Final Report For:

ARB Agreement A6-161-30

THE EFFECTS OF PRESENT AND POTENTIAL AIR POLLUTION ON IMPORTANT SAN JOAQUIN VALLEY CROPS: SUGAR BEETS

Robert F. Brewer
Associate Horticulturist
San Joaquin Valley Agricultural
Research and Extension Center
University of California
Parlier, CA 93648

May 1, 1978

Final Report ARB Agreement A6-161-30

ABSTRACT

Sugar beets were grown at Parlier in Fresno County in air from which varying proportions of the existing pollutants had been removed, either by deliberate filtering with activated carbon or passive removal by air handling equipment. Two types of growth chambers were used, one a conventional greenhouse-shaped unit with plastic covered sides and top, and a second experimental unit with plastic walls and open top. All of the chambers were equipped with motor driven blowers which changed the air twice each minute. In addition to the enclosed, power-ventilated plots there were also outside control plots to provide an estimation of the "chamber effect". Three air treatments were used in the chambers: ambient or non-filtered air, filtered air passed through activated carbon filters, and a mixture consisting of two thirds ambient and one third filtered air.

The primary objectives of this study were to determine the effects, if any, of existing levels of pollution in the central San Joaquin Valley on growth and sugar yields of this extremely important (nearly 50 million dollars annually) agricultural crop and to relate injury symptoms and yield suppression with ozone dose. A secondary objective was simultaneous comparison of closed, greenhouse type exposire chambers with a new open top design.

Growing conditions including light, humidity, temperature, air movement and ozone concentrations were monitored in all of the experimental plots. Excellent plant growth was obtained which assures strong responses, if any, to air pollutants. The most serious problem encountered was a severe invasion of beet armyworm and cabbage loppers in three of the chambers receiving all or part filtered air.

At no time were we able to discern recognizable ozone or PAN injury symptoms on the sugar beet foliage in any of the treatments. When the beets were harvested in early November and the yield data subjected to statistical analysis, none of the growth chamber treatments were statistically different at the .05 confidence level. There was a trend toward increased top weights with filtered air in the open top chambers, but the weights were not statistically different. In one case (sugar production)

the outside plots produced significantly more sugar than the growth chamber plots, but there were no differences among the closed plots not readily attributable to insect or mildew damage. Growth and sugar production in the open top chambers were much closer to that in outside plots than was the case with the closed chambers.

The obvious conclusion to be made as a result of these experiments is that sugar beets are not now being significantly damaged by prevailing air pollution in the central San Joaquin Valley. Injury symptoms reported in Southern California would indicate that sugar beets are probably much more sensitive to PAN than to ozone. If and when PAN should become a significant component of valley air pollution, sugar beets might well be injured and additional research should be carried out to reassess the situation at that time.

Two rows of Thompson Seedless grapes were uniformly pruned to 6 canes each in the spring of 1978. Prunings from each vine were weighed and measured to provide an indication of statistical variation within and between vines as a guide to establishing an exclusion-type experiment on Thompson Seedless grapes in 1979. Statistical analysis of these data indicated that 10% or greater differences could be measured with 20 to 1 odds (.05 probability) if 3 units containing 3 vines each were used per treatment.

This report was submitted in fulfillment of Contract A6-161-30 by the University of California under the sponsorship of the California Air Resources Board. Work on this project was completed as of March 1, 1978.

Table of Contents

List of Figures

List of Tables

Acknowledgements

The advice and assistance of the following people and organizations is gratefully acknowledged.

1. George Ferry, Extension Director, University of California Cooperative Extension, Hanford, California.
2. Dr. L. M. Burtch, Chief Agronomist, Spreckles Sugar Division, Amstar Corporation, Mendota, California.
3. Robert Reynolds, Contract Officer, California Air Resources Board Research Division, Sacramento, California.

The Effects of Present and Potential Air Pollution on Important San Joaquin Valley Crops: Sugar Beets

INTRODUCTION

California is the leading sugar beet producing state in the United States, producing approximately 8.5 million tons on 326,000 acres with a market value in excess of 250 million dollars[1/]. Of this total the four southern San Joaquin Valley counties of Fresno, Tulare, Kings and Kern produce over a third or nearly 3 million tons on 64,000 acres bringing over 42.5 million dollars to the area's economy.

On the basis of research experiences and visible symptoms, sugar beets have been considered sensitive to photochemical air pollution for nearly 30 years. Dr. Albert Ulrich[2/], working in the "Phytotron" at Earhart Plant Research Laboratory at California Institute of Technology around 1950, encountered considerable difficulty growing sugar beets to maturity while conducting his classic nutritional experiments. Dr. Ulrich discovered that if the air in which the plants were grown was first passed through activated carbon the difficulties, mainly tissue collapse on lower leaf surfaces, were not encountered. These and other abnormal growth problems led to the first large scale use of activated carbon for cleaning air used in experimental greenhouses. Activated carbon greenhouse filters are now commonplace in California and many other states.

Typically sugar beets are planted during the late winter and early spring in the central San Joaquin Valley for harvest the following fall or winter. In some cases the beets are overwintered and harvested a year or more after planting. Maximum root growth and sugar production occur during periods of warm, long days and cool nights. Although not killed by prevailing California winter temperatures, sugar beets grow very slowly during the winter months, and often "bolt" (send up a flower stalk) as a result of exposure to a warm period following a prolonged cold period. When "bolting" occurs root growth stops and sugar content decreases[3/].

1/ 1976 Principal Crops and Livestock Commodities, Calif. Dept. of Food and Agric.

2/ Personal communication.

3/ Hills, F. J. and S. S. Johnson, 1973. The Sugar Beet Industry in California, Calif. Agr. Expt. Sta. Circular 562.

In the Central Valley sugar beets are usually planted on single 30 inch raised beds, or on double beds with two rows spaced 14 to 16 inches apart on beds spaced 40 to 48 inches center to center. Irrigation water is supplied by overhead sprinklers or by furrows between the rows.

SCOPE AND PURPOSE OF PROJECT

The objectives of the work described in this report were as follows:

1. To determine whether sugar beets grown in the central San Joaquin Valley are being damaged by current ambient levels of oxidant-type air pollution.
2. To determine several points on the ozone dose-response curve for sugar beets so that valid assessments of current and projected economic losses can be made with a reasonable degree of confidence.
3. To compare the suitability of open top type growth chambers with conventional closed top greenhouse type chambers for comparing the performance of plants in filtered and non-filtered air.
4. To establish a base-line for producing Thompson Seedless grapes which can be used in a future project with that crop.

To meet the first three of the above objectives, sugar beets were grown in air containing varying amounts of the oxidants present in ambient air at the Kearney Horticultural Field Station located at Parlier, California approximately 15 miles southeast of Fresno. Activated carbon filters were used to remove all or part of the air pollutants in the air before it was forced into plastic covered growth chambers. Other factors potentially affecting plant growth were kept as nearly the same as possible between treatments so that differences in growth, if any, could be attributed to air quality.

MATERIALS AND METHODS

Treatments - The four different air treatments utilized in these tests were as follows:

1. Ambient Air - Outside Plot
2. Ambient Air - Growth Chamber
3. Carbon Filtered Air - Growth Chamber
4. 1/3 Carbon Filtered Air - Growth Chamber

Each treatment was replicated 3 times with each of the growth chamber treatments utilizing 2 conventional greenhouse chambers[4/] of the type used for previous studies with cotton and one specially designed open top chamber developed for this study. All of the growth chamber plots were 12 feet square or 144 square feet in area. Outside control (non-covered) plots were twice as large as the covered plots (16 x 18 or 288 square feet). Figure 1 shows the layout of the plots utilized in the 1977 experiments with sugar beets.

