	0.13
Cotton South Greenhouse	Height/Plant (cm)					Trend difference
	No. Flowers/Plant		0.36		0.23	0.04
	Tip Necrosis[c] 8/1, 9/9, 9/28, 10/10, 10/19, 10/26, 11/1		0.45	*	0.9	0.02
	Tip Necrosis (% leaves/plant) 8/1, 9/9, 9/28, 10/10, 10/19, 10/26, 11/1		5.85	*	27.86	1.69
	Margin Necrosis (% leaves/plant) 8/1, 9/9, 9/28, 10/10, 10/19, 10/26, 11/1		5.42	*	27.75	3.01
	Spot Necrosis (% leaves/plant) 8/1, 9/9, 9/28, 10/10, 10/19, 10/26, 11/1		0.77	*	6.37	0.87
	Surface Chlorosis (% leaves/plant) 7/8, 8/1, 9/9, 9/28, 10/10, 10/19, 10/26, 11/1		29.12	*	23.39	0.90
Barley - North Greenhouse	Spot Chlorosis (% leaves/plant) 8/17, 8/24, 9/1, 9/8, 9/14		4.17	10.25	*	2.9

Table 18 (cont.)

Crop	Variable	Harvest	Nominal Treatment Level (lbs/a·yr) 0	500	1000	Standard Error
Barley - North Greenhouse	General Chlorosis (% leaves/plant) 8/17, 8/24, 9/1, 9/8, 9/14, 9/29, 10/7, 10/12		29.9	34.3	*	2.75
Barley - South Greenhouse	Tip Necrosis[c] 7/19, 8/8, 9/14, 9/23		0.33	*	0.36	0.0001
	Margin Necrosis (% leaves/plant) 7/19, 8/8, 9/14, 9/23		1.39	*	2.96	0.14
Cotton - Field	Chlorosis (% leaves/plant) 7/5, 7/13, 7/26, 8/3, 8/25, 9/2, 9/12, 9/15, 9/27, 10/13		15.4	12.1	*	0.58
	Chlorosis (% area/leaf) 7/5, 7/13, 7/26, 8/3, 8/25, 9/2, 9/12, 9/15, 9/27, 10/13		24.3	19.2	*	1.16
	Chlorosis - Surface Yellow[c] 8/25, 9/2, 9/12, 9/15, 9/27, 10/13		0.38	0.29	*	0.03
Alfalfa - Field	Chlorosis (% leaves)		6.94	*	9.5	0.62
	Margin Necrosis[c]		0.08	*	0.28	0.04
North Greenhouse Alfalfa Transplants	Height (cm)/Plant	Seventh	32.6	30.87		0.40
	Diameter (NS) (cm)	Second	16.25	18.00		0.56
	(NS) (cm)	Fourth	20.30	24.15		0.06
	(EW) (cm)	Fourth	19.25	22.75		0.72

Table 18 (cont.)

Crop	Variable	Harvest	Nominal Treatment Level (lbs/a·yr) 0	500	1000	Standard Error
	No. of Stems/Plant	Third[d]	11.04	13.00		0.05
	Percent Bloom/Plant	Second	3.00	0.83		0.20
		Third[d]	3.54	4.79		0.76
	Chlorosis - Surface Yellow in Population[c]	First	0.46	0.04		0.01
North Greenhouse Alfalfa Seedlings	Height (cm)/Plant	Second	49.97	47.20		0.36
	No. of Stems/Plant	Fifth	30.83	33.75		0.07
	Abscission in Population[e]	Fourth	0.94	1.06		0.02
	Spot Chlorosis (% area/leaf)	Fifth	19.58	7.92		2.26
South Greenhouse Alfalfa Transplants	Abscission in Population[e]	Third	0.58		1.00	0.06
	Surface Chlorosis (% leaves/plant)	Fifth	55.00		30.83	3.11
South Greenhouse Alfalfa Seedlings	Abscission in Population[e]	Fourth	0.50		0.84	0.03

[a] Dates are 'isted for individual variables which were significant only for the dates listed, all dates listed were analyzed collectively.

[b] Each value represents the mean number of leaves, squares, or bolls shed for 12 plants.

[c] In each observation, condition was noted as "1," present or "0," absent. The resultant mean represents the fraction of the population affected with the condition.

d Linear response difference between treatment.

[e] In each observation, condition was noted as "0," no leaves abscised, "1," few leaves abscised, or "2," many leaves abscised. The resultant mean represents an index of the severity of the condition throughout the population.

Table 18 (cont.)

Harvest Data

Crop	Variable	Nominal Treatment Level (lbs/a-yr): No Tmt.	0	10	100	500	1000	Standard Error	b	S_b
Cotton - North Greenhouse	Fresh Weight Bracts/Plant (g)	*	21.58	29.76	28.73	31.36	*	1.39	--	--
	Dry Weight Bracts/Plant (g)	*	18.91	25.92	25.62	34.89	*	2.28	--	--
	Seed Cotton Weight/Plant (g)	*	63.90	83.31	81.56	88.94	*	3.67	--	--
	Lint Weight/Plant (g)	*	24.92	32.49	30.81	34.69	*	1.43	--	--
Alfalfa - Field	Leaf Surface Salt/ Leaf Area									
	mmhos/cm^2	0.0077	0.0066	0.0082	0.0139	0.0159	0.0274	0.0025	0.1839	0.0293
	mg/cm^2	0.0014	0.0015	0.0027	0.0087	0.0103	0.0248			
	Leaf Surface Salt/ Plant Dry Weight									
	mmhos/g	0.8997	0.7225	0.8983	1.5455	1.9025	3.2763	0.2721	0.0023	0.0002
	mg/g	0.1779	0.1575	0.2858	0.8990	1.2127	2.8552			
Cotton - Field Hand Harvested	No. Bolls	147.0	152.0	138.4	135.1	116.9	*	7.02	-0.0561	0.0172
	Seed Cotton (g/plot)	583.3	631.0	543.9	516.4	439.7	*	30.41	-0.2876	0.0744
Alfalfa Seedlings North Greenhouse	Leaf Surface Salt/ Leaf Area									
	mmhos/cm^2	*	0.0034	0.0036	0.0036	0.0091	*	0.00048	--	--
	mg/cm^2	*	0.0084	0.0090	0.0093	0.0266	*			
	Leaf Surface Salt/ Plant Dry Weight									

Table 18 (cont.)

Crop	Variable	No Tmt.	Nominal Treatment Level (lbs/a-yr) 0	10	100	500	1000	Standard Error	b	S_b
	mmhos/g	*	0.4766	0.5730	0.6005	1.1443	*	0.02400	0.00127	0.00006
	mg/g	*	0.7643	0.9287	1.2242	2.7100	*			
Alfalfa Seedlings South Greenhouse	Fresh Weight (g)	*	84.64	*	*	*	96.15	1.54	--	--
	Leaf Surface Salt/ Leaf Area									
	mmhos/cm^2	*	0.0025	*	*	*	0.0115	0.0004	--	--
	mg/cm^2	*	0.0061	*	*	*	0.0346	0.0015		
	Leaf Surface Salt/ Plant Dry Weight									
	mmhos/g	*	0.4086	*	*	*	1.5552	0.0330		
	mg/g	*	1.0483	*	*	*	4.7179	0.218		
Alfalfa Transplants North Greenhouse	Leaf Surface Salt/ Leaf Area									
	mmhos/cm^2	*	0.0033	0.0032	0.0040	0.0079	*	0.00065	0.09430	0.00860
	mg/cm^2	*	0.0070	0.0070	0.0098	0.0224	*			
	Leaf Surface Salt/ Plant Dry Weight									
	mmhos/g	*	0.3668	0.4169	0.5074	0.9638	*	0.026	0.00116	0.00006
	mg/g	*	0.7643	0.9287	1.2242	2.7100	*			
Alfalfa Transplants South Greenhouse	Leaf Surface Salt/ Leaf Area									
	mmhos/cm^2	*	0.0033	*	*	*	0.0121	0.0007	--	--
	mg/cm^2	*	0.0084	*	*	*	0.0365	0.0021		

Table 18 (cont.)

Crop	Variable	No Tmt.	Nominal Treatment Level (lbs/a·yr) 0	10	100	500	1000	Standard Error	b	S_b
	Leaf Surface Salt/ Plant Dry Weight									
	mmhos/g	•	0.3644	•	•	•	1.3805	0.0044	--	--
	mg/g	•	0.9273	•	•	•	4.1347	0.021		
Barley North Greenhouse	No. Seeds/Plant	•	263.00	198.67	203.08	296.67	•	18.01	--	--
	Leaf Surface Salt/ Plant Dry Weight (mg/g)	•	3.82	3.76	3.98	6.22		0.53		
Barley South Greenhouse	Leaf Surface Salt/ Plant Dry Weight (mg/g)		5.31				11.66	0.862		
Cotton South Greenhouse	Total Fresh Weight/	•	459.26	•	•	•	416.02	6.50	--	--
South Greenhouse	Plant (g)									
	Total Dry Weight/ Plant (g)	•	128.53	•	•	•	115.29	0.93	--	--
	Leaf Surface Salt/ Dry Weight of Leaves (mg/g)	•	22.28	•	•	•	29.18	0.92	--	--

Table 18 (cont.)

Porometer Data

Crop	Variable	Nominal Treatment Level (lbs/a-yr) No Tmt.	0	10	100	500	Standard Error	b	S_b
Cotton - Field	Leaf Temperature (C)	33.47	33.24	33.67	33.46	33.05	0.14	-0.00121	0.00035
	Temperature Differential (C)	2.4327	2.5765	2.3332	2.4230	2.6246	0.0586	0.00057	0.00015
Barley North Greenhouse, P.M.	Leaf Temperature (C)	*	26.83	26.98	27.28	27.78	0.19	0.0017065	0.000456
	Temperature Differential (C)	*	1.63	1.46	1.30	1.16	0.08	-0.000729	0.000191

Table 18 (cont.)

Tissue Analyses

Crop	Variable	Nominal Treatment Level (lbs/a-yr)			Standard Error
		Control[a]	500	1000	
North Greenhouse					
Cotton	Na	662.43	4186.92	—	419.37
	Cl	5301.00	9900.92	—	302.80
Alfalfa (Transplants)	Na	344.75	833.32	—	48.28
	Cl	6335.86	7508.19	—	112.89
Barley	Na	1882.67	2872.67	—	82.39
	Mn	72.80	59.18	—	1.98
Field					
Cantaloupe	N	15419.38	13473.50	—	469.98
Cotton	Na	1005.94	4651.86	—	121.68
	Ca	35314.00	31329.00	—	828.85
	Mg	4275.14	3320.29	—	111.00
	B	48.36	40.64	—	1.78
	Cl	18046.29	22500.29	—	515.02
Alfalfa	Na	911.00	—	3653.00	152.26
	Cl	9801.25	—	14848.63	764.92

[a] The sprayed control was analyzed in the greenhouse study, and unsprayed controls in the field study.

statistically significant (Figure 26, Data Summary Volume Table J-5). There was no significant difference in the number of nodes/plant between the treated plants and the controls. The number of flowers per plant per observation (seasonal average)* was significantly lower for the nominal 1000 lbs/a·yr treatment (0.23 flowers/plant) than in the control (0.36 flowers/plant) (Table 18, Data Summary Volume Table J-5). There was no significant difference in the number of bolls in the treated plants and the controls. No other statistically significant visual phenological differences were observed.

In the north greenhouse, statistical analysis showed that turgidity, epinasty, and number of stems/plant were not affected by the simulated saline treatment.

A comparison of plant heights (only between control and the nominal 500 lbs/a·yr treatment) showed that: 1) control plants and treated plants were not different from 14 June to 11 July; 2) the treated plants were significantly taller than control plants from 11 July to 15 August; and 3) control plants were significantly taller than treated plants from 15 August to 5 October (Figure 27, Data Summary Volume Table J-4).

In the earlier part of the growing season, the number of nodes on the nominal 500 lbs/a·yr treated plants during the middle and latter part of the growing season is significant, and that the simulated saline drift treatments appear to have reduced the height of the treated plants from 15 August to 5 October (Figure 27, Data Summary Volume Table J-4).

No significant differences were observed in the number of squares and the number of flowers between control plants and the nominal 500 lbs/a·yr treatment; however, the number of bolls/plant (seasonal average) and flowers/plant (seasonal average) was significantly greater for the nominal 500 lbs/a·yr treatment (12.2 bolls/plant) than for the controls (10.3 bolls/plant) (Data Summary Volume Table J-4). In addition, the seasonal average of the number of plants per observation in which squares and leaves were shed is statistically greater in the treated plants (nominal 500 lbs/a·yr) than in the control plants (Table 18, Data Summary Volume Table J-4)

*The average value for all individual measurements taken during the entire growing season.

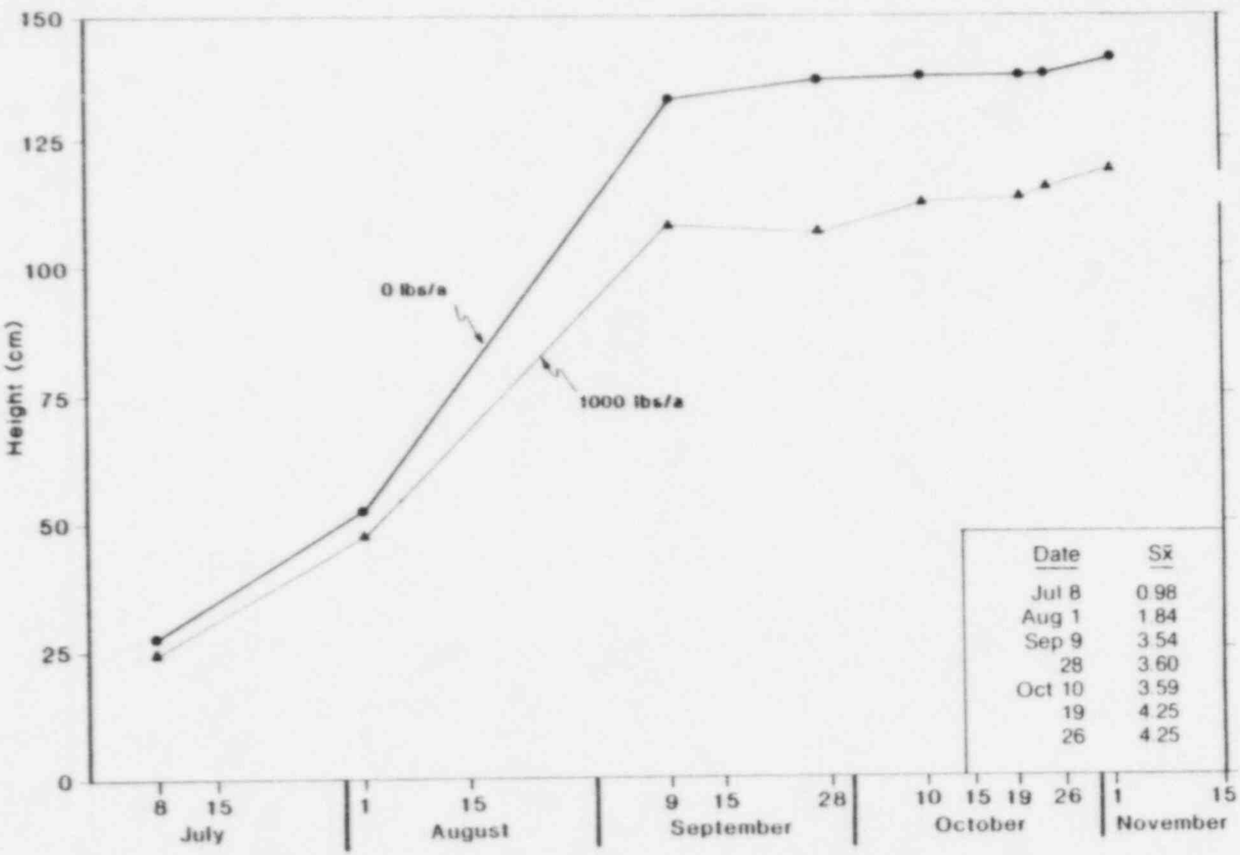


Figure 26. Mean plant heights of cotton treated with nominal 1000 lbs/a·yr simulated saline drift