Growth Chambers - The conventional greenhouse shaped growth chambers were 12 feet square, 7 feet tall at the eves, 10 feet at the peak and contained approximately 1200 cubic feet of air. Individual motor driven blowers delivered 2400 cubic feet of air per minute, enough to change the chamber air twice each minute. This has been found necessary to prevent excess temperature buildup during hot weather.

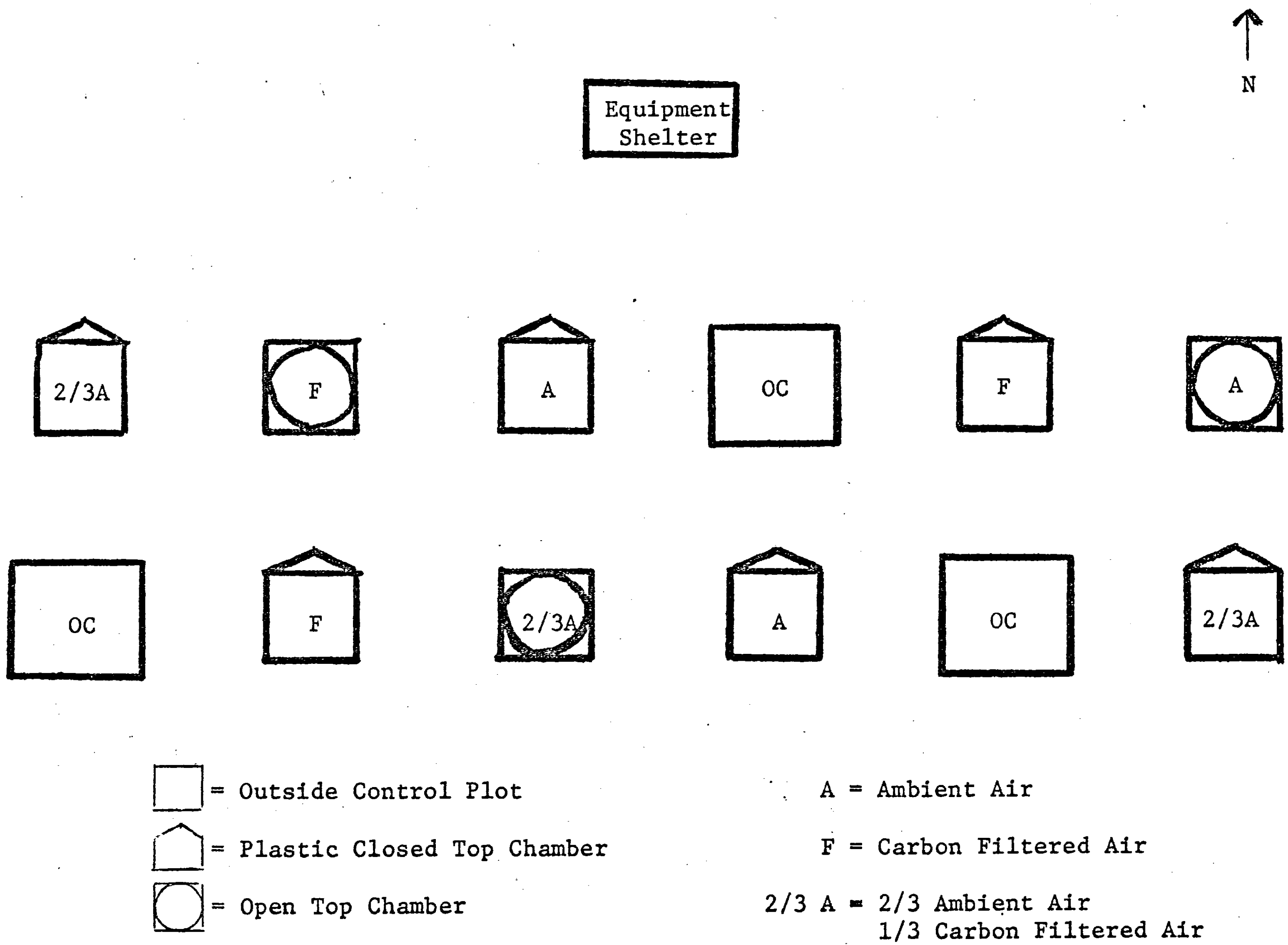
The open top chambers tapered from a 12 foot square base to a 10 foot circular open top 8 feet above the soil surface (see figures 2 and 3). Blowers on these chambers delivered 1600 cubic feet of air per minute, enough to change the air volume twice per minute. Air was ducted into the base of the open top chambers by perforated 6 and 8 inch PVC pipe and released upward to flush out the chambers and resist intrusion of outside air through the open top (see figures 3 and 5).

All of the air entering the filtered units through the blowers first had to pass through a coarse and then a fine fiberglass filter pad, then through activated carbon filters which removed essentially all of the oxidant air pollutants. Adjustments were made on the two thirds ambient-one third filtered blowers to insure that only one third of the air entering the blower passed through a carbon filter. Blowers on chambers receiving the ambient treatment had only a coarse metal screen ahead of the blower. Commercial inclined tube-type manometers were used to monitor blower and filter performance.

Glazing Materials - Roof panels on the conventional greenhouse chambers and the entire side walls of the open top chambers were glazed with a 8 mil clear

4/ Brewer, R. F. and G. Ferry, 1974. Effects of Air Pollution on Cotton in the San Joaquin Valley, Calif. Agr., June, 1974, pp 6-7.

Figure 1. Plot Layout for Sugar Beet Air Pollution Experiment
Kearney Horticultural Experiment Station, 1977