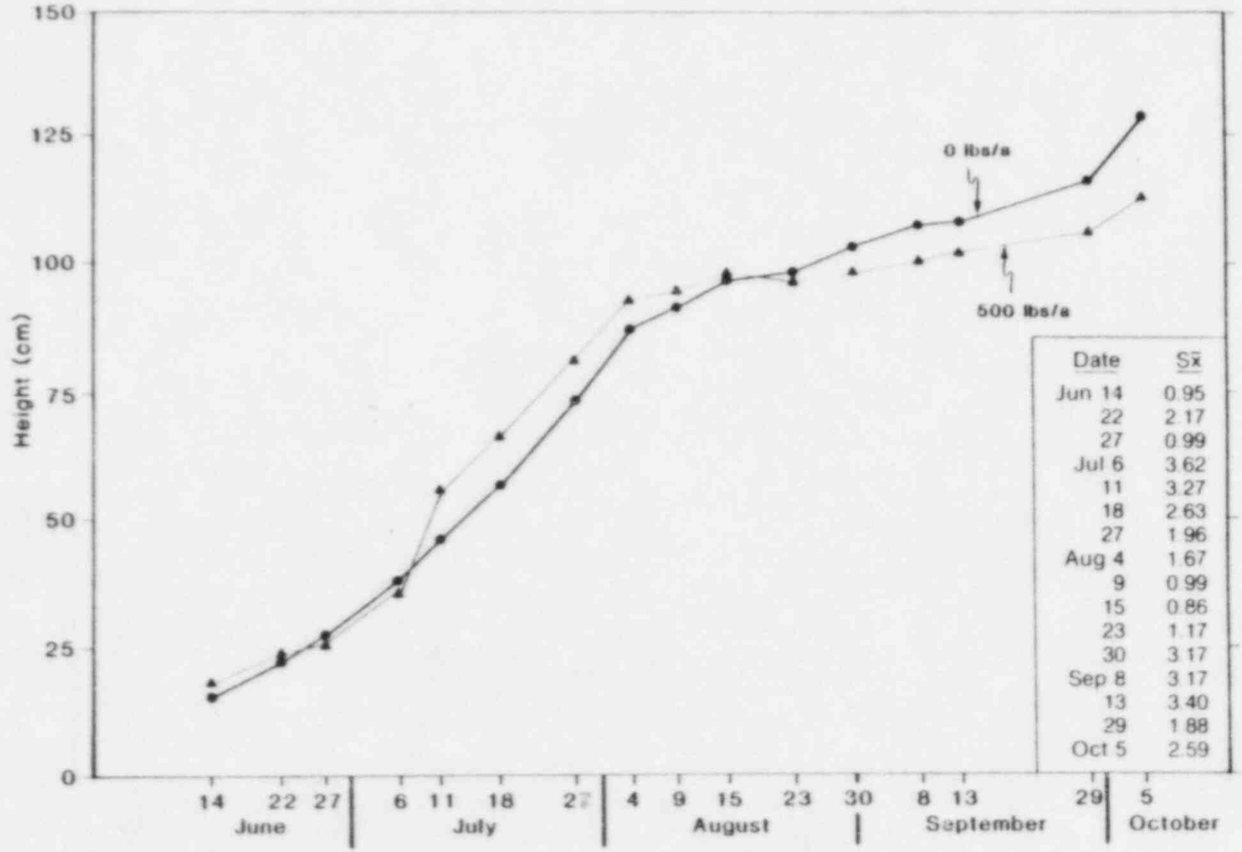


Figure 27. Mean plant heights of cotton treated with nominal 500 lbs/a·yr simulated saline drift

5.3.1.4. Foliar Injury

Tip and marginal necrosis were observed on the leaves in both the control and the nominal 1000 lbs/a·yr treated plants; however, the percentage of leaves/plant showing tip and/or marginal necrosis over time was significantly greater in the saline treated plants (Table 19, Data Summary Volume Table J-5). Based on seasonal averages, the nominal 1000 lbs/a·yr treatment exhibited approximately five times more leaf tip and margin necrosis/plant than the controls (Table 19). This necrosis was observed throughout the growing season. The percent area of the affected leaves showing tip and margin necrosis in the nominal 1000 lbs/a·yr ranged from 0.42% to 23.33% (Data Summary Volume Table J-5).

The seasonal averages of the percent leaves/plant showing spot necrosis was significantly higher in the treated plants (0.77%) than in the controls (6.37%), but this higher percentage was observed only during the earlier observation dates (Table 18, Data Summary Volume Table J-5). These results may have been influenced by the use of insecticides and nutritional deficiencies.

Tip, margin, and spot chlorosis were not observed on the cotton plants (nominal 1000 lbs/a·yr or 0 lbs/a·yr) during most of the observation periods. However, these plants did exhibit pale green general chlorosis throughout the growing season. The nominal 1000 lbs/a·yr treated plants showed significantly less general chlorotic leaves/plant than the controls over the growing season (Data Summary Volume Table J-5).

Plants in the north greenhouse treated with the nominal 500 lbs/a·yr treatment did not exhibit increases in marginal, or spot necrosis (% leaves/plant) when compared to the controls. However, the number of leaves exhibiting tip necrosis was significantly greater in the treated plants (7.3%) than in the controls (4.1%) from 30 August to 5 October. Analysis of the data in Data Summary Volume Table J-4 shows that from 6 July to 27 July, the necrotic injury probably was caused by leafburn from an insecticide. The seasonal average of percent leaf area having marginal necrosis was significantly higher in the nominal 500 lbs/a·yr treatment (3.23%) than in the controls (0.7%) (Table 18, Data Summary Volume Table J-4).

Table 19.

Visual Evaluations for Necrosis in Cotton
Treated with Nominal 1000 lbs/a-yr Simulated Saline Drift

Variable	Nominal Treatment Levels (lbs/a-yr)	Date								Seasonal Average	
		7/18	8/1	9/9	9/28	10/10	10/19	10/26	11/1	%	$S_{\bar{x}}$
Tip Necrosis	0	0	0	0	0	0	1.7	17.5	3.8	5.9	1.69
% Leaves/Plant	1000	0	1.7	19.6	35.4	30.0	36.7	37.5	34.2	27.9	
Margin Necrosis	0	0	0	0	0.8	0.4	17.5	11.3	8.0	5.4	3.01
% Leaves/Plant	1000	0	0.4	0	0	19.2	36.7	37.5	34.2	27.8	

From 30 August to 15 October, the simulated saline drift treatment produced significantly more leaf marginal curling deformity in the treated plants than in the controls (Table 18).

5.3.1.5. Harvest Yields

Average lint yields of 35.3 g/plant and 32.7 g/plant were obtained from the control and the nominal 1000 lbs/a·yr treatment, respectively. Seed cotton weights averaged 90.6 g/plant and 84.0 g/plant for the controls and treatment groups, respectively. This reduction in lint and seed cotton yields in the nominal 1000 lbs/a·yr treated plants was not statistically significant (Data Summary Volume Table I-7). The dates of first appearance of flowers, bolls, and seed cotto. vere the same for both treatments (Data Summary Volume Table J-4).

The simulated saline drift treatment did not appear to have changed the quality of the cotton lint. Minor differences were noted among some of the fiber analysis variables, but no consistent trends were observed for micronaire (fiber fineness), length, uniformity, strength, grade, trash, or color (Data Summary Volume Table I-6). For example, cotton fiber fineness was of better quality in the nominal 1000 lbs/a·yr treatment than in the control, but the uniformity of the cotton was of better quality in the control than in the nominal 1000 lbs/a·yr treatment.

The biomass harvest was significantly reduced by approximately 10% by the nominal 1000 lbs/a·yr treatment compared to the control on a fresh and dry weight basis (Table 20). These data correspond with the reduced heights of cotton plants in the nominal 1000 lbs/a·yr treatment (Figure 26).

In the north greenhouse, the simulated saline drift did not cause a reduction in fresh weight of leaves, fresh weight of stems, total fresh weight, dry weight of leaves, total dry weight of the plant, seed cotton weight, and lint weight in the nominal 500 lbs/a·yr treatment group as compared to the control.

Table 20.

Cotton Plant Biomass

Variable	Nominal Treatment Levels (lbs/a·yr)	Average Weight (g/plant)	$S_{\bar{x}}$
Total Fresh Weight	0	459.3	7.51
	1000	416.0	
Total Dry Weight	0	128.5	2.28
	1000	115.3	

A comparison of the mean weights of the seed cotton and the lint yields obtained for all treatments in the north greenhouse shows that there was a significant increase in the lint and seed cotton weights in all levels of the saline drift treated plants over controls (Data Summary Volume Table I-7). Seed cotton weight of 63.9, 83.3, 81.6, and 88.9 g/plant were obtained from the control and the nominal 10, 100, and 500 lbs/ac·yr treated plants, respectively. Total lint yields of 24.9, 32.5, 30.8, and 34.7 g/plant were obtained from the control and the nominal 10, 100, and 500 lbs/ac·yr treated plants, respectively. The nominal 500 lbs/a·yr treatment also significantly increased fresh and dry weight of the bracts as compared to the control (Data Summary Volume Table I-7).

5.3.1.6. Physiological Measurements

Porometer measurements of the cotton taken from the same leaf in the morning and afternoon showed no significant effects from the treatments for transpiration, diffusive resistance, leaf temperature, and temperature differential (Data Summary Volume Tables K-4 to K-11). Neither the seasonal mean response nor trend over time were found to be different. No differences were observed in the leaf water potential measurements in the 0 and the nominal 500 lbs/a·yr treated plants (Data Summary Volume Table L-1).

5.3.2. Alfalfa

5.3.2.1. Resident Salts on Alfalfa Plant Surfaces

Electroconductivity measurements of alfalfa seedlings and transplants washes from the four harvests in the south greenhouse reveal significant differences in the salts accumulation on the treated plants when compared to the controls (Data Summary Volume Tables I-11, I-12). A comparison of the seasonal averages of the salts on the surfaces of the controls and the nominal 1000 lbs/a·yr treated plants from the four harvests shows that there was a statistically significant increase in the resident salts per unit leaf area (mg salts/cm^2) and on a dry weight basis (mg salts/g) for the nominal 1000 lbs/a.yr treatment as compared to the controls. The concentration of salts on the plant surfaces of the nominal 1000 lbs/a·yr treatments of both seedling and

transplant alfalfa for all harvests was approximately three to four times higher than in the controls (Table 21).

Alfalfa transplants and seedlings in the north greenhouse also showed increased resident surface salts when treated with increasing levels of saline drift solutions (Data Summary Volume Tables I-9, I-10). Analysis of the seasonal means of the transplants shows that there was a significant difference among the treatments with an increase in resident salts on a dry weight basis (mg/g) and leaf area basis (mg/cm^2) with increasing treatment levels (Data Summary Volume Table I-10). The level of resident surface salt on the nominal 500 lbs/a·yr treated plants was approximately three to four times that of the distilled water controls (Table 18, Data Summary Volume Tables I-9, I-10).

5.3.2.2. Alfalfa Tissue Analysis

The Cl^- and Na^+ content was significantly greater in the nominal 500 lbs/a·yr treated plants than in the controls at each harvest. The Na^+ content of the treated plants (833 ppm seasonal average) was twice that of the controls (344 ppm seasonal average), whereas the Cl^- content of the treated plants varied from 10 to 33 percent greater than that in the controls (Data Summary Volume Table M-6). The Cl^- content of the treated (7508 ppm seasonal average) and control plants (6355 seasonal average) was always greater than the Na^+ content of these plants (Table 18).

5.3.2.3. Phenological Responses

None of the treatments of alfalfa transplants and seedlings in the south greenhouse affected plant heights, turgidity, diameters, epinasty, stem numbers, and percent bloom (Data Summary Volume Table J-10).

In the north greenhouse, the growth and development of alfalfa transplants treated with nominal 500 lbs/a·yr simulated saline drift were not reduced and in some instances were increased. In the second harvest, the percent bloom was significantly lower in the nominal 500 lbs/a·yr (0.83%) treatment than in the control (3%). In the third harvest the percent bloom

Table 21.

Surface Salts on South Greenhouse Alfalfa

Nominal Treatment Levels (lbs/a·yr)	Seasonal Average Transplants (mg/cm² leaf area)	Seasonal Average Seedlings (mg/cm² leaf area)	Seasonal Average Transplants (mg/g dry weight)	Seasonal Average Seedlings (mg/g dry weight)
0	0.0084	0.0061	0.9273	1.0483
1000	0.0365	0.0346	4.1347	4.7179
$S_{\bar{x}}$	0.0021	0.0015	0.021	0.218

averages were statistically greater for the nominal 500 lbs/a·yr treated plants than in the control plants. In the seventh harvest mean height was significantly lower for the nominal 500 lbs/a·yr treatment (30.9 cm) compared to the control (32.6 cm). The number of stems/plant in the third harvest was statistically higher in the nominal 500 lbs/a·yr treatment (13) than in the control (11). Plant diameters also were statistically higher for the nominal 500 lbs/a·yr treatment than in the control in the second (18 cm vs 16.3 cm), and fourth (24.2 cm vs 20.3 cm) harvests.

Growth and development of the alfalfa seedlings treated with nominal 500 lbs/a·yr simulated saline drift were not different from the control plants except during the second harvest. In the second harvest, the heights were significantly reduced by the nominal 500 lbs/a·yr treatment (47 cm) as compared to the control (50 cm). During the fifth harvest, the number of stems/plant was significantly higher in the nominal 500 lbs/a·yr treated plants (33.8) than in the control plants (30.8). During the fourth harvest period, there was significantly greater leaflet abscission in the nominal 500 lbs/a·yr treatment as compared to the control (Table 18, Data Summary Volume Table J-8).

5.3.2.4. Foliar Injury

No significant differences for any necrotic symptoms were found between the control plants and the nominal 1000 lbs/a·yr treated plants. (Data Summary Volume Table J-10).

The most common chlorotic symptom observed on the 0 and nominal 1000 lbs/a·yr treated alfalfa was general chlorosis. Spot and margin chlorosis were less prominent. No significant differences were observed for chlorosis except in the fifth transplant harvest, when the control plants had significantly more leaflets exhibiting general chlorosis/plant (55.0%) than the nominal 1000 lbs/a·yr treated plants (30.8%) (Table 18, Data Summary Volume J-10).