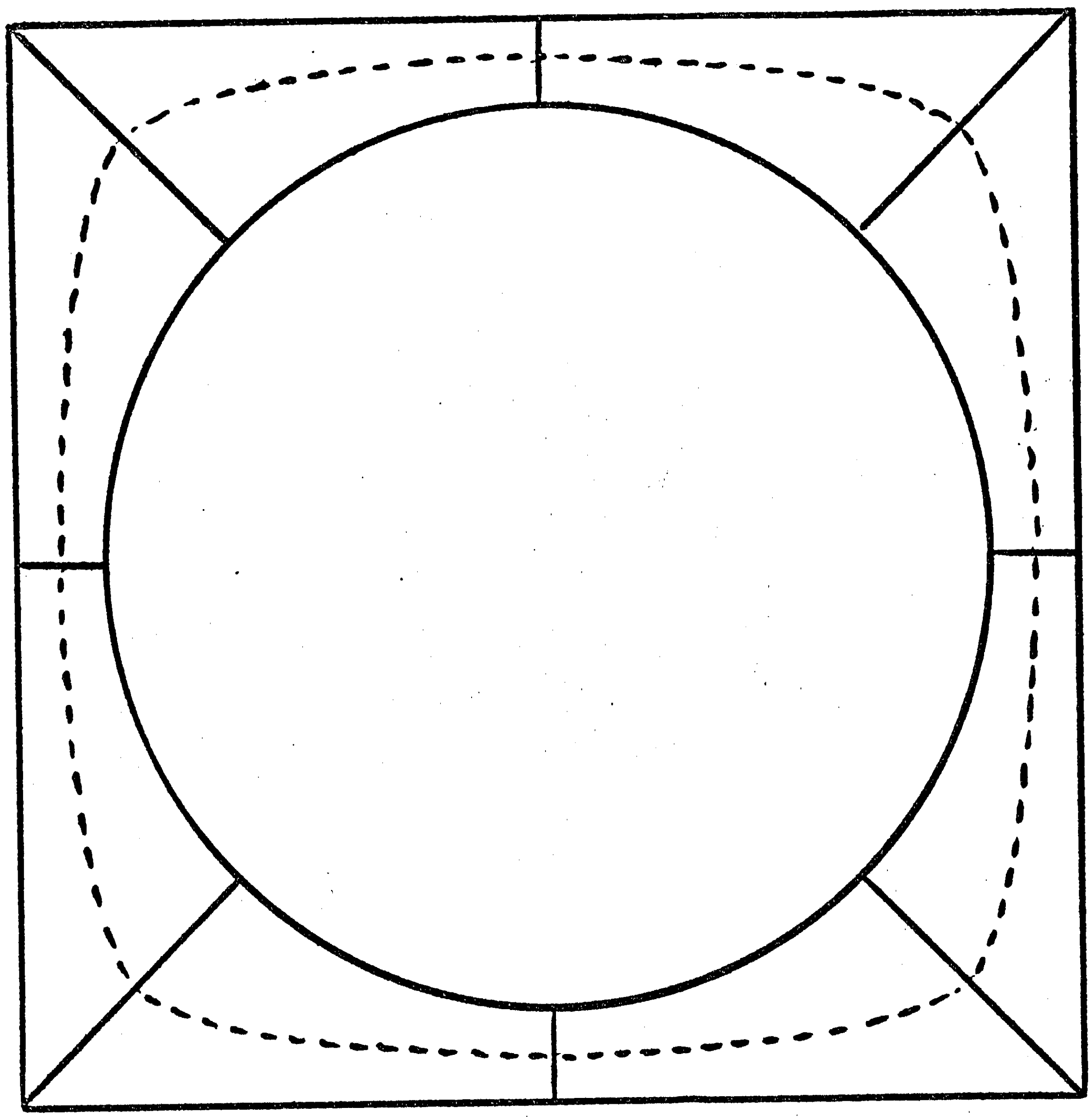


Figure 2. Overhead view of open top growth chamber showing 12' square base and 10' circular open top.

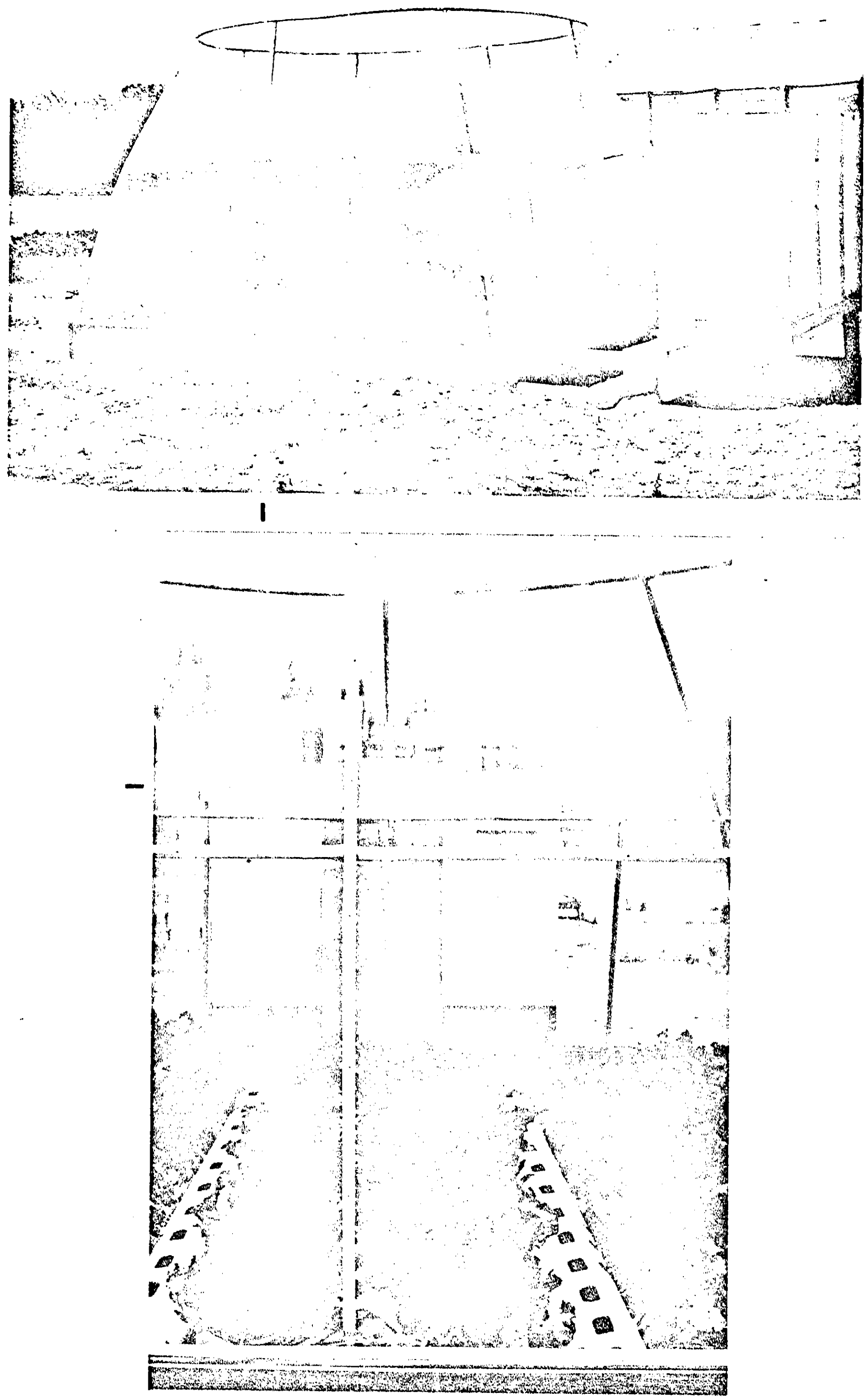


Figure 3. Side and end views of open top chambers showing blower units, air ducts, and sugar beets. Chambers are covered with 8 mil vinyl plastic.

vinyl plastic. Vinyl was found more transparent to light throughout the 4 to 7 micron light spectrum than other readily available clear plastics. Absorbance of three glazing materials, polyvinyl chloride, polybutyrate, and duPont Mylar are shown in figure 4. Teflon TEP, a more durable material was ruled out as a potential material due to its high cost (over $1.00 per square foot) and difficulties in anchoring. Side panels on the conventional greenhouse chambers were glazed with "Mylar". All of the plastic was washed down daily to remove dust which accumulated due to static electricity. Periodic scrubbing with a soft brush and mild detergent helped keep the plastics clear throughout the growing season.

Instrumentation

Ozone Monitoring - Ozone concentrations at plant height at one of the outside plots and inside each of the plastic growth chambers were monitored using three separate Daisibi ozone monitors. One machine monitored ambient treatments, one filtered chambers and one 2/3rds ambient chambers. A series of electrically timed solenoid valves sequentially sampled each of the chambers receiving a particular air treatment. Output from each of the three ozone monitors was logged on a multipoint potentiometer recorder. Schematically the arrangement was a shown in figure 5.

Original plans called for recording the ozone meter output data on punched tape but delivery of some of the necessary equipment was not obtained until October, 1977 when the study was nearly over.

The three Daisibi ozone monitors were calibrated by ARB staff personnel and out data compared with that obtained by the Fresno County APCD monitoring station approximately one third mile to the east. In most cases the correlation was excellent, with a slight tendency for their ambient values to be slightly higher than ours.

Temperature and Humidity - Air, leaf and soil temperatures in plots receiving the four different treatments were measured using copper-constantin thermocouples. Temperatures of incoming air and air temperature at 2' (just above the plant canopy) were monitored continuously for all of the growth chambers.

Outside air temperatures and air temperature at plant height in one of the outside control plots were monitored continuously and recorded on a 24 point potentiometric recorder with built in cold junction compensation.

Revolving drum type hygrothermographs were also placed about 1 foot above the soil surface in the plant canopy to record temperature and humidity conditions in both type growth chambers receiving each of the different air treatments.

Light intensities at several times during the day in the two types of growth chambers as well as outdoor plots were determined using both a professional Panlux visible light meter and a Lambda[5/] quantum sensor which measures photosynthetically active radiation (PAR). Slight differences in light intensity were found between the two types of chambers, but no differences existed between chambers of the same type. As might be expected, light conditions in the open top chambers most nearly approximated those in the outdoor plots. Detailed measurement data will be presented later in this report.

Soil Moisture - Soil moisture stress was measured in all plots with porous ceramic tipped tensiometers located at 12" and 24" alongside the beet row. Most of the irrigation water was supplied by perforated biwall PVC drip line buried approximately 2" below the surface in the center of each bed between the beet rows. Soil moisture tension was maintained at 25 centibars or less during the growing season, but was allowed to climb slightly in the last month before harvest. Soil moisture was maintained to approximately the same values in all plots by applying supplementary water to drier plots using a garden hose.

Soil Preparation

After all of the experimental plots were laid out as indicated in figure 1, the original soil, a Hanford sandy loam, was removed to a depth of 12 inches from an area extending 2 feet in all directions beyond the boundaries of all plots. The removed soil was deposited in a large pile and mixed well with a skiploader. The excavated plots were then refilled with a 50/50 blend of the original soil and a Grangeville loam. Two cubic feet of lime neutralized sphagnam peat moss and 6 cubic feet of weed-free steer manure were blended in each 12' x 12' plot to improve tilth. The 16' x 18'

5/ Lambda Quantum Sensor, LI-190S, Lambda Instrument Co., Lincoln, Nebraska.

Figure 4. Light transmission characteristics of various plastics.

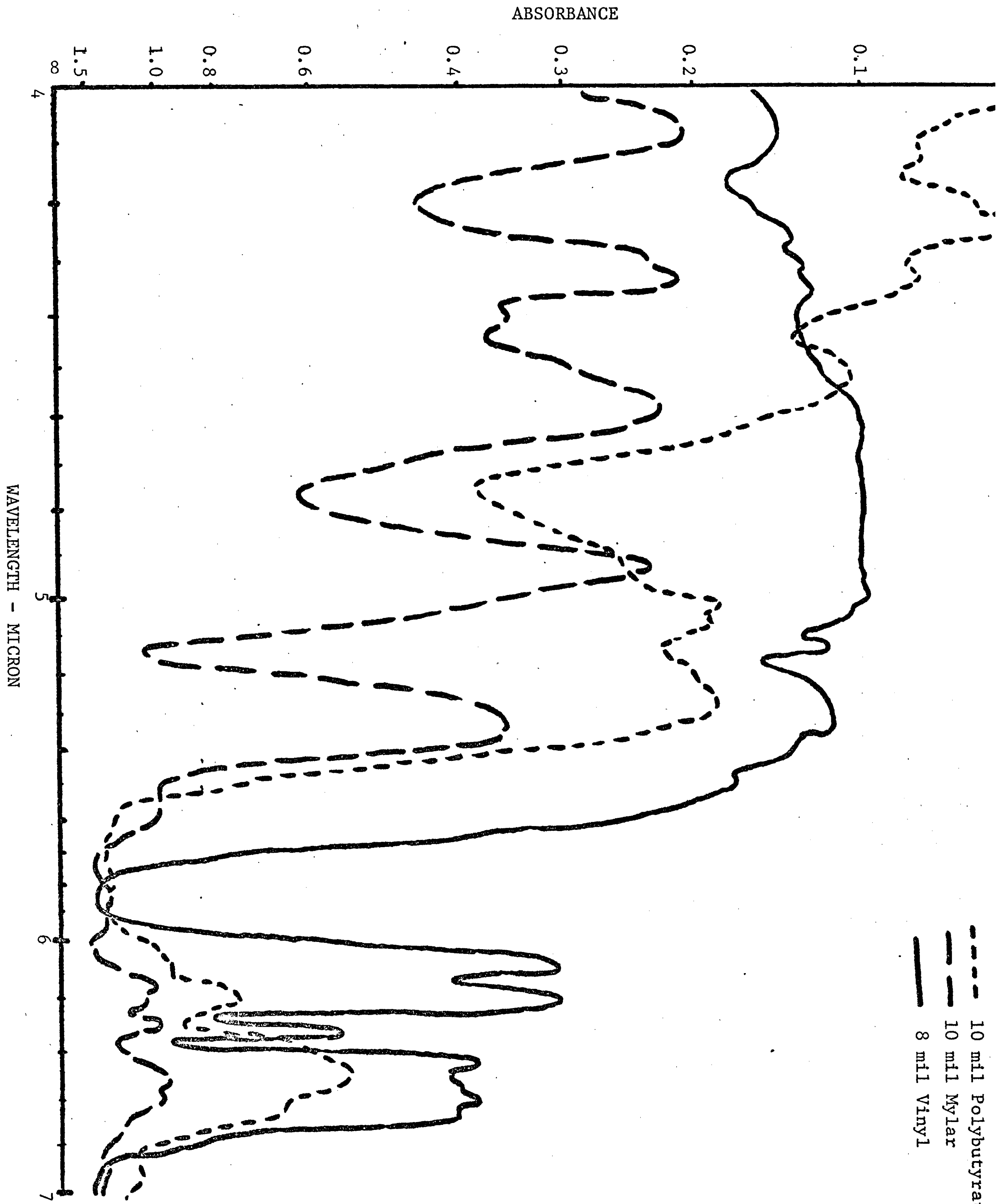
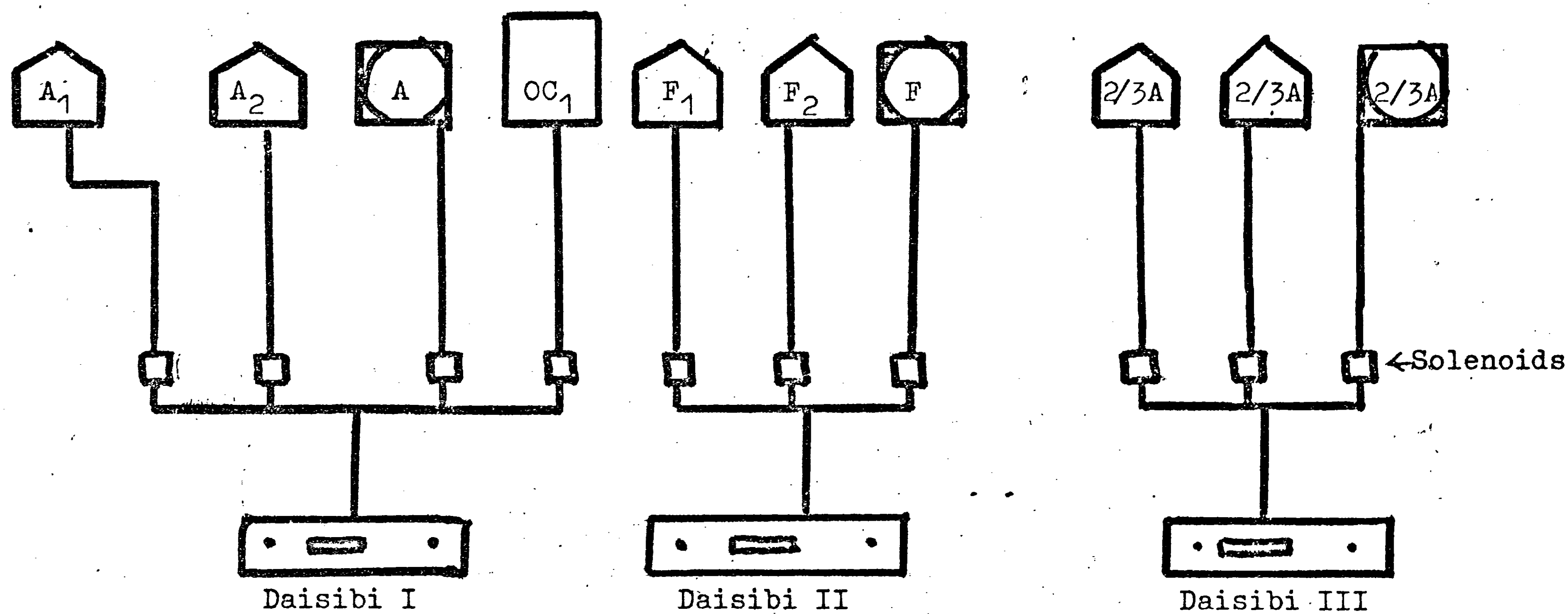