There were no statistically significant differences between treatments for leaf deformities. All alfalfa plants abscised a few leaflets throughout the

study. The abscission of the nominal 1000 lbs/a·yr treated plants was significantly greater than the controls during the third harvest period for the transplants and the fourth harvest period for the seedlings (Table 18, Data Summary Volume Table J-10).

For both transplants and seedlings, no statistically significant differences were observed between the control and the nominal 500 lbs/a·yr treatment for tip or margin necrosis. The treated and untreated alfalfa transplants in the north greenhouse showed essentially no tip or margin necrosis during the first four harvest periods. Only in the latter harvest periods were any necrotic symptoms observed in the transplants, but these differences were not significant. (Data Summary Volume Tables J-8, J-9). No tip or margin necrosis was observed in the seedlings in the first three harvests. Throughout the study, neither the transplants nor seedlings had tip and/or margin necrosis exceeding 12% for the control and treated plants (Data Summary Volume Tables J-8, J-9). In general, approximately 5% of the area of each affected leaflet in the seedlings and transplants had tip and/or margin necrosis.

No significant difference in spot necrosis was observed between the control and the nominal 500 lbs/a·yr treatment. Spot necrosis was detected during several of the harvest periods in both seedling and transplanted alfalfa, but both the number of leaves/plant showing necrotic spots and the area of those affected leaves was 5% or less.

The most common form of chlorosis noted in the alfalfa was pale green and yellow general. In general, there were no significant difference for chlorosis between the nominal 500 lbs/a·yr treatment and the control. In the first harvest period, the control transplants exhibited significantly greater general yellow chlorosis than the nominal 500 lbs/a·yr treatment. Seedlings in the fifth harvest exhibited a greater percentage of spot chlorosis per affected leaf (Table 18, Data Summary Volume Table J-8).

5.3.2.5. Harvest Yields

The alfalfa harvest showed that the simulated saline drift treatments did not cause a reduction in fresh weight, dry weight, or leaf area/alfalfa plant as compared to control plants (Data Summary Volume Tables I-9, I-10, I-11, I-12). No significant differences were noted among the treatments and the control except in the fresh weight of the alfalfa seedlings in the nominal 1000 lbs/a·yr treatment (Tables 18, 22). The differences in dry weights between treatments were not significant.

5.3.2.6. Physiological Measurements

There were no significant differences in transpiration, diffusive resistance, leaf temperature, and temperature differential in the mean or trend over time responses (Data Summary Volume Section K).

5.3.3. Barley

5.3.3.1. Resident Salts on Barley Plant Surfaces

At harvest, the 500 lbs/a·yr treated barley plants had significantly more resident salts on their surfaces than the control plants, the nominal 10 lbs/a·yr, and nominal 100 lbs/a·yr treatments (Table 23, Data Summary Volume Table I-8). Salt accumulation on surfaces of the nominal 10 and 100 lbs/a·yr treated plants was not statistically different from the controls.

There was a significant increase in resident salts for the nominal 500 lbs/a·yr treatment (6.2 mg/g dry weight) compared to the control (3.8 mg/g dry weight) (Table 23). There was also a significant increase in resident salts for the nominal 1000 lbs/a·yr treatment (11.7 mg/g dry weight) compared to the control (5.3 mg/g dry weight) (Table 23).

5.3.3.2. Barley Tissue Analysis

Barley plants treated with the nominal 500 lbs/a·yr simulated saline drift solution contained significantly more Na^+ than the control plants. The Na^+

Table 22.

Harvest Data for Greenhouse Alfalfa

Place and Plant	Nominal Treatment Levels (lbs/a·yr)	Seasonal Average: Fresh Weight (g/plant)	$S_{\bar{x}}$	Dry Weight (g/plant)	$S_{\bar{x}}$	Leaf Area (cm^2/plant)	$S_{\bar{x}}$
South House							
Seedlings	0	84.6		13.9		2040.7	
	1000	96.2		15.8		1964.1	
			1.5		0.4		95.0
Transplants	0	76.4		13.8		1747.8	
	1000	77.6		13.4		1661.4	
			4.9		0.8		26.3
North House							
Seedlings	0	68.1		11.7		1622.1	
	10	72.9		12.3		1591.6	
	100	71.3		13.0		1736.3	
	500	71.8		12.9		1725.9	
			4.6		0.8		49.1
Transplants	0	46.6		8.5		1024.8	
	10	47.6		8.4		1055.0	
	100	46.4		8.4		1116.8	
	500	51.5		9.3		1237.8	
			1.5		0.2		35.4

Table 23.

Deposition of Simulated Saline Solutions on Barley Plant Surfaces

Variable	Nominal Treatment Levels (lbs/a·yr)	North Greenhouse (mg/g dry weight)	North Greenhouse $S_{\bar{x}}$	South Greenhouse (mg/g dry weight)	South Greenhouse $S_{\bar{x}}$
Leaf surface salt per plant	0	3.82		5.31	
	10	3.76			
	100	3.98			
	500	6.22			
	1000			11.66	
			0.53		0.86

content was 1883 ppm and 2872 ppm for the controls and the nominal 500 lbs/a·yr treated plants, respectively (Table 18). Chloride content of the treated plants was slightly higher than the controls, but the means were not statistically different. Manganese content was significantly lower in the treated group (59.2 ppm) as compared to the control (72.8 ppm). Concentrations of other ions did not appear to be affected by the saline treatments.

5.3.3.3. Phenological Responses

The saline drift treatments did not appear to alter the development of the vegetative or reproductive structures. None of the plants showed epinasty or the lack of turgidity (Data Summary Volume Table J-6, J-7).

5.3.3.4 Foliar Injury

Barley plants grown in both greenhouses exhibited some tip, spot, and/or margin necrosis during the growing season but no significant differences were observed until the latter part of the growing season (Data Summary Volume Table J-6, J-7). From 19 July to 14 September, there was significantly more marginal necrosis on a percent leaves/plant basis for the nominal 1000 lbs/a·yr treatment (3% seasonal average) than in the controls (1.4% seasonal average). The percentage of leaves/plant exhibiting spot necrosis was similar in all the treatments in both greenhouses. No significant differences were observed among the treatments in the percent area of each leaf showing necrotic symptoms. Tip, margin and/or spot necrosis were similar in the nominal 500 lbs/a·yr treated plants and the control plants.

All barley plants showed chlorosis. About 13% of the leaf blades/plant in both the controls and treated plants showed marginal or tip chlorosis. There was a significant increase in the percentage of leaf blades/plant exhibiting spot and general chlorosis in the nominal 500 lbs/a·yr treated plants as compared to the control plants (Data Summary Volume Table J-7). The seasonal means for spot chlorosis were 4.17% and 10.3% in the control and nominal 500 lbs/a·yr treatment, respectively. The seasonal means for general chlorosis were 29.9% for controls and 34.3% for the nominal 500 lbs/a·yr treatment (Data Summary Volume Table J-6).

5.3.3.5. Harvest Yields

The above ground biomass of the barley plants was not significantly affected by any of the saline treatments (Data Summary Volume Table I-8). A comparison of the number of spikes, spikelets, seeds, and seed weights of the nominal 500 lbs/a·yr and nominal 1000 lbs/a·yr treatments and their respective controls showed that salt deposition did not appear to have reduced yield. However, the number of seeds/plant for the nominal 500 lbs/a·yr treatment was significantly higher than in the controls (Data Summary Volume Table I-8). The seed set was 29% for the controls and 35% for the nominal 500 lbs/a·yr treatment in the north greenhouse. There was no significant difference between control and the nominal 1000 lbs/a·yr treatment in number of seeds/plant (Data Summary Volume Table I-8).

5.3.3.6. Physiological Measurements

In general, no biologically significant differences were observed between the various treatments for transpiration (Data Summary Volume Tables K-10, K-11), diffusive resistance (Data Summary Volume Tables K-4, K-5), leaf temperature (Data Summary Volume Tables K-6, K-7), and temperature differential (Data Summary Volume Tables K-8, K-9). However, in the north greenhouse the afternoon leaf temperature was significantly higher in the nominal 500 lbs/a·yr treated plants (27.8 C) than in the controls (26.8 C).

There were no significant differences between treatments for leaf water potential (Data Summary Volume Section L).

5.4. FIELD EXPERIMENTAL RESULTS

5.4.1. Cotton

5.4.1.1. Resident Salts on Cotton Leaf Surfaces

Based on the leaf wash data, resident salts on the leaf surfaces increased with increasing treatment levels (Tables 24, 25). The differences were not statistically significant, however, there were over four times more salts on the

Table 24.

Cotton Leaf Wash (Field)
Data on a Leaf Area Basis
(mg/cm^2 leaf area)

Nominal Treatment Levels (lbs/a·yr)	Date					Average
	6/17	6/23	8/4	9/8	9/16	
No TMT	0.0024	0.0059	0.0045	0.0065	0.0049	0.0048
0	0.0035	0.0058	0.0057	0.0044	0.0055	0.0050
10	0.0056	0.0058	0.0057	0.0041	0.0060	0.0054
100	0.0126	0.0136	0.0059	0.0041	0.0079	0.0088
500	0.0356	0.0443	0.0095	0.0089	0.0157	0.0228
$S_{\bar{x}}$	0.0016	0.0025	0.0010	0.0011	0.0006	0.0007

Table 25.

Cotton Leaf Wash (Field)
Data on a Dry Weight Basis
(mg/g dry weight)

Nominal Treatment Levels (lbs/a·yr)	Date					Average
	6/17	6/23	8/4	9/8	9/16	
No TMT	0.39	1.10	0.94	1.62	1.28	1.07
0	0.62	1.08	1.31	1.02	1.36	1.06
10	0.90	0.98	1.32	1.05	1.61	1.18
100	1.98	2.47	1.39	0.98	2.09	1.78
500	6.15	8.00	2.18	2.30	4.42	4.61
$S_{\bar{x}}$	0.25	0.39	0.19	0.33	0.17	0.13

nominal 500 lbs/a·yr treatment (Figure 28) as compared to the unsprayed control, on both a dry weight and leaf area basis.

5.4.1.2. Cotton Leaf Tissue Analysis

Sodium ion and Cl^- concentrations were significantly higher at the 1% level of significance in the nominal 500 lbs/a·yr treatment when compared to the control. Sodium increased from 1006 ppm to 4652 ppm in the control and nominal 500 lbs/a·yr treated plants, respectively. Chloride in the tissue increased from 18046 in the control to 22500 ppm in the nominal 500 lbs/a·yr treatment (Table 18, Data Summary Volume M-2).

In the nominal 500 lbs/a·yr treatment leaf tissue, boron, calcium, and magnesium were significantly lower when compared to the control. Levels of boron dropped (significant at the 5% level) from 48.4 ppm in the controls to 40.6 ppm in the nominal 500 lbs/a·yr treatment. Calcium levels declined (significant at the 2% level) from 35300 ppm in the controls to 31300 ppm in the nominal 500 lbs/a·yr treatment. Magnesium levels declined (significant at the 1% level) from 4275 ppm in the controls to 3320 ppm in the nominal 500 lbs/a·yr treatment (Table 18).

No other statistically significant differences in ion concentrations were detected.

5.4.1.3. Phenological Responses

The morphological development of the nominal 500 lbs/a·yr treated plants was not different from the unsprayed controls (Data Summary Volume Table J-2). The nominal 500 lbs/a·yr treatment mean plant heights were slightly greater than those in the unsprayed control; however, neither the seasonal mean nor the response over time were found to be significantly different. The unsprayed control and nominal 500 lbs/a·yr plants remained fully turgid, and no evidence of epinasty was found.

The only visually evident, statistically significant, change to the plants was the degree of chlorosis. Beginning 25 August, the unsprayed control plants

Figure 28. Cotton plants at the Marana field site on 6 November 1983

showed more general chlorosis (38%) compared to the plants in the nominal 500 lbs/a·yr treatment (29%) (Table 18, Data Summary Volume Table J-2). Chlorosis on the control plants also was observed on a greater number of leaves/plant (15.4% and 12.1% for the unsprayed control and nominal 500 lbs/a·yr treatment, respectively) (Table 18, Data Summary Volume Table J-2).

While not statistically significant, a slight reduction in necrosis was observed in the nominal 500 lbs/a·yr treatment when compared to the controls.

5.4.1.4. Harvest Yields

The machine-harvested plots showed no statistical differences in yield (Table 26).

The hand-harvested yields from the nominal 10 lbs/a·yr treatment were not statistically different from the sprayed and unsprayed controls. The nominal 100 lbs/a·yr treatment had statistically lower yield than the sprayed control but it was not statistically different from the unsprayed control or the nominal 10 lbs/a·yr treatment. Yield from the nominal 500 lbs/a·yr treatment was significantly lower than the nominal 10 lbs/a·yr treatment and the sprayed and unsprayed controls (Table 26, Figure 29).

The machine- and hand-harvested plots showed an increase in yield for the sprayed controls. The hand-harvested plots showed a trend toward reduced yields when the unsprayed (no treatment) control is compared to the nominal 10, 100, and 500 lbs/a·yr treatments.

The machine-harvested plots showed a nonsignificant increase in yield when the nominal 10 lbs/a·yr treatment is compared to the no treatment control, and the nominal 100 lbs/a·yr and 500 lbs/a·yr treatments had nonsignificant decreases in yield when compared to the no treatment control.

Boll production throughout the season was consistently higher in the sprayed control when compared to the nominal 10, 100, and 500 lbs/a·yr treatments (Figure 30); however, only the sprayed control and the nominal 500 lbs/a·yr treatments were statistically different. The total number of bolls produced by the end of the season in the sprayed control plots was statistically

Table 26.

Field Cotton Harvest Data
(Results from hand- and machine-harvested plots
which represent two independent estimates of yield)

Nominal Treatment Levels (lbs/a·yr)	Hand-Harvested Plots[1] Seed Cotton (lbs/a)[4]	(n)	Machine-Harvested Plots: Seed Cotton[2] (lbs/a)	(n)	Lint[3] First Pick (bales/a)[5]	(n)	Lint[3] Second Pick (bales/a)[5]	(n)	Lint[3] Total (bales/a)[5]	(n)
No TMT	2527.2^{ab}	8	2269.6	7	1.35	8	0.39	7	1.62[6]	7
0	2734.3^{a}	8	2594.4	8	1.44	8	0.42	8	1.86	8
10	2356.5^{ab}	8	2316.2	8	1.28	8	0.38	8	1.66	8
100	2237.4^{bc}	8	2238.8	7	1.20	7	0.37	8	1.60[6]	7
500	1905.2^{c}	8	2124.4	8	1.17	8	0.35	8	1.52	8
LSD (0.05)	381.6		NS		NS		NS		NS	
$S_{\bar{x}}$	30.4		133.3		0.08		0.03		0.10	

[1]Total seed and lint weight hand harvested over the season as bolls opened.

[2]Total seed and lint weight from the first (1 November) and second (1 December) machine-harvested picks.

[3]Lint weight after ginning.

[4]Means followed by the same letters within a column are not significantly different when using the LSD test at the 5% level.