Figure 5. Schematic arrangement of air sampling system.



outside plots received twice the amount of peat and manure. Soil samples were taken after the plots were reestablished. Soil analyses were made for nitrogen, phosphorus, potassium, calcium, pH and salinity. Results of these analyses (table 1) confirmed that the soils were well mixed and uniform in texture and nutrient content from plot to plot.

Cultural Practices

The sugar beets were planted on raised double-row beds, with the rows 18 inches apart on the raised bed and the bed centers 4 feet apart. This provided 6 rows of beets in the 12 x 12 enclosed plots and 8 rows in the 16 x 18 outdoors plots. Figures 6 and 7 show top and end views of the rows.

All plots were hand seeded on April 15 using certified seed obtained from William B. Fischer, sugar beet farm advisor in Fresno County. Shallow furrows made in the center of each raised bed were flooded with water after seeding. Initial plant emergence was somewhat erratic but after an additional soaking an acceptable stand of beets was obtained in all plots by April 25, 1977. The biwall drip line was installed after the beets were up but before thinning. The beet plants were thinned May 20 to stand approximately 9 inches apart providing about 15 plants per row for a total of 90 plants in the enclosed units and 23 plants per row or a total of 184 plants in the outside plots. The greenhouse-type chambers complete with blowers and filters were installed and in operation by June 3, 1977 at which time the beets were in the second leaf stage and about 3 inches tall. Intially plant growth was normal in all plots, but by June 30 beet armyworm and cabbage looper infestations were found in three chambers - plots 1, 5 and 8, all closed top chambers receiving all or one third filtered air. Hardest hit was plot 8 receiving the filtered air treatment. A commercial form of Bacillus thuringiensis, Dipel, was not effective in stopping the armyworms but a thorough spraying with Dylox, an organic phosphate, ended the invasion. All plots were treated even though few worms were to be found on the plants in the open top, ambient closed top, or outdoor plots. Aphids were controlled by a material called Pirimor and mites by Kelthane. Mildew infestations were encountered in mid September mainly in the closed chambers but were effectively controlled by spraying all plots twice with a systemic mildewcide called Bay Meb.

Irrigation frequency was determined by moisture tension as indicated by two porous cup-type tensiometers in each plot; one at 12" depth and one

Table 1. Results of soil analyses made 4/19/77 on experimental plots. Values (except pH and E.C.) represent ppm in soil as extracted by sodium acetate.

Plot No.	NO_3^--N	P_2O_5	K_2O	Ca	E.C.*	pH
1	14	67	53	820	3.1	7.8
2	20	57	53	810	3.5	7.8
3	15	56	47	790	3.5	7.8
4	13	50	50	770	3.4	7.8
5	16	60	40	700	3.6	7.8
6	20	73	53	850	3.3	7.7
7	14	57	53	790	3.4	7.8
8	13	70	47	760	3.3	7.7
9	17	73	43	720	3.6	7.6
10	23	67	47	720	3.0	7.9
11	14	50	53	730	2.7	7.7
12	13	67	43	730	3.2	7.7
Mean	16.0	63.1	48.5	765.8	3.30	7.7
Mean Dev.	2.16	6.4	4.0	36.2	2.0	.08
Std. Dev.	0.78	7.4	4.7	39.6	2.7	.1

* E.C. is an abbreviation for electrical conductivity which is related to total salt content or salinity.

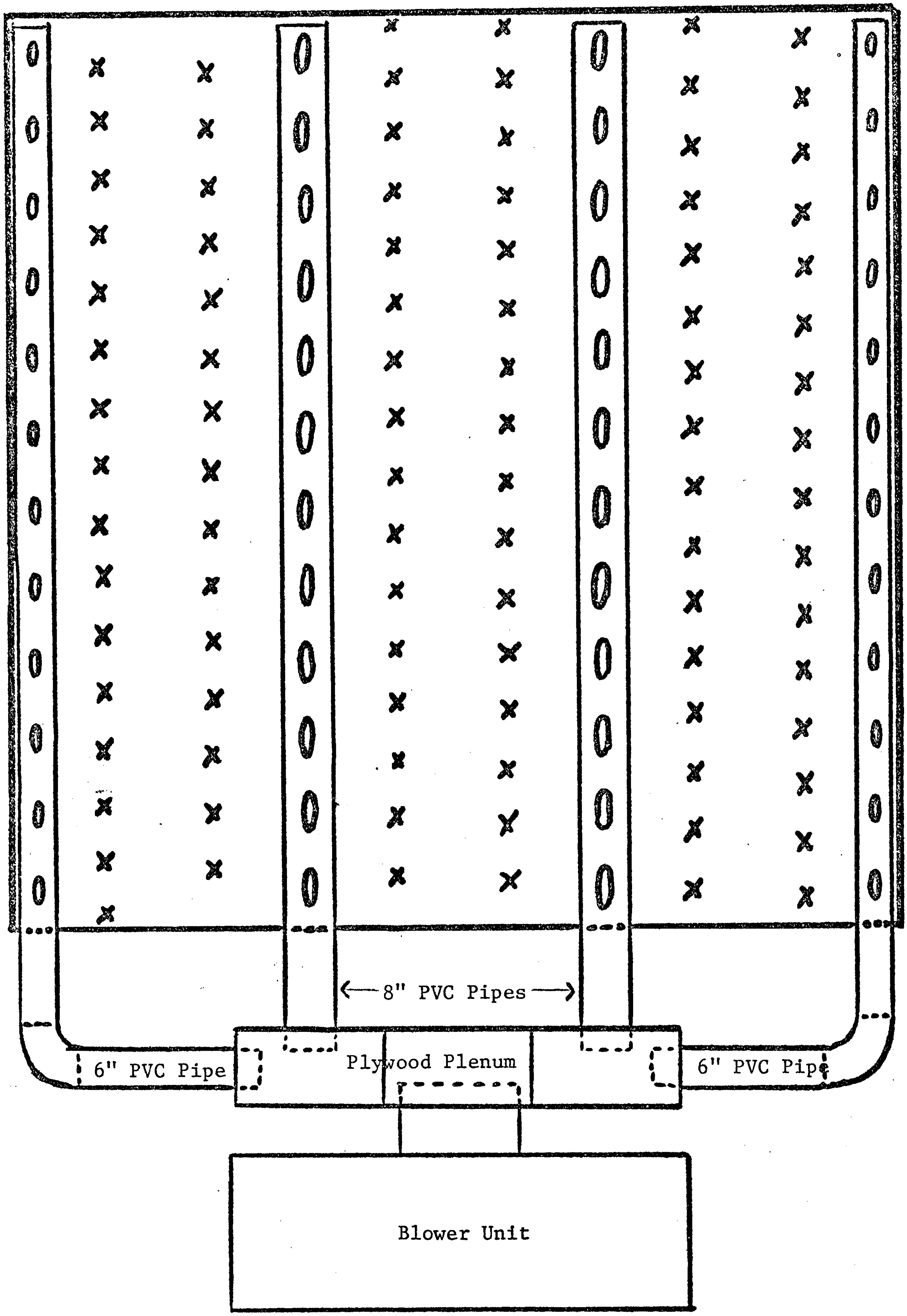


Figure 6. Layout of sugar beet rows (X's) and air ducts in open top chamber plots.

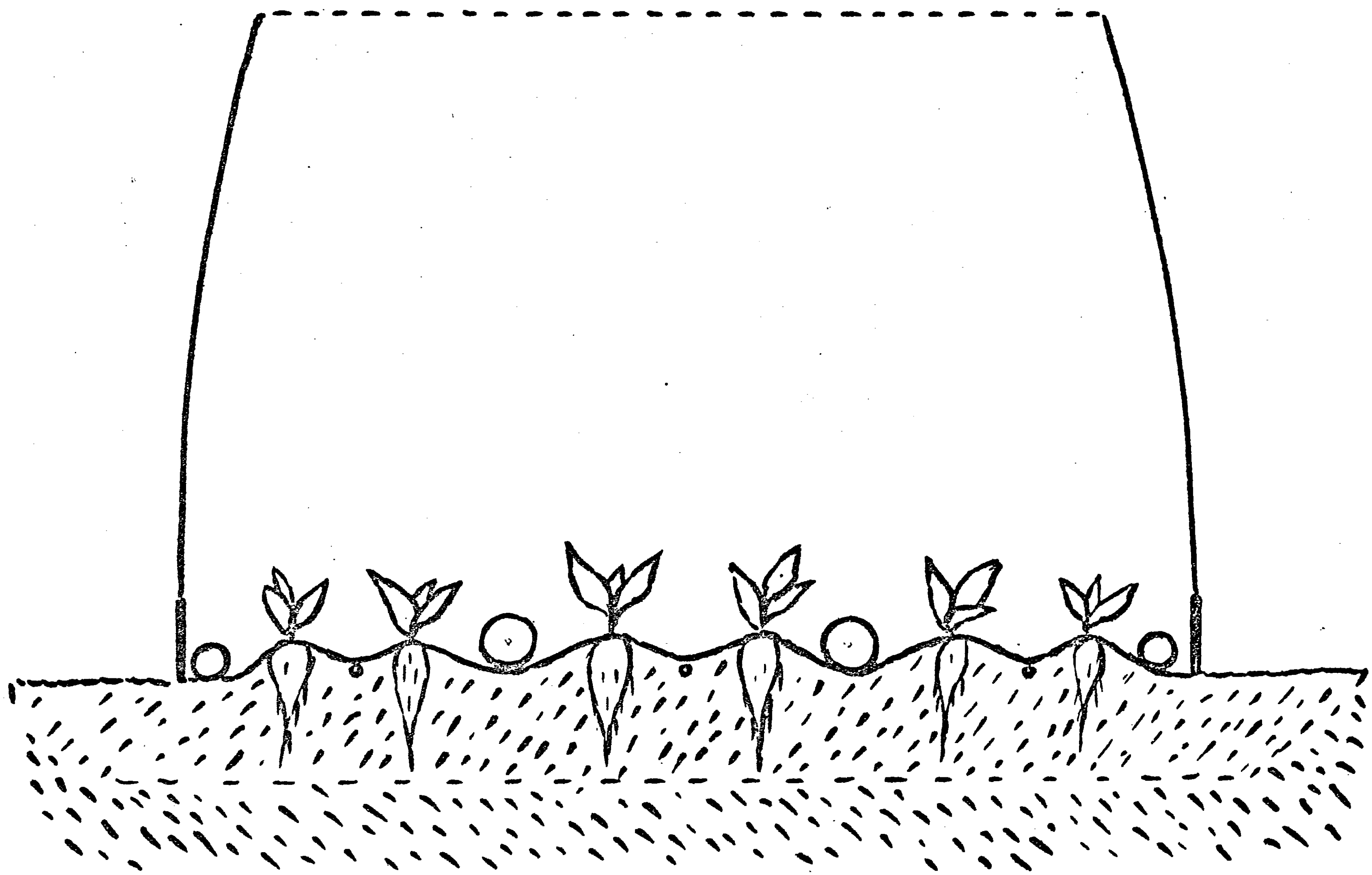


Figure 7. End view of sugar beet rows showing location of raised double beds and air ducts. Plantings in closed top and outside plot were the same but no air ducts were used.

at 24". Water was applied very slowly to the whole plots through the buried perforated biwal tubing. A pressure control valve and 200 mesh stainless steel screen filter in the water supply lines assured a uniform supply of clean water to each plot. Obviously dry areas around the perimeters of the plots were watered by garden hose as needed.

The plastic covered growth chambers, especially the closed greenhouse type, attracted dust due to static charge on the plastic. Daily washings with a garden hose kept this dust accumulation problem to a minimum. Several more thorough washings during the season with a soft brush and a mild detergent effectively removed spray residues and water streaks from the plastic. No deterioration in transparency of the vinyl plastic was apparent during the 5 months that the chambers were in place.

Growing Conditions

Temperature and Humidity

Forced ventilation of the growth chambers (two changes of air per minute) helped keep growing conditions in the chambers close to those in the outside plots, or field conditions. Some differences did exist, however, particularly in the closed, greenhouse type chambers. Thermocouples were used to monitor air entering and flowing through the various chambers and a shielded hygrothermograph was placed in the plant canopy. Results of these monitorings indicated the following:

1. Air upon entering all of the chambers was essentially the same temperature as air in the outside plots, indicating that mechanical transport or filtration did not add measurable heat.
2. Air temperatures in the closed top chambers were on the average approximately 3^{o} F higher both day and night than those measured in the outside plots. On very warm days this difference increased during midday to as much as 5^{o} F.
3. Air temperatures in the open top chambers averaged within 1^{o} F those recorded for the outside plots, but here, too, the differences increased to about 2^{o} F at midday on hot days. At night temperatures in the open top chambers were within 0.5^{o} F of those in the outside plots.
4. Relative humidity in the plant canopy of closed top chambers averaged 5% higher at night and 10% higher at midday compared with

relative humidity at a similar location in the outside plots. During the afternoon the RH was the same or slightly lower in the closed chambers as compared with outside.