[5]One bale equals 480 lbs of lint.

[6]Total yield differs from the sum of the first and second picks because of 1 missing replication in either the first or second pick. This necessitated omitting the corresponding pick from the other harvest for statistical analysis.

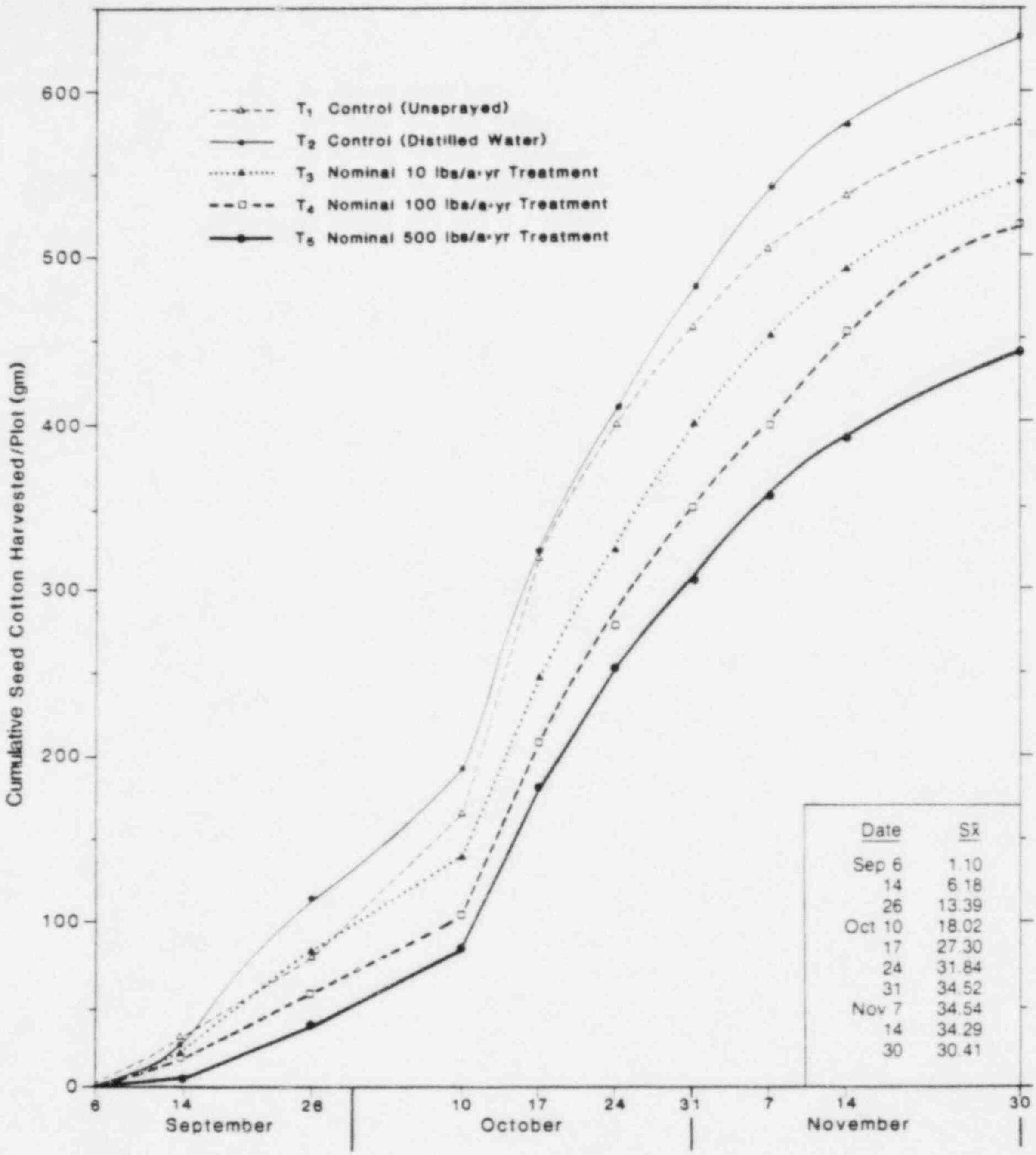


Figure 29. Cumulative hand harvested seed cotton (field)

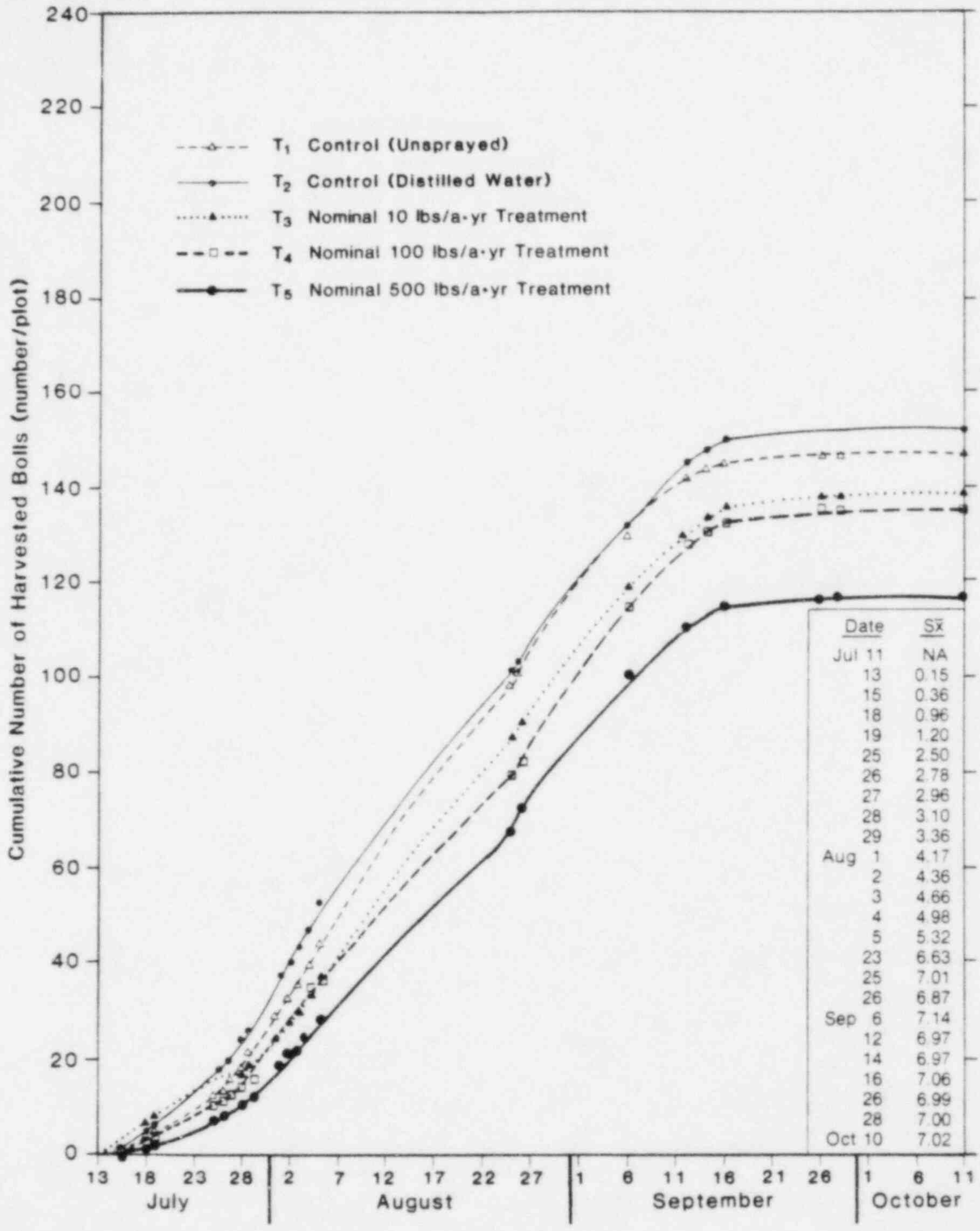


Figure 30. Cumulative cotton bolls harvested (field)

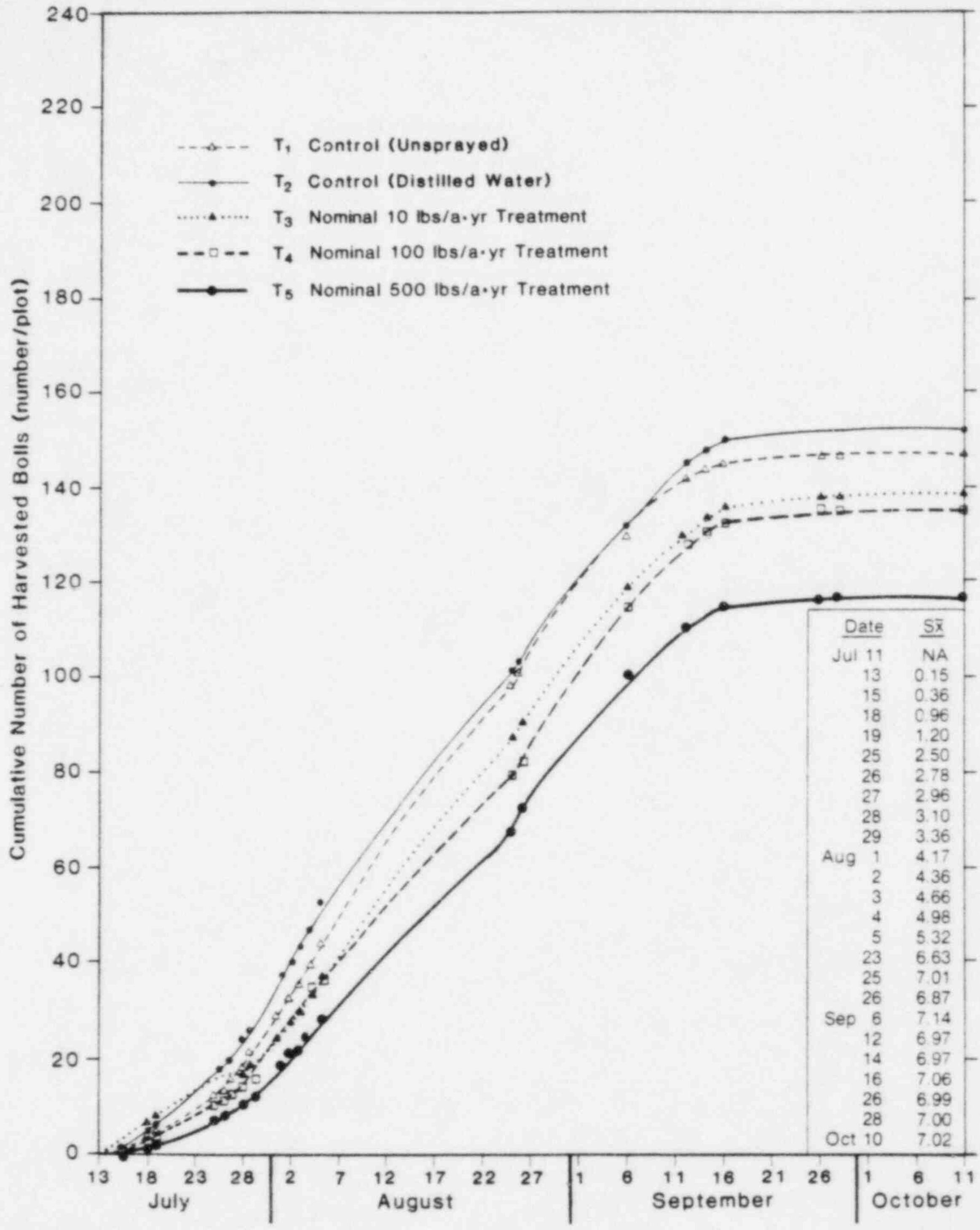


Figure 30. Cumulative cotton bolls harvested (field)

greater than the total number produced in either the nominal 100 or 500 lbs/a·yr plots (Table 27). No statistical differences were observed in the number of flowers or in the number of rotten bolls produced in the hand-harvested plots.

The fiber quality of samples from the machine-harvested plots showed no meaningful differences between treatments. Micronaire showed a slight, non-significant increase ranging from 37.50 to 40.25 for the nominal 500 lbs/a·yr treatment and the controls, respectively (Data Summary Volume Table I-2). A similar nonsignificant trend was observed for fiber strength, with the nominal 500 lbs/a·yr treatment having slightly weaker fibers. Based on the mean responses (Data Summary Volume Table I-2), the relationship between simulated saline drift treatment and fiber length is not resolved. There were no differences in either the grade or the amount of trash across the treatments.

5.4.1.5. Physiological Measurements

The measurements taken with a steady state porometer showed no meaningful significant differences in either transpiration or diffusive resistance. The nominal 10 lbs/a·yr treatment was found to have higher leaf temperatures than both the unsprayed control and the nominal 500 lbs/a·yr treatments (Table 28). The untreated control leaves were significantly warmer than those in the nominal 500 lbs/a·yr treatment. There was a significant trend towards cooler leaf temperatures from the nominal 10 to nominal 500 lbs/a·yr treatments ($b = 0.0012$, $S_b = 0.00035$) at the 1% level of significance.

Corresponding differences were observed for the temperature differential measurements during the season (Table 28). There was a significant difference between the unsprayed control (0 lbs/a·yr) and the nominal 10 lbs/a·yr treated leaves, with the nominal 10 lbs/a·yr treated leaves having the lower temperature differential. There was a significant linear increase in the temperature differential from nominal 10 lbs/a·yr to nominal 500 lbs/a·yr ($b = 0.000567$, $S_b = 0.000152$) at the 0.01 level of significance (Table 18).

Table 27.

Field Cotton Flowering and Boll Data

Nominal Treatment Levels (lbs/a·yr)	Flowers/7 ft of Row	Bolls/7 ft of Row[1]	Rotten Bolls/7 ft of Row
NO TMT	410.0	147.0[a]	43.3
0	418.8	152.0[a]	49.4
10	387.1	138.4[a]	46.4
100	391.8	135.1[ab]	49.5
500	389.5	116.9[b]	47.4
LSD (0.05)	NS	20.3	NS
$S_{\bar{x}}$	13.4	7.0	5.2

[1] Means followed by the same letter within a column are not significantly different using the LSD test at the 5% level.

Table 28.

Field Cotton Leaf Temperatures as Measured by LiCor Porometer
(Seasonal Average)

Nominal Treatment Levels (lbs/a·yr)	Leaf Temp (C)	$S_{\bar{X}}$	Temperature Differential (Cuvette - Leaf Temp, C)	$S_{\bar{X}}$
No TMT	33.47		2.43	
0	33.24		2.58	
10	33.67		2.33	
100	33.46		2.42	
500	33.05		2.62	
		0.14		0.06

No differences were observed in the leaf water potential between the 0 lbs/a·yr and the nominal 500 lbs/a·yr treatments which were the only treatments measured (Data Summary Volume Table L-1).

5.4.2. Alfalfa

5.4.2.1. Resident Salts on Alfalfa Plant Surfaces

Salt deposition on the leaf surfaces was monitored before the second and third harvests. On both sampling dates, there were significantly more salts in residence on the plants on a leaf area basis (mg/cm^2) and on a dry weight basis (mg/g D.W.) (Data Summary Volume Table I-5). Based on seasonal averages, there was a consistent increase in resident salts from 0.16 mg/g in the sprayed controls to 0.29, 0.90, 1.21, and 2.86 mg/g for the nominal 10, 100, 500, and 1000 lbs/a·yr treatments, respectively (Table 18, Data Summary Volume Table I-5).

5.4.2.2. Alfalfa Tissue Analysis

The Na^+ levels were increased significantly at the 1% level from 911 ppm in the unsprayed controls to 3653 ppm in the nominal 1000 lbs/a·yr treatment. Chloride content was also significantly increased at the 1% level from 9801 ppm in the unsprayed controls to 14849 ppm in the nominal 1000 lb/a·yr treatment (Table 18).

Copper levels were reduced in the nominal 1000 lb/a·yr treatment (significant at the 0.068 level) from 18.4 ppm to 10.6 ppm in the controls and nominal 1000 lbs/a·yr treatments, respectively. Calcium levels declined (significant at the 0.064 level) from 16200 ppm in the controls to 15000 ppm in the nominal 1000 lbs/a·yr treatment. No other significant differences were detected; however, there were trends toward reduced levels of potassium, iron, manganese and magnesium in the nominal 1000 lbs/a·yr treatment (Data Summary Volume Table M-3). Results of the boron analysis were invalid due to the accidental contamination of the water used in the analysis.

5.4.2.3. Phenological Responses

Visual evaluations on the unsprayed control and nominal 1000 lbs/a·yr alfalfa plots revealed only a few treatment effects (Data Summary Volume Table J-3). The heights of the plants were unaffected and at no time was there any epinastic response or any indication of lack of turgidity.

The nominal 1000 lbs/a·yr treatment induced significantly more leaflet necrosis than the unsprayed control (0 lbs/a·yr). The seasonal mean incidence of marginal necrosis showed that 28% of the leaflets were affected with marginal necrosis in the nominal 1000 lbs/a·yr treatments as compared to only 8% in the 0 treatment plots (Data Summary Volume Table A-3). In the last two sets of visual evaluations before the second and third harvests there was significantly more tip necrosis in the nominal 1000 lbs/a·yr treatment than in the control. These symptoms occurred after 6 to 7 weeks of repeated treatment application.

The incidence of leaflet chlorosis (% leaves/plant) was significantly lower in the sprayed controls compared to the nominal 1000 lbs/a·yr treatment, 6.9% and 9.5%, respectively. A significantly higher incidence of white marginal chlorosis was observed in the nominal 1000 lbs/a·yr treatment on 24 October (Figure 31). No chlorosis was observed in the control plots. A similar significant difference was seen on 3 November when 42% and 17% of the leaflets were affected in the nominal 1000 lbs/a·yr treatment and the control plots, respectively (Table 18, Data Summary Volume Table J-3).

5.4.2.4. Harvest Yields

The simulated saline drift treatments did not have any statistically significant effect on the yields of the three harvests, or on the total yield produced during the season (Data Summary Volume Table I-5).

5.4.2.5. Physiological Measurements

The simulated saline drift treatments had no measurable effect on any of the characteristics evaluated with the porometer. There were no statistically

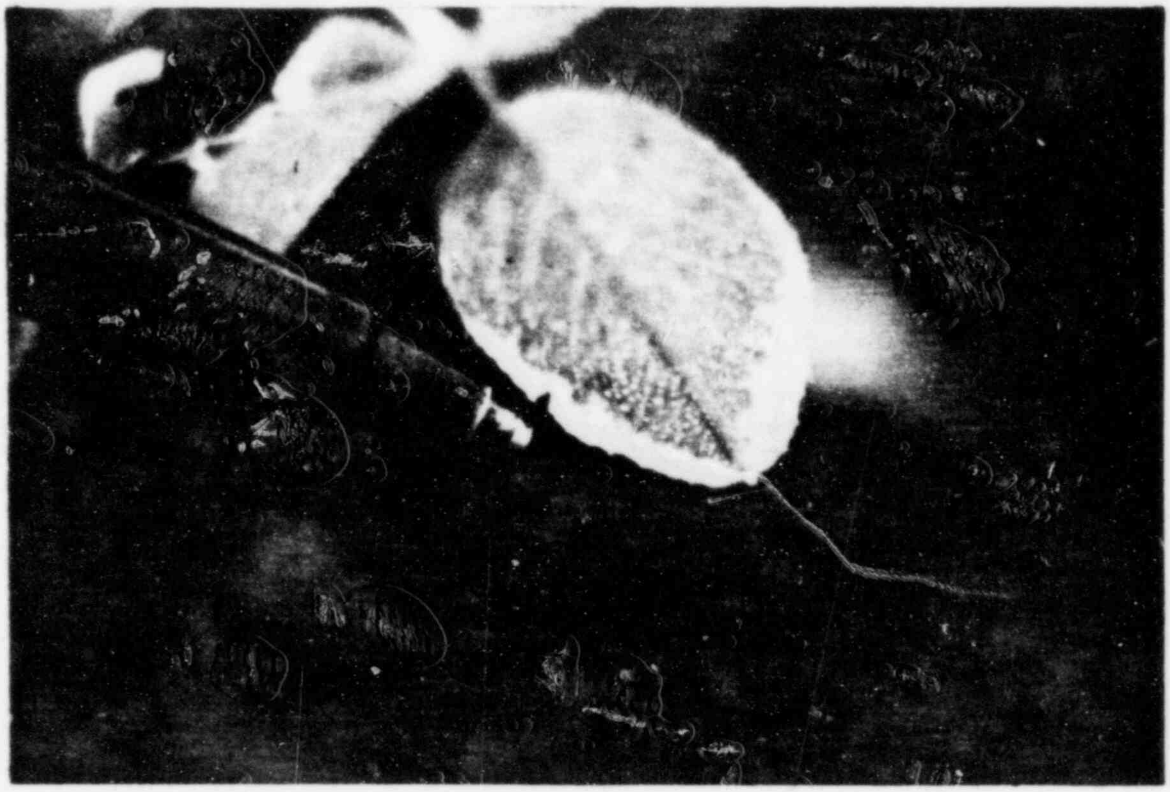


Figure 31. White marginal chlorosis on an alfalfa leaflet at the Marana field site

significant differences in transpiration or diffusive resistance. Leaf temperatures and the temperature differential measurements showed no differences in the seasonal mean response or the trend over time response (Data Summary Volume Tables K-3).

5.4.3. Cantaloupe

5.4.3.1. Resident Salts on Cantaloupe Plant Surfaces

The amount of salts resident on the cantaloupe leaves in the control, and the nominal 10, nominal 100, and nominal 500 lbs/a·yr treatments were not significantly different. The amount of salts resident on the plants in the nominal 500 lbs/a·yr treatment was 58% greater on a leaf area basis (mg/cm^2) and a dry weight basis (mg/g) than on the unsprayed controls (Data Summary Volume Table I-1).

5.4.3.2. Cantaloupe Tissue Analysis

Nitrogen levels were lower (at the 5% significance level) in the nominal 500 lbs/a·yr treatment with values of 15419.4 and 13473.5 ppm respectively for the unsprayed controls and the nominal 500 lbs/a·yr plots (Table 18, Data Summary Volume Table M-1). Lead levels were higher (at the 6.9% level of significance) in the nominal 500 lbs/a·yr treatment (0.75 ppm) compared to the unsprayed controls (1.06 ppm). No other significant differences were found

5.4.3.3. Phenological Responses

There were no statistically significant differences in the visual evaluations made on the cantaloupe plants (Data Summary Volume Table J-1). Numbers of flowers and fruit/plant were unaffected by the salt treatments. Similar amounts of chlorosis and necrosis were observed between the 0 lbs/a·yr and nominal 500 lbs/a·yr treated plants throughout the season.

5.4.3.4. Harvest Yields

No differences were observed at any of the four harvest dates for fresh weight, or total number of melons/harvest, or the total yield for the entire season (Data Summary Volume Table I-1).

5.4.3.5. Physiological Measurements

Measurements made with the porometer revealed no significant differences in transpiration, diffusive resistance, leaf temperature, and temperature differential (Data Summary Volume Table K-1).

6. DISCUSSION

6.1. SIMULATED SALINE DRIFT COMPOSITION AND DELIVERY

The composition of the simulated saline solution used in this study consisted of 28 different compounds in specified concentrations. The ionic composition was similar to that predicted by Bechtel Power Corporation for the blowdown water and drift of the cooling towers at the Palo Verde Nuclear Generating Station. The various treatment levels were chosen to approximate or exceed the predicted deposition levels in the off-site agricultural areas. The petri dish data and the delivered volume concentration data defined the actual quantities of salts delivered to the plots. Monitoring of the simulated saline drift treatment solutions by the University Analytical Center indicated that the treatment solutions used in this study contained about 75% of the TDS of the selected treatment levels.

It was not possible to apply the simulated saline drift in a dry crystalline state. However, water in the fine droplets of the simulated saline drift evaporated quickly, and the plants in both greenhouses and the field were dry within seconds of treatment applications.

The droplet sizes of the simulated saline drift were found to be within 1% and 5% of the targeted 100 μ for the field and greenhouse, respectively. This droplet size was selected based on previous work (Mulchi and Armbruster, 1981; McCune et al., 1977).

6.2. CLIMATIC COMPARISONS

According to McCune et al. (1977), foliar injury from saline particles is greater at a relative humidity of 85% compared to the effects at a relative humidity of 50%. The climatic conditions at both the greenhouse and field study sites (Figures 25 and 22, respectively) indicated that relative humidities exceeded 75% were recorded throughout the growing season (Table 17). The weekly mean maximum and minimum relative humidities were consistently higher at the Marana Field site compared to the Palo Verde field site. Because relative humidity was usually higher at Marana than at the Palo Verde field site, the likelihood of salt-induced plant injury probably would be greater at Marana.

Rainfall at Marana and at the Palo Verde field site was similar until late August. Marana received 1.25 in. more rain during September than the Palo Verde field site. An unusually large storm at the end of September and beginning of October resulted in 5.5 in. of rain at Marana. This represents more than 50% of the normal annual rainfall in this region. During the same period there was only 0.75 in. of rain at the Palo Verde field site.

The abnormally high amount of rainfall could have washed off salts accumulated on the leaf surfaces, but leaf tissue analysis of the cotton and alfalfa showed significantly higher amounts of both Na^+ and Cl^- in the high treatment plots (nominal 500 lbs/a·yr and nominal 1000 lbs/a·yr) than in the controls.

The Palo Verde field site mean maximum temperatures were 2.6 C higher than the mean maximum temperatures recorded at the Marana field site, for the duration of this study. The significance of differences in temperatures between the Palo Verde field site and Marana are unknown.

6.3. HARVEST YIELDS

6.3.1. Greenhouse

6.3.1.1. Cotton

Cotton yield at harvest depends upon the sequential development of the reproductive structures. Squares become flowers and flowers are transformed into mature bolls that contain the seed cotton. A decrease in any of these reproductive structures ultimately will affect harvest yield. The number of green bolls (seasonal average) was significantly higher on the treated plants (12.2 bolls/plant) than the controls (10.3 bolls/plant) except during the last two observations (Data Summary Volume Table J-4). Cotton plants treated with nominal 500 lbs/a·yr of simulated saline drift yielded significantly more seed cotton and lint/plant than the controls (Data Summary Volume Table I-1, I-4). This higher yield of seed cotton on the treated plants may have resulted from the timing of the termination of the cotton experiments in the north greenhouse. At termination the control plants had about 5 times more green bolls on a weight basis than the nominal 500 lbs/a·yr treated plants, indicating that the bolls of treated plants matured before the controls (Data Summary

Volume Table J-4). If all the green bolls on the control plants matured and opened, yield of the control might have been similar to or greater than the yield of the nominal 500 lbs/a·yr treated plants.

The number of flowers/plant (seasonal averages) was significantly reduced in the nominal 1000 lbs/a·yr treatment as compared to the control (Table 18). A consequence of such a reduction in flowering may be a decrease in the number of bolls and ultimately a decrease in the amount of seed cotton. A consistent, but nonsignificant reduction in the number of bolls/plant was observed from 9 September to 1 November in the nominal 1000 lbs/a·yr treated plants (Data Summary Volume Table J-5). There was a nonsignificant reduction in seed cotton, and lint weights were reduced by about 8% in the nominal 1000 lbs/a·yr treated plants as compared to the control plants (Data Summary Volume Table I-7). This 8% reduction may be attributed in part to the reduced numbers of flowers and bolls.

6.3.1.2. Alfalfa and Barley

Alfalfa and barley yields in both greenhouses were not significantly affected by any treatment, despite some observed foliar injury. These results were similar to the findings of Maas, Grattan and Ogata (1982), who observed that barley and alfalfa top growth was not significantly affected by salts applied by sprinkler irrigation.

Mulchi and Armbruster (1981) correlated yield losses with Na^+ and Cl^- content of corn and soybean leaf tissue sprayed with saline aerosol mist. For corn, a salt sensitive species, the authors predicted a 35.5% reduction in yield with tissue having a Cl^- content of 1% (10000 ppm) on a dry weight basis. For soybean, also a salt sensitive species, they predicted a 20% reduction in yield with tissue Cl^- content of 1% on a dry weight basis. Corn and soybean plants containing 1% Na^+ in their leaf tissue were projected to have a yield reduction of approximately 64% and 58%, respectively.

Since corn and soybean are salt-sensitive plants, the internal concentration of Cl^- and/or Na^+ necessary to produce similar yield losses for salt tolerant plants such as tobacco, barley, and alfalfa would probably be

tolerant to foliar salts applied by sprinkler irrigation. They found that cotton, alfalfa and barley absorb 26000 ppm, 17500 ppm and 52500 ppm of Cl^-, respectively without reductions of top growth biomass.

In our greenhouse studies, significant yield reductions were not observed in part because levels of toxic ions sufficient to produce yield losses were not attained and cotton, alfalfa and barley are salt-tolerant species. The Na^+ and Cl^- tissue content of the nominal 500 lbs/a·yr treated cotton, alfalfa, and barley plants never exceeded 10000 ppm (Table 18). The Na^+ and Cl^- content for the nominal 500 lbs/a·yr treatment was 2872 and 7824 ppm for barley, 833 and 7508 ppm for alfalfa, and 4187 and 9901 ppm for cotton, respectively (Table 18). The differences in the amounts of Na^+ and Cl^- absorbed by the three species in the greenhouse study were probably dependent upon: 1) dosage; 2) number of applications; 3) amount of salts retained on the leaf surfaces; and 4) the quantity absorbed into the tissue.

The Na^+ and/or Cl^- did not accumulate to sufficient levels in the plant tissue to cause significant yield losses probably because these plants were treated with small, chronic doses of saline drift solution and these doses were insufficient to increase the internal concentrations to the toxic levels. Four months of spraying with the nominal 100 lbs/a·yr treatment solution (1.34 μg Cl^-/cm^2·day) would be required to deliver a total concentration of 176 μg Cl^-/cm^2, which is the level reported by Mulchi and Armbruster (1981) to induce a 10% yield reduction in the salt sensitive corn species. At the nominal 1000 lbs/a·yr treatment level (13.4 μg Cl^-/cm^2·day), about 27 calendar days would be required to reach a Cl^- concentration of 360 $\mu g/cm^2$, which is the level noted by Mulchi and Armbruster (1981) to induce a 10% yield reduction in soybean. These calculations demonstrate that long-term applications of salts would be required before salt induced yield losses could be expected in salt-tolerant species. Alfalfa was harvested on an average of every 21 days, which is an insufficient time to accumulate toxic quantities of Na^+ and/or Cl^-.