5. Relative humidities recorded in the open top chambers averaged 3 or 4% higher than those in outside plots at night, were essentially the same from sunup to noon, then lagged 4 or 5% behind those in the outside plot from midday until 6 p.m.

Light

Light intensities in the open top chambers were found to range from 98 to 99% of that in the outside plots, but in the closed chambers the range was 91 to 93% with maximum shading at midday. The following table illustrates the situation.

Table 2. Light intensities, 9/28/77, various plots (foot candles)

	10:30 a.m.	12:30 p.m.	3:30 p.m.
Outside Plot	8336	8723	8256
Closed Top	7725	7956	7616
Open Top	8272	8672	8160

Light intensity measurements made with a Lambda Instrument photometer equipped with a quantum sensor measuring only that portion of the light spectrum active in photosynthesis indicated similar relationship between closed top, open top and outside plot light conditions. Table 3 contains quantum data for measurements on November 2, 1977.

Table 3. Quantum values (lux) for open and closed sugar beet plots, 11/2/77

	8 a.m.	10 a.m.	12 noon	2 p.m.
Outside Plot	27,800	38,600	38,200	29,400
Closed Top	20,600(-25)	28,400(-25)	28,400(-25)	20,800(-29)
Open Top	25,400(-8%)	34,900(-9%)	35,000(-7)	24,900(-15)

Table 4. Air movement in the three types of plots as determined with a Weather Measure model W-141 hot wire anemometer.

Plot Type	Location	11:45 AM	3:30 PM
Outdoor Plot	1	100 FPM	105 FPM
	2	150	100
	3	175	110
	4	150	105
	5	150	90
	6	175	105
	7	150	95
	8	125	100
		mean 147	mean 101
Closed Chambers	1	95	100
	2	110	110
	3	120	125
	4	125	125
	5	130	145
	6	95	100
	7	125	110
	8	150	125
		mean 119	mean 117
Open Top Chamber	1	100	100
	2	80	90
	3	150	120
	4	90	100
	5	120	100
	6	100	80
	7	120	110
	8	100	100
		mean 108	mean 100

In this case quantum values in the closed units ranged from 71 to 75% of those outside, while open top values ranged from 85 to 93% of outside with maximum shading early and late in the day.

Air Movement

Air movement and exchange were slightly less in the open top chambers than in those with closed tops, and were apparently influenced somewhat by outside air movement as indicated by the data in table 4. Note that air movement in the open top unit averaged 8 FPM less at 3:30 PM when it was relatively still outside than it had earlier (11:45 AM) when it was somewhat breezy.

Ozone Concentrations During Experiment

Ozone in the outside air and in the various chambers was monitored with two and later three Daisibi ozone monitors. Table 5 indicates the approximate relationships among the concentrations found on a typical "smoggy" summer day.

Table 5. Relative ozone concentrations (ppm) in various units.

Air Treatment	Outside	Closed Top	Open Top
Ambient	0.12	0.101	0.110
2/3 Ambient	--	0.072	0.073
Filtered	--	0.004	0.027

These data indicate passing ambient air through a blower unit removes about 15% of the ozone and open top chambers supplied with filtered air are subject to some intrusion of outside, non-filtered air into the open top, especially when natural air movement over the chambers exceeded 175 FPM (2 MPH). Without an upwind baffle or wind screen this intrusion approximated one third of the air entering the chamber since the ozone concentrations observed were one third those found in ambient air. After installation of an upwind air deflector the intrusion was reduced to about 25% as indicated in table 5.

Maximum peak daily ozone concentrations for the various treatments are presented in tables 6A through 6G. A maximum of 0.19 PPM 0_3 was recorded on

Table 6A. Peak ozone concentrations (pphm) by day

Outdoor Plots

Day	May	June	July	Aug.	Sept.	Oct.
	Month					
1	4	8	9	15	12	9
2	5	9	8	13	17	13
3	5	7	6	14	17	19
4	5	15	6	18	14	17
5	5	12	7	17	12	12
6	5	12	9	13	13	6
7	4	12	9	10	12	9
8	4	9	15	14	13	10
9	4	6	8	14	13	14
10	5	6	7	16	9	11
11	5	10	7	16	11	12
12	4	10	9	15	10	13
13	6	12	10	13	13	16
14	7	10	10	13	10	14
15	7	10	11	13	7	11
16	5	12	12	11	6	12
17	4	9	11	6	6	9
18	6	9	13	13	5	12
19	7	8	9	8	4	11
20	9	11	6	12	6	17
21	8	13	6	10	9	13
22	6	10	9	9	10	14
23	6	9	10	11	9	9
24	7	14	10	7	10	12
25	5	12	8	7	12	11
26	7	11	8	6	9	8
27	7	10	11	10	9	4
28	8	11	13	8	9	5
29	8	12	14	14	4	5
30	11	12	11	14	7	5
31	14	–	13	10	–	7

Table 6B. Peak ozone concentrations (pphm) by day

Open-top houses: ambient air

	Month					
Day	May	June	July	Aug.	Sept.	Oct.
1	4	7	8	14	11	8
2	5	8	7	12	16	12
3	5	7	6	13	16	17
4	5	14	6	17	13	16
5	5	11	7	16	11	11
6	5	11	8	12	12	6
7	4	11	8	9	11	8
8	4	8	14	13	12	9
9	4	6	7	13	12	13
10	5	6	7	15	8	10
11	5	9	7	15	10	11
12	4	9	8	14	9	12
13	6	11	9	12	12	15
14	7	9	9	12	9	13
15	7	9	10	12	7	10
16	5	11	11	10	6	11
17	4	8	10	6	6	8
18	6	8	12	12	5	11
19	7	7	8	7	4	10
20	8	10	6	11	6	16
21	7	12	6	9	8	12
22	6	9	8	8	9	13
23	6	8	9	10	8	8
24	7	13	9	7	9	11
25	5	11	7	7	11	10
26	7	10	7	6	8	7
27	7	9	10	9	8	4
28	7	10	12	7	8	5
29	7	11	13	13	4	5
30	10	11	10	13	7	5
31	13	-	12	9	7	7

Table 6C. Peak ozone concentrations (pphm) by day

Closed houses: ambient air

Day	Month: May	June	July	Aug.	Sept.	Oct.
1	3	6	7	12	10	7
2	4	7	6	10	14	10
3	4	6	5	11	14	15
4	4	12	5	14	11	14
5	4	10	6	14	10	10
6	4	10	7	10	10	5
7	3	10	7	8	10	7
8	3	7	12	11	10	8
9	3	5	6	11	10	11
10	4	5	6	13	7	9
11	4	8	6	13	9	10
12	3	8	7	12	8	10
13	5	8	8	10	10	13
14	6	10	8	10	8	11
15	6	8	9	10	6	9
16	4	10	10	9	5	10
17	3	7	9	5	5	7
18	5	7	10	10	4	10
19	6	6	7	6	3	9
20	8	9	5	10	5	14
21	7	10	5	8	7	10
22	5	8	7	7	8	11
23	5	7	8	9	7	7
24	6	11	8	6	8	10
25	4	10	6	6	10	9
26	6	9	6	5	7	6
27	6	8	9	8	7	3
28	7	9	10	6	7	4
29	6	10	11	11	3	4
30	9	10	9	11	6	4
31	11	-	10	8	-	6