6.3.2. Field

6.3.2.1. Cotton

Although vegetative development and growth of the cotton plants did not appear to be adversely affected by the saline drift treatments, the reproductive development of flowers and squares to bolls may have been impacted. Independent hand-harvest and machine-harvest yield estimates were made in the different rows of the same cotton plots (Table 26). The hand-harvested yields from the nominal 10 lbs/a·yr treatment were not statistically different from the sprayed and unsprayed controls or the nominal 100 lbs/a·yr treatment. The nominal 100 lbs/a·yr and nominal 500 lbs/a·yr treatments had statistically lower yields than the sprayed control. Yield from the nominal 500 lbs/a·yr treatment were significantly lower than the nominal 10 lbs/a·yr treatment and the sprayed and unsprayed controls.

There were no statistical differences for yield in the machine harvested plots; however, there was a trend toward reduced yields with increasing treatment levels in the sprayed plots (Table 26). Yield from the unsprayed control was less than the yield from the nominal 10 lbs/a·yr treatment and was only slightly less than the yield from the nominal 100 lbs/a·yr treatment.

Yields from the sprayed controls in the hand-harvested and machine-harvested plots were greater than the yields from the corresponding unsprayed controls. Although nonsignificant, the hand-harvested plots showed a decrease in yield for the nominal 10 lbs/a·yr treatment compared to the unsprayed control. The different responses observed with the sprayed and unsprayed controls may be attributed in part to the slight nutrient content of the sprayed control treatment solution (Data Summary Volume Section C) and/or possible alterations to the canopy microclimate caused by the moisture provided by the sprayed control. The greater precision of the hand-harvested method, which involved harvesting seed cotton as it matured, may have aided in the detection of statistical differences.

The flower tagging study provided a possible explanation for the significant reduction in yield in the hand-harvested plots. The number of

flowers produced was not different among the treatments; however the number of bolls was statistically different at the nominal 500 lbs/a·yr compared tc the sprayed and unsprayed controls and the nominal 10 lbs/a·yr treatment (Table 27). Floral initiation did not appear to be affected by the simulated saline drift. In the treated plots, however, fewer of the flowers developed into mature bolls, and boll production in the simulated saline drift plots was consistently lower than in the controls. The simulated saline treatments may have had an effect on pollination and/or boll development. These results agree with the findings of Maas, Grattan and Ogata (1982) who observed that sprinkling for 6 weeks with saline solutions appeared to decrease the fresh weight of bolls by 37%. Studies by Busch and Turner (1965, 1967) comparing flood irrigation with sprinkler irrigation using water with 3000 ppm salt content found yield reduction of 32% in short staple cotton and 57% in long staple cotton in the sprinkler irrigated plants.

Other workers have investigated the affects of foliar applied salts on reproductive development. Hassan (1981) observed that NaCl sprayed on bean plants (Phaseolus vulgaris) stimulated vegetative growth but reduced flower, pod, and seed growth. Bernstein and Francois (1975) reported lower yields from bell peppers sprinkled with saline water. More leaf burn and lower yields were observed when plants were sprinkled at 2.3 day intervals (seasonal average) compared to 3.5 and 4.75 day intervals, and they attribute the yield reduction primarily to foliar salt absorption. Eisikowitch (1979/1980) reported that a salt sensitive ecotype of the horned poppy (Glaucium flavum, Crantz) has difficulty setting seed when exposed to sea spray.

Caution should be used when comparing the yield results of the greenhouse and field studies because of the different environmental conditions under which the plants were grown. The canopy characteristics, spacing of the plants, and root development were different. Field plants absorbed salts from both their foliar surfaces and soil, whereas greenhouse plants absorbed salts primarily from their leaf surfaces. Greenhouse plants were exposed to regulated temperatures and humidities, and modified light, whereas field plants were exposed to natural conditions similar to those in off-site agricultural areas near the Palo Verde Nuclear Generating Station.

6.3.2.2. Alfalfa and Cantaloupe

Alfalfa and cantaloupe harvest yields were not significantly affected by the saline treatments. However, over the season there was a nonsignificant decrease (2580 lbs/a) in the amount of alfalfa biomass produced in the nominal 1000 lbs/a·yr treatment compared to the controls. The tendency toward reduced harvest yield, in addition to the observed significant increase in chlorosis and necrosis, indicated that the vegetative development of the alfalfa treated with the nominal 1000 lbs/a·yr simulated saline drift was hindered. However, the nominal 500 lbs/a·yr treatment had a yield nearly identical to that of the controls.

The nominal 1000 lbs/a·yr treated greenhouse alfalfa did not show a similar yield reduction. This may be attributed in part to the more frequent greenhouse harvest that resulted in decreased exposure to the simulated saline drift. Therefore, no injuries or yield reductions were noted for the treated greenhouse alfalfa.

There were no significant differences in cantaloupe fruit yields. Lead content was increased from 0.75 ppm in the control to 1.06 ppm in the nominal 500 lbs/a·yr treatment (significant at the 0.069 level). These levels of lead are below the 7 ppm standard established by the Food and Drug Administration for lead content in food products (personal communication).

6.4. PHENOLOGICAL AND PHYSIOLOGICAL RESPONSES

6.4.1. Greenhouse

6.4.1.1. Cotton

Cotton plant heights were significantly reduced in both the nominal 500 and nominal 1000 lbs/a·yr treated plants compared to the controls, especially toward the end of the growing period when the salts had accumulated within the tissue (Table 18). The fresh and dry weights of the nominal 1000 lbs/a·yr treated cotton plants were significantly reduced as compared to the controls (Table 18). These results correspond with those of Maas and Hoffmann (1977), who reported that the growth rate and ultimate size of many plant species

decrease as the soil Na^+ and Cl^- concentrations exceed a threshold level. The top growth of plants was frequently suppressed more than the root growth; however, not all plant species were affected equally. In contrast to this study and those of Maas and Hoffmann (1977), Maas, Grattan and Ogata (1982) reported that after six weeks of sprinkler irrigation the fresh and dry weights of cotton were not reduced. The difference between the results of this study and those of Maas, Grattan and Ogata (1982) may be attributed to the longer duration of treatment in this study.

In addition to growth reduction, the number of nodes/plant was significantly reduced on the nominal 500 lbs/a·yr treatment (Data Summary Volume Table J-4); however, the number of nodes/plant was not significantly reduced in the nominal 1000 lbs/a·yr treated plants. The reduced growth of the nominal 500 lbs/a·yr treated plants appears to have been caused by both node reduction and internode length reduction. In contrast, growth reduction in the nominal 1000 lbs/a·yr treated plants was caused by internode length reduction only.

Reduced growth of the simulated saline drift treated cotton plants may be caused by: 1) development of a water deficit or adverse water relations; 2) development of nutrient deficiencies or nutrient imbalances; and/or 3) accumulation of toxic levels of ions.

As salts accumulate within the foliage, there could be a corresponding water potential reduction resulting in a water deficit, decreased transpiration, and reduced growth. The water potential and transpiration in the nominal 500 and 1000 lbs/a·yr simulated saline drift treated cotton plants were not significantly different from the control plants (Data Summary Volume Tables K-4 to K-11, L-1). The results suggest that the effect of the saline drift on growth was caused by factors other than adverse changes in the water status of the plants.

None of the essential mineral nutrients were significantly decreased in the nominal 500 lbs/a·yr treated cotton plants as compared to the controls. Only Na^+ and Cl^- content were significantly increased in the treated plants. The high levels of Na^+ in the nominal 500 lbs/a·yr treated plants did not result in a corresponding reduction of the potassium ion concentration as reported in

previous studies (Maas, Grattan and Ogata, 1982; Bernstein, 1975). The results of this study suggest that the effects of saline drift on growth were caused by factors other than adverse effects on plant nutrition.

Cotton tissue analysis showed that the Na^+ level of the nominal 500 lbs/a·yr treatment was six times the level of the controls and the Cl^- level was twice that of the controls. Greenway and Munns (1980) reported that growth reductions caused by toxic ions were generally greater than reductions predicted from water potential or osmotic effects alone. The authors reported that the growth and yield of avocado, soybean, and grape vines were reduced at such low Cl^- concentrations that adverse effects due to low water potential are implausible. These studies indicated that osmotic potential was probably not a major factor in reducing growth. The results of our study suggest that the effects of simulated saline drift may be caused by the toxicity of Na^+ and/or Cl^-.

Based on our results we are not able to explain the mechanism for the observed reduction in growth of the greenhouse cotton treated with nominal 500 and nominal 1000 lbs/a·yr simulated saline drift.

6.4.1.2. Alfalfa and Barley

Alfalfa and barley in the nominal 500 lbs/a·yr treatment sustained some leaf injury, but the vegetative growth, fresh and dry weights, and heights were not significantly reduced as compared to controls, except for two of the seven alfalfa harvests. These results are in agreement with Maas, Grattan and Ogata (1982) who found that sprinkler irrigation with saline solution did not affect the top growth of alfalfa and barley.

6.4.2. Field

Leaf temperatures of the treated cotton plants were significantly cooler than those of the control plants. The higher salt content in the treated tissue may have caused greater succulence, which could result in cooler leaves. No other differences were detected in the physiological responses of any of the field crops which is in agreement with the greenhouse results.

The phenological changes noted in the greenhouse were not observed in the field and these differences can not be explained by the tissue Na^+ and Cl^- levels. Cotton tissue of the field controls had more Na^+ and Cl^- than the nominal 500 lbs/a·yr treated greenhouse plants. These differences may be due to environmental factors.

6.5. FOLIAR INJURY

6.5.1. Greenhouse

No significant tip and marginal necrotic injury was observed on cotton and barley treated with the two highest rates of simulated saline drift (nominal 500 and nominal 1000 lbs/a·yr) until the latter part of the growing season. For example, tip, margin, and spot necrosis were first detected in the nominal 1000 lbs/a·yr treated cotton plants 19 days after initial spraying as compared to the controls. Because alfalfa plants were harvested on an average of every 21 days, salt deposition from the simulated saline drift apparently did not accumulate to a threshold level sufficient to cause injury.

In addition to necrosis, simulated saline drift caused chlorosis. The application of simulated saline drift to cotton and barley plants increased the level of chlorotic injury during the latter part of the growing period. The spot, marginal, and general surface chlorosis observed from 6 July to 18 July probably was caused by insecticide. During August, the general surface chlorosis of the nominal 500 lbs/a·yr treatment and the control was probably caused by nutrient deficiencies. However, from 30 August to biomass harvest, the percentage of leaves/plant showing chlorosis was significantly higher in the nominal 500 lbs/a·yr treatment (45.8% seasonal average), than in the controls (37.5% seasonal average), indicating that some of the general chlorosis may have been caused by the simulated saline drift (Data Summary Volume Table J-4).

Several previous investigations have shown that foliar injury is dependent upon the internal concentrations of Na^+ and Cl^- in the leaf tissue. Curtis, Lauver and Francis (1977) and Bernstein (1975) reported that moderate salt-induced injury symptoms developed in several salt-sensitive woody species when the leaves of these plants had accumulated about 2000 ppm of Na^+ or 5000 ppm of Cl^-. Hindawi,

Raniere and Rea (1976) observed incipient injury occurred on young bush beans containing approximately 160 ppm of Na^+ and 3770 ppm of Cl^-.

The relationship between tissue content of Na^+ and Cl^- and foliar injury (chlorosis and necrosis) in this study is unclear. Chloride ion content in all three plant species exceeded 5000 ppm in controls and the nominal 500 lbs/a·yr treated plants. In addition, the Cl^- content in the cotton and alfalfa was significantly greater in the treated plants than in the controls; however, the Cl^- content in the barley was not statistically different in the treated plants as compared to the controls.

Both barley and cotton tissue contained Na^+ concentrations that exceeded the toxic levels reported by Bernstein (1975), Curtis, Lauver and Francis (1977) and Hindawi, Raniere and Rea (1976) whereas the Na^+ content of treated alfalfa was well below toxic levels.

While a number of investigators have observed that the accumulation of Na^+ and Cl^- to a specific level causes foliar injury, it is unclear which of the two ions induces the injury (Bernstein, 1975). McCune et al. (1977) reported that the degree of foliar injury in several woody and herbaceous plants was correlated with the Cl^- content in the tissue. Mass, Clark and Francois (1982), however, found that the degree of leaf injury in the pepper plant does not correlate with levels of Cl^-.

6.5.2. Field

It is apparent from the leaf tissue analyses that the Na^+ and Cl^- were absorbed into the foliage of the treated plants. The leaves in the control group in the cotton plants contained more than 18000 ppm Cl^-, and the leaves from the nominal 500 lbs/a·yr treated plants contained about 22500 ppm Cl^-. Both these values are well in excess of the 5000 ppm Cl^- suggested as a possible threshold level for toxic affects in some woody plants (Bernstein, 1975). The cotton tissue sampled from the nominal 500 lbs/a·yr plots had more than four and a half times more Na^+ than the control plants (4652 ppm Na^+ for the nominal 500 lbs/a·yr treatment group; 1006 ppm for the controls, significant at the 1% level). The increased level of the Na^+ was contrasted by significant decreases in boron, calcium and magnesium. Significant reductions also were observed in levels of copper and calcium, and nonsignificant reductions were observed for potassium, iron, manganese, and magnesium.

In contrast to the greenhouse cotton, the absorption of salts from the simulated saline drift treatments had very little effect on the foliage of the field cotton plants. There were indications that it actually enhanced vegetative growth. Because 38% of the control plants showed general chlorosis compared to only 29% of the treated plants (Data Summary Volume Table A-2), it would appear that the simulated saline drift, with its high concentration of essential elements for plant growth, was acting as a fertilizer. Foliar application is an efficient method of fertilization (Wittwer and Bukovac, 1969), although Peoples et al. (1980) found that foliar fertilizers applied to cotton grown in Arizona had no measurable effect on yield.

Alfalfa plants treated with nominal 1000 lbs/a·yr of simulated saline drift had significantly more leaflet necrosis and chlorosis than the controls. These results concur with the work of Maas, Grattan and Ogata (1982) who found that spraying alfalfa with saline solution resulted in some marginal necrosis. In our study, the leaf tissue from the nominal 1000 lbs/a·yr treatment at the final harvest contained less Na^+ and less Cl^- than the cotton tissue from the nominal 500 lbs/a·yr plots. This may be explained in part by the decreased number of application days on the alfalfa due to the repeated harvesting. The alfalfa was detrimentally affected at lower tissue Na^+ and Cl^- levels then was observed in the cotton. This suggests a greater susceptibility to damage from foliar applied salts. Maas, Grattan and Ogata (1982) also found that alfalfa is less tolerant to foliar salts than cotton.

The alfalfa tissue from the nominal 1000 lbs/a·yr plots had three and a half times more Na^+ than the control plants. Significant reductions were observed in levels of copper and calcium in the nominal 1000 lbs/a·yr treatment. A trend toward reduced levels was observed for potassium, iron, magnessium and mangenese in the nominal 1000 lbs/a·yr alfalfa.

Greenhouse alfalfa did not show any foliar injury as observed in the field. This may be explained in part by the more frequent harvest in the greenhouse and the corresponding decrease in exposure to the simulated saline drift.

The vegetative development of the cantaloupe plants showed no detectable effects from saline deposition. In contrast to the elevated Na^+ and Cl^- levels in the leaf tissue of cotton and alfalfa cantaloupe fruit did not show increased Na^+ and Cl^- levels.

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~~Exhibit 19a~~

EXHIBIT RB-5a

NADP DATA REPORT
PRECIPITATION CHEMISTRY

Fourth Quarter, 1980
Volume III, Number 4

1 October 1980 to 31 December 1980

prepared by

Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, Colorado 80523

April 1982

Tombstone
Arizona

Included in nonstandard data set because of discontinuous sampling starting 9/9/80. Please refer to the nonstandard data sets, pages 321-322, for available precipitation chemistry.

NATIONAL ATMOSPHERIC DEPOSITION PROGRAM
REPORT WRITTEN APR 7, 1982

ORGAN PIPE
ARIZO A
USDI-NATIONAL PARK SERVICE

STATION 030620
PIMA COUNTY
ELEVATION 510 METERS

WET SAMPLES - WEEKLY

DATE ON MODAYR	DATE OFF MODAYR	LAB PH	LAB CONDUCTIVITY MICRO S/CM	SAMPLER VOL L	SAMPLER DEP CM	RAIN GAGE CM	COLL EFF	LAB TYPE (1)	NOTES (2)	TIME ON GMT	TIME OFF GMT	OBS
92980	100780	--	--	--	--	--	--		NA	--	--	ML
100780	101480	--	--	--	--	--	--		NA	--	--	ML
101480	102180	--	--	--	--	--	--		NA	--	--	ML
102180	102880	--	--	--	--	--	--		NA	--	--	ML
102880	110480	--	--	--	--	--	--		NA	--	--	ML
110480	111180	--	--	--	--	--	--		NA	--	--	ML
111180	111880	--	--	--	--	--	--		NA	--	--	ML
111880	112580	--	--	--	--	--	--		NA	--	--	ML
112580	120280	--	--	--	--	--	--		NS	--	--	ML
120280	120980	6.67	59.7	.013	.02	.05	.36	T		1630	2130	ML
1c0580	121680	--	--	.000	.00	0.00	--	T		2130	1600	ML
121640	122380	--	--	--	--	--	--		NA	--	--	ML
122380	123080	--	--	--	--	--	--		NA	--	--	ML
123080	10681	--	--	--	--	--	--		NA	--	--	ML

-- INDICATES MISSING DATA

SEE TABLE EXPLANATIONS (1),(2)

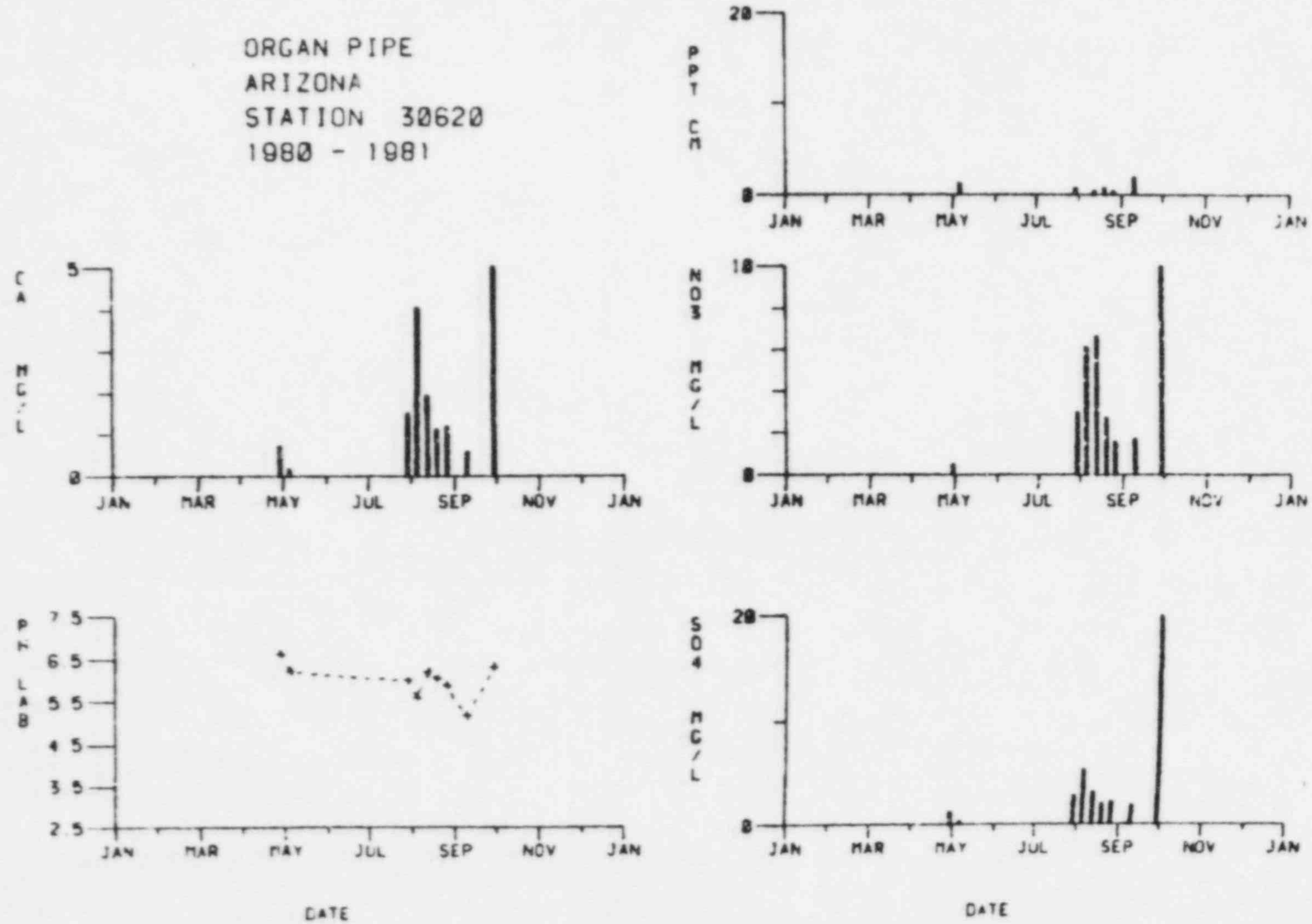
CONCENTRATIONS (MILLIGRAMS PER LITER FOR THE SAMPLE PERIOD)

DATE ON	DATE OFF	CA	MG	K	NA	NH4	NO3	CL	SO4	PO4	H
92980	100780	--	--	--	--	--	--	--	--	--	--
100780	101480	--	--	--	--	--	--	--	--	--	--
101480	102180	--	--	--	--	--	--	--	--	--	--
102180	102880	--	--	--	--	--	--	--	--	--	--
102880	110480	--	--	--	--	--	--	--	--	--	--
110480	111180	--	--	--	--	--	--	--	--	--	--
111180	111880	--	--	--	--	--	--	--	--	--	--
111880	112580	--	--	--	--	--	--	--	--	--	--
112580	120280	--	--	--	--	--	--	--	--	--	--
120280	120580	--	--	--	--	--	--	--	--	--	--
120980	121680	--	--	--	--	--	--	--	--	--	2.14E-4
121680	122380	--	--	--	--	--	--	--	--	--	--
122380	123080	--	--	--	--	--	--	--	--	--	--
123080	10681	--	--	--	--	--	--	--	--	--	--

NOTE - SULPHATE AS SO4; NITRATE AS NO3; AMMONIUM AS NH4; PHOSPHATE AS PO4

NATIONAL ATMOSPHERIC DEPOSITION PROGRAM

ORGAN PIPE
ARIZONA
STATION 30620
1980 - 1981



NATIONAL ATMOSPHERIC DEPOSITION PROGRAM
REPORT WRITTEN APR [illegible], 1982

TOMBSTONE
ARIZONA
SAES-UNIVERSITY OF ARIZONA

STATION 030180
COCHISE COUNTY
ELEVATION 1400 METERS

WET SAMPLES - WEEKLY

DATE ON MODAYR	DATE OFF MODAYR	LAB PH	LAB CONDUCTIVITY MICRO S/CM	SAMPLER VOL L	SAMPLER DEP CM	RAIN GAGE CM	COLL EFF	LAB TYPE (1)	NOTES (2)	TIME ON GMT	TIME OFF GMT	OBS
093080	100780	--	--	--	--	--	--		NN	--	--	
100780	101480	--	--	--	--	--	--		NN	--	--	
101480	102180	--	--	--	--	--	--		NN	--	--	
102180	102880	--	--	--	--	--	--		NN	--	--	
102880	110480	--	--	--	--	--	--		NN	--	--	
110480	111180	--	--	--	--	--	--		NN	--	--	
111180	111880	--	--	--	--	--	--		NN	--	--	
111880	112580	--	--	--	--	--	--		NN	--	--	
112580	120280	--	--	--	--	--	--		NN	--	--	
120280	120980	--	--	--	--	--	--		NN	--	--	
120980	121680	--	--	--	--	--	--		NN	--	--	
121680	122380	--	--	--	--	--	--		NN	--	--	
122380	123080	--	--	--	--	--	--		NN	--	--	

-- INDICATES MISSING DATA

SEE TABLE EXPLANATIONS (1),(2)

CONCENTRATIONS (MILLIGRAMS PER LITER FOR THE SAMPLE PERIOD)

DATE ON	DATE OFF	CA	MG	K	NA	NH4	NO3	CL	SO4	PO4	H
93080	100780	--	--	--	--	--	--	--	--	--	--
100780	101480	--	--	--	--	--	--	--	--	--	--
101480	102180	--	--	--	--	--	--	--	--	--	--
102180	102880	--	--	--	--	--	--	--	--	--	--
102880	110480	--	--	--	--	--	--	--	--	--	--
110480	111180	--	--	--	--	--	--	--	--	--	--
111180	111880	--	--	--	--	--	--	--	--	--	--
111880	112580	--	--	--	--	--	--	--	--	--	--
112580	120280	--	--	--	--	--	--	--	--	--	--
120280	120980	--	--	--	--	--	--	--	--	--	--
120980	121680	--	--	--	--	--	--	--	--	--	--
121680	122380	--	--	--	--	--	--	--	--	--	--
122380	123080	--	--	--	--	--	--	--	--	--	--

NOTE - SULPHATE AS SO4; NITRATE AS NO3; AMMONIUM AS NH4; PHOSPHATE AS PO4

~~Exhibit 10b~~

EXHIBIT RB-5b

NADP DATA REPORT
PRECIPITATION CHEMISTRY

Fourth Quarter 1981
Volume IV, Number 4

1 October 1981 to 31 December 1981

prepared by

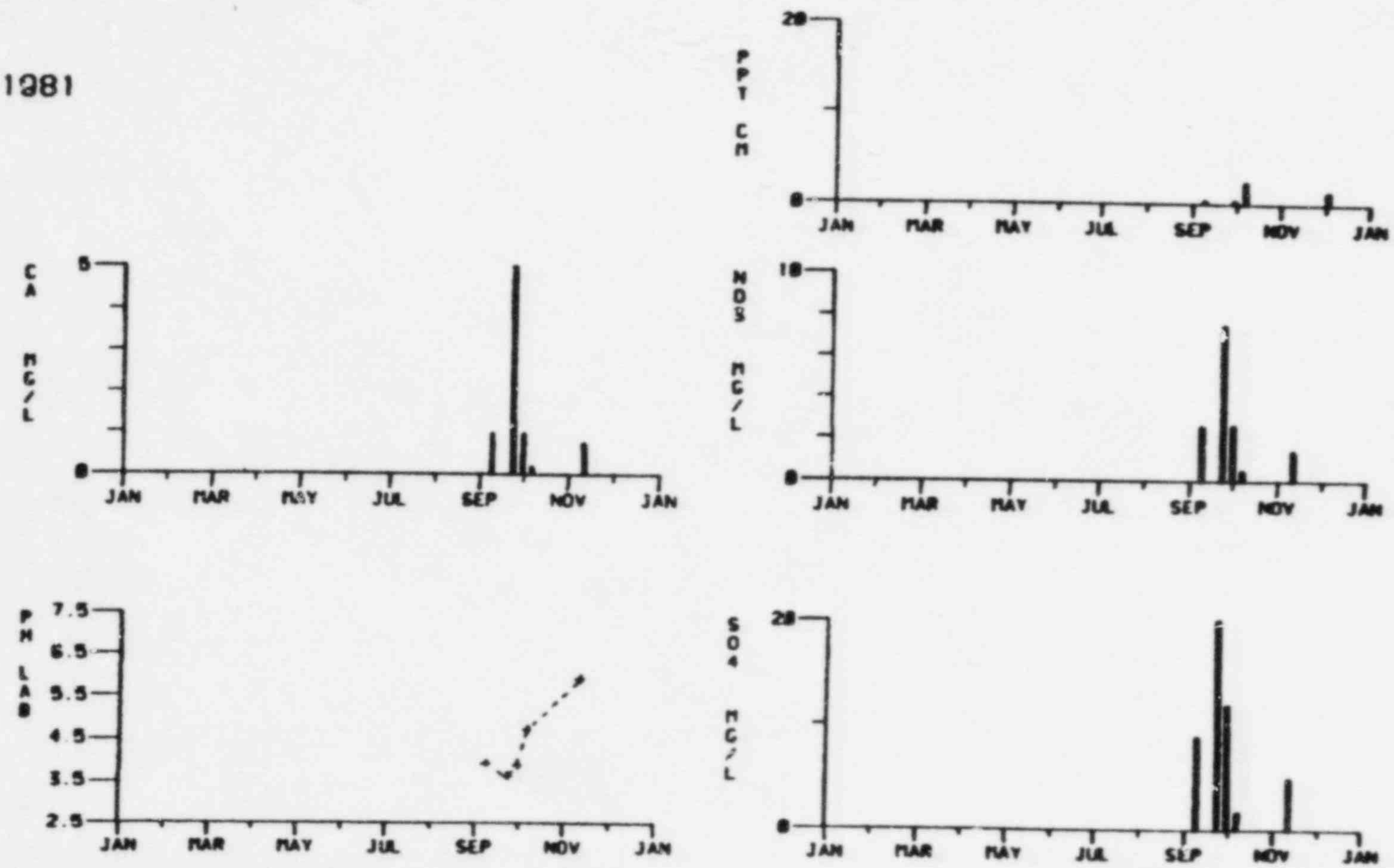
Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, Colorado 80523

October 1983

ARIZONA National Atmospheric Deposition Program

OLIVER KNOLL
STATION 30360

1981



ARIZONA

National Atmospheric Deposition Program

GRAND CANYON NATIONA
STATION 30370

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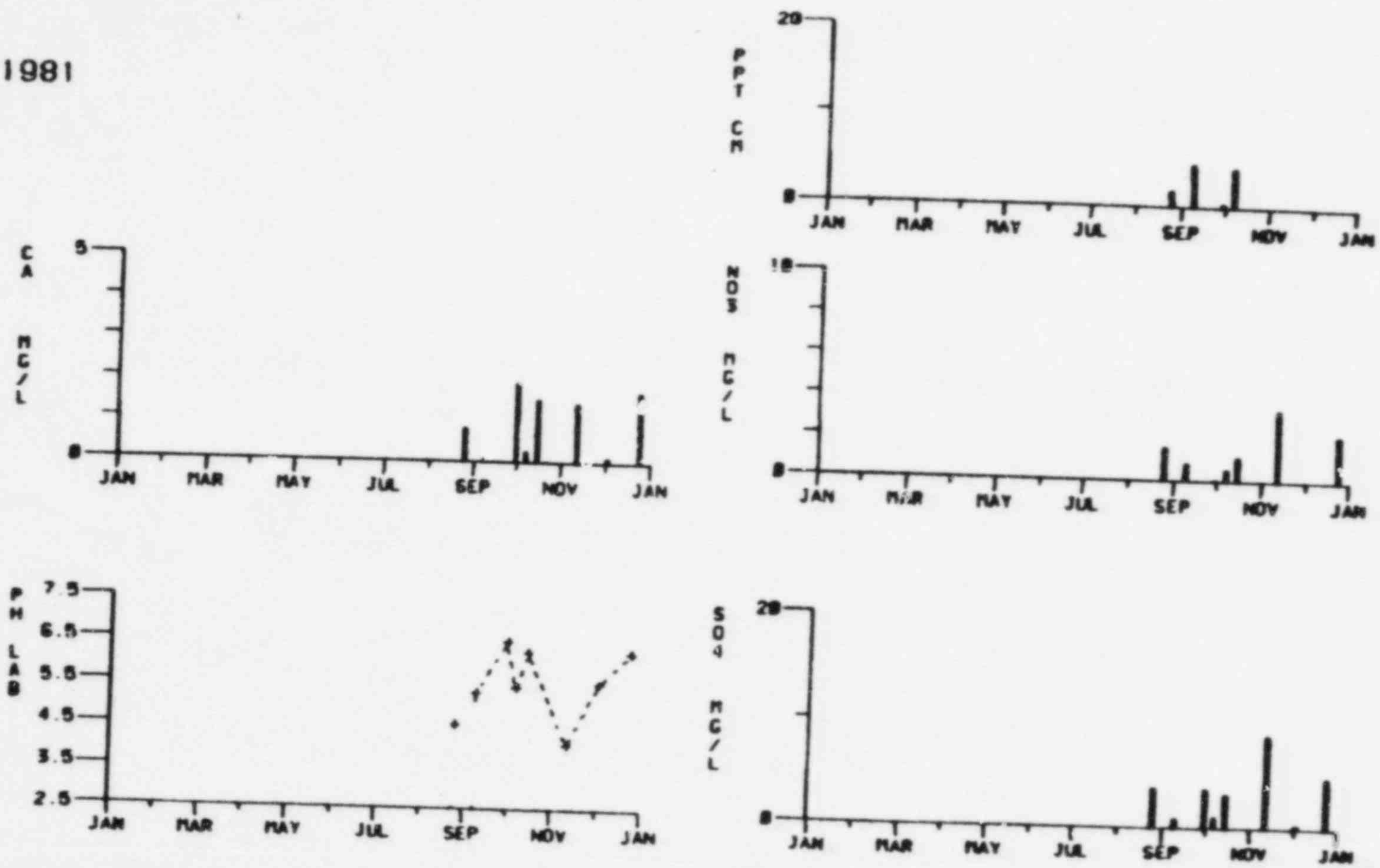

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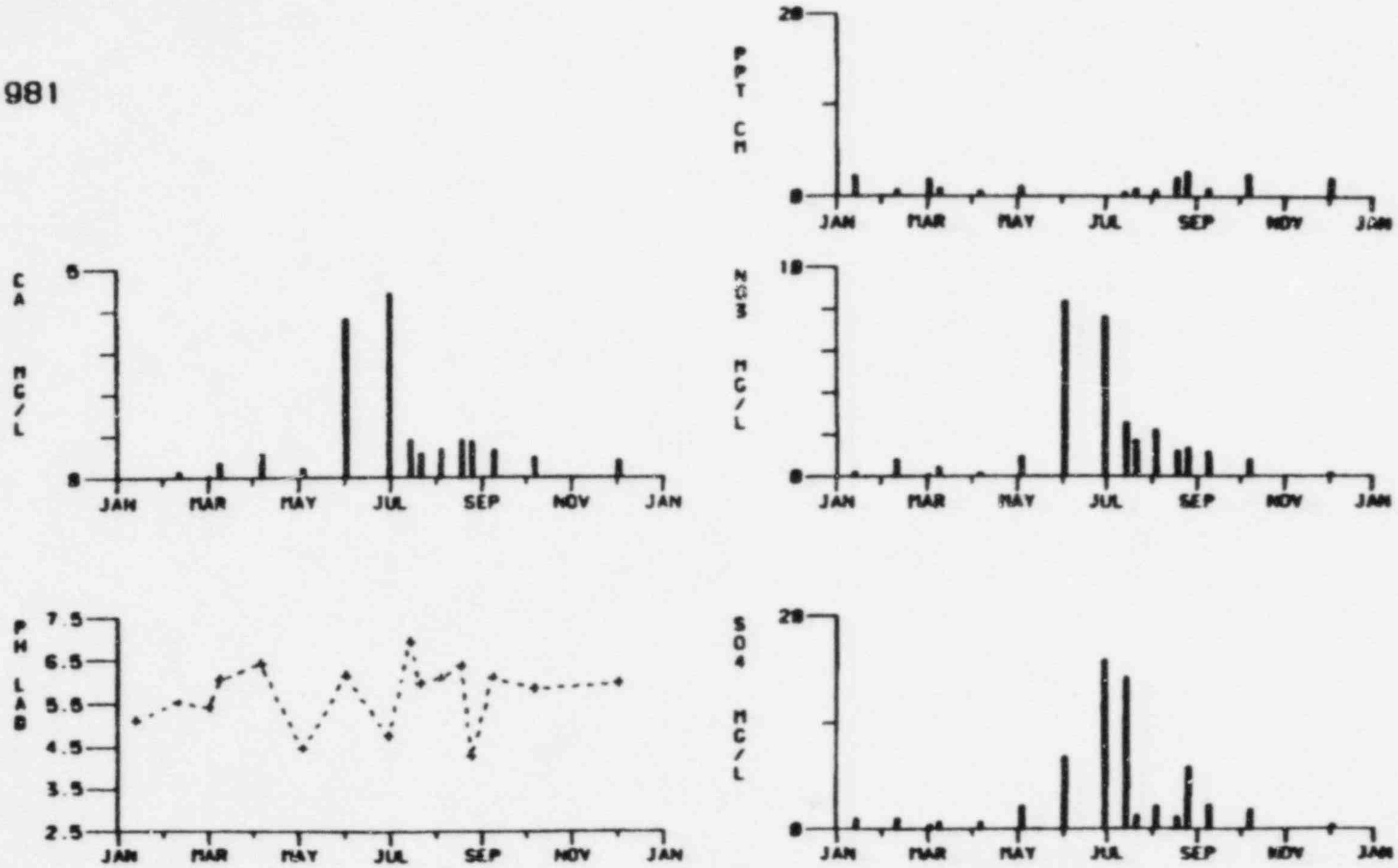
National Atmospheric Deposition Program

ORGAN PIPE
STATION 30620

1981



~~Exhibit 19c~~

EXHIBIT RB-5c

NADP* DATA REPORT
PRECIPITATION CHEMISTRY

Fourth Quarter 1982
Volume V, Number 4

1 October 1982 to 31 December 1982

prepared by

Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, Colorado 80523

March 1984

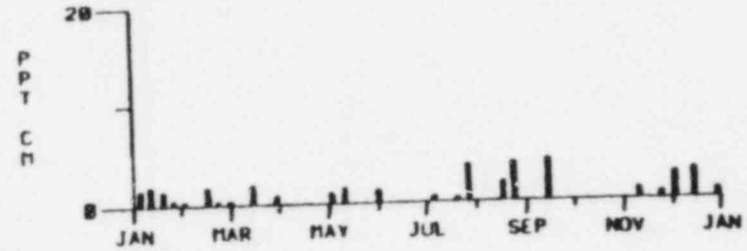
* National Atmospheric Deposition Program

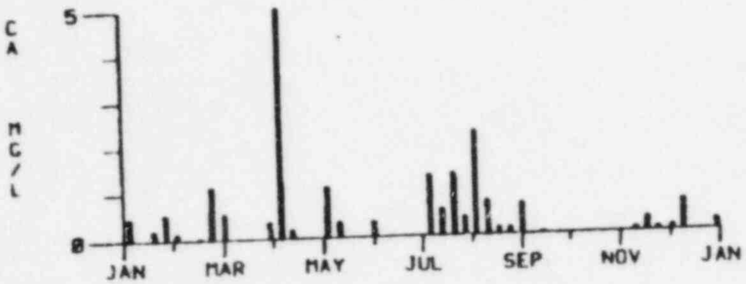
ARIZONA

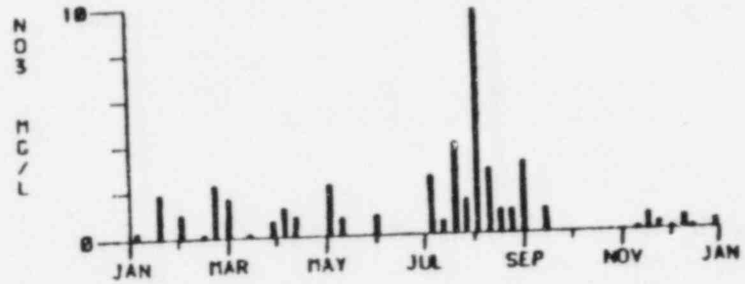
Notional Atmospheric Deposition Program

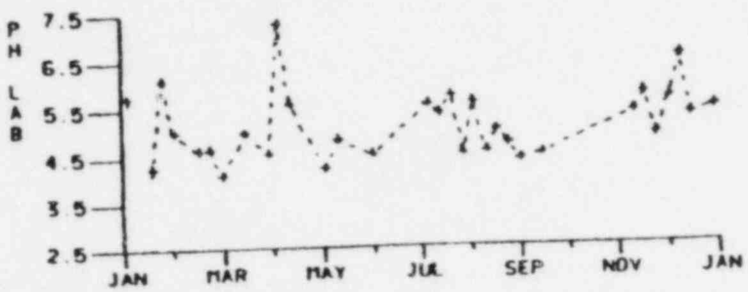
OLIVER KNOLL
STATION 30360

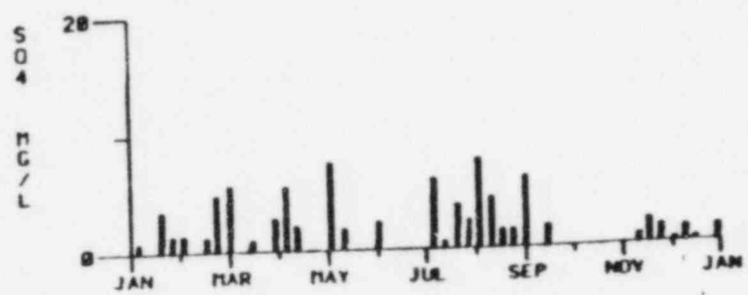
1982











ARIZONA National Atmospheric Deposition Program

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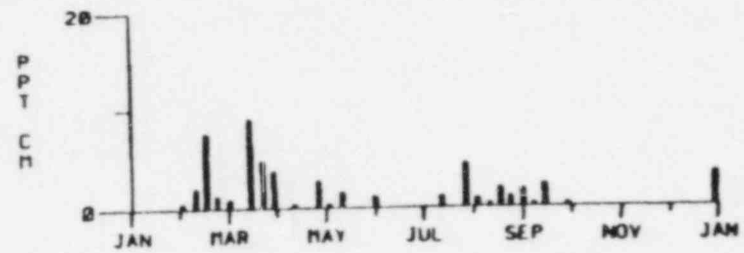

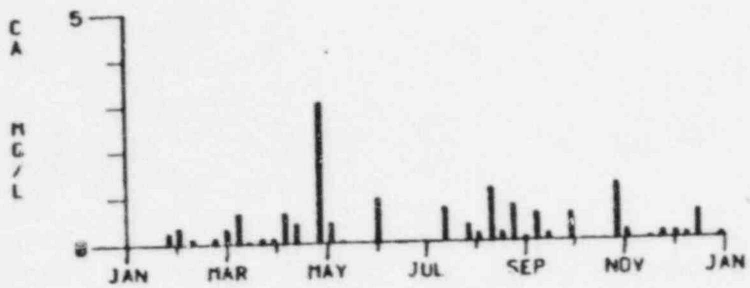

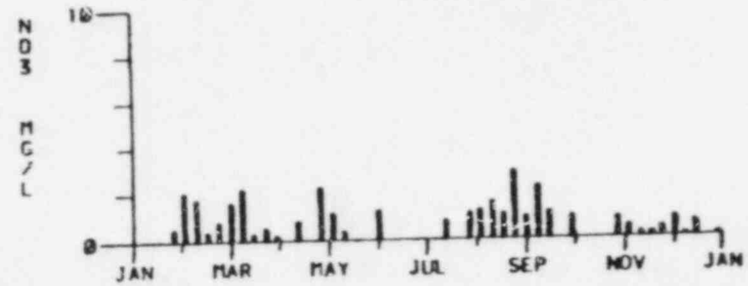

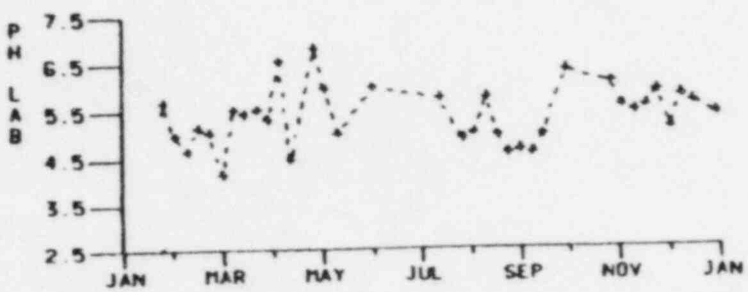

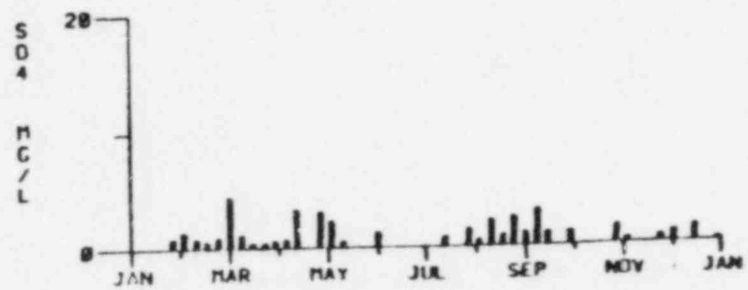

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