Table 6D. Peak ozone concentrations (pphm) by day

Open-top houses: 2/3 ambient air

Day	May	June	July	Aug.	Sept.	Oct.
			Month			
1	2	5	5	9	7	5
2	3	5	5	8	10	8
3	3	4	4	8	10	11
4	3	9	4	11	8	10
5	3	7	4	10	7	7
6	3	7	5	8	8	4
7	2	7	5	6	7	5
8	2	5	9	8	8	6
9	2	4	4	8	8	8
10	3	4	4	10	5	7
11	3	6	4	10	7	7
12	2	6	5	9	6	8
13	4	7	6	8	8	10
14	4	6	6	8	6	8
15	4	6	7	8	4	7
16	3	7	7	7	4	7
17	2	5	7	4	4	5
18	4	5	8	8	3	7
19	4	5	5	5	2	7
20	5	7	4	7	4	10
21	5	8	4	6	5	8
22	4	6	5	5	6	8
23	4	5	6	7	5	5
24	4	8	6	4	6	7
25	3	7	5	4	7	7
26	4	7	5	4	5	5
27	4	6	7	6	5	2
28	5	7	8	5	5	3
29	5	7	8	8	2	3
30	7	7	7	8	4	3
31	8	-	8	6	-	4

Table 6E. Peak ozone concentrations (pphm) by day

Closed houses: 2/3 ambient air

Day	May	June	July	Aug.	Sept.	Oct.
			Month			
1	2	4	5	8	6	5
2	3	5	4	7	9	7
3	3	4	3	7	9	10
4	3	8	3	9	7	9
5	3	6	4	9	6	6
6	3	6	5	7	7	3
7	2	6	5	5	6	5
8	2	5	8	7	7	5
9	2	3	4	7	7	7
10	3	3	4	8	5	6
11	3	5	4	8	6	6
12	2	5	5	8	5	7
13	3	6	5	7	7	8
14	4	5	5	7	5	7
15	4	5	6	7	4	6
16	3	6	6	6	3	6
17	2	5	6	3	3	5
18	3	5	7	7	3	6
19	4	4	5	4	2	6
20	5	6	3	6	3	9
21	4	7	3	5	5	7
22	3	5	5	5	5	7
23	3	5	5	6	5	5
24	4	7	5	4	5	6
25	3	6	4	4	6	6
26	4	6	4	3	5	4
27	4	5	6	5	5	2
28	4	6	7	4	5	3
29	4	6	7	7	2	3
30	6	6	6	7	4	3
31	7	-	7	5	-	4

Table 6F. Peak ozone concentrations (pphm) by day

Open-top houses: filtered air

Day	May	June	July	Aug.	Sept.	Oct.
			Month			
1	1	2	3	4	4	3
2	2	3	2	4	5	4
3	2	2	2	4	5	6
4	2	4	2	5	4	5
5	2	4	2	5	4	4
6	2	4	3	4	4	2
7	1	4	3	3	4	3
8	1	3	4	4	4	3
9	1	2	2	4	4	4
10	2	2	2	5	3	3
11	2	3	2	5	3	4
12	1	3	3	4	3	4
13	2	4	3	4	4	5
14	2	3	3	4	3	4
15	2	3	3	4	2	3
16	2	4	4	3	2	4
17	1	3	3	2	2	3
18	2	3	4	4	2	4
19	2	2	3	2	1	3
20	3	3	2	4	2	5
21	2	4	2	3	3	4
22	2	3	3	3	3	4
23	2	3	3	3	3	3
24	2	4	3	2	3	4
25	2	4	2	2	4	3
26	2	3	2	2	3	2
27	2	3	3	3	3	1
28	2	3	4	2	3	2
29	2	4	4	4	1	2
30	4	–	4	3	–	2
31	4	–	4	3	–	2

Table 6G. Peak ozone concentrations (pphm) by day

Closed houses: filtered air

Day	May	June	July	Aug.	Sept.	Oct.
			Month			
1	0	1	1	1	1	1
2	0	1	0	1	1	1
3	0	1	0	1	1	2
4	0	1	0	2	1	1
5	0	1	0	1	1	1
6	0	1	1	1	1	0
7	0	1	1	1	1	1
8	0	1	1	1	1	1
9	0	0	0	1	1	1
10	0	0	0	1	1	1
11	0	1	1	1	1	1
12	0	1	1	1	1	1
13	0	1	1	1	1	1
14	0	1	1	1	1	1
15	0	1	1	1	0	1
16	0	1	1	1	0	1
17	0	1	1	0	0	1
18	0	1	1	1	0	1
19	0	1	0	1	0	1
20	1	1	0	1	0	1
21	1	1	1	1	1	1
22	0	1	1	1	1	1
23	0	1	1	1	1	1
24	0	1	1	0	1	1
25	0	1	1	0	1	1
26	0	1	1	0	1	1
27	0	1	1	1	1	0
28	1	1	1	1	1	0
29	1	1	1	1	0	0
30	1	1	1	1	0	0
31	1	-	1	1	-	0

October 3, 0.18 PPM was recorded on August 4, and 0.17 PPM readings were observed on August 5, September 2 and 3 and on October 4 and 20.

Ozone Dose for 1977 Growing Season

The ozone concentration data collected on site during the 1977 growing season supplemented by Fresno County data from the nearby Parlier Station were used to calculate ozone exposures in the various treatments from May 1 through October 31, 1977. Exposure dose was calculated using two different threshold levels, .05 and 0.1 pphm-hours and was obtained by totaling the hourly mean concentrations in excess of 5 or 10 pphm for the above period. The calculated doses were as follows:

Table 7. Ozone dose, 1977 growing season

Treatment	Ozone dose in pphm-hours	
	Threshold .05 ppm	Threshold 0.10 ppm
Outside	4,437	350
Ambient Chamber - Closed	2,085	122
Ambient Chamber - Open Top	3,635	215
2/3rds Ambient Chamber - Closed	349	0
2/3rds Ambient Chamber - Open Top	417	0
Filtered Chamber - Closed	0	0
Filtered Chamber - Open Top	1	0

PLANT RESPONSES

At no time during the course of these experiments were we able to observe classic ozone or PAN injury symptoms on the sugar beet foliage in any of the treatments. Plants in the "outside control" plots were noticeably lighter green in color late in the season, but there were no stipple, interveinal chlorosis or other symptoms commonly associated with ozone injury. Results of nitrate tests conducted by the Spreckles sugar laboratory indicated lower nitrogen concentration in beets from the outside plots indicating the lighter green foliage color was probably due to exhaustion of the nitrogen supply

Apparent chlorophyll contents of plants in the various plots as determined with an Ennis and Associates chlorophyll meter[6/] are summarized in table 8.

Table 8. Apparent chlorophyll content of mature sugar beet foliage and "Nitrate" content of roots from the same plots expressed on a scale of 1 to 4 where 1 = low, 4 = high.

Treatment	Plot	Apparent Chlorophyll	"Nitrate" in Roots‡
Outside Control	4	.45 mg/g	2.0
	7	.30	1.0
	11	.35	2.6
Ambient Chambers	3	1.00	3.0
	10	1.05	4.0
	(6)	1.00	3.3
2/3rds Ambient Chambers	1	.75	3.0
	12	.87	3.7
	(9)	.87	3.7
Filtered Chambers	5	.95	3.0
	8	.95	3.3
	(2)	.80	3.0

○ = Open Top Chambers

‡ = Nitrate scale of 1 to 4 where 1 = low, 4 = high

Sugar Beet Yields

The blowers supplying air to the growth chambers were shut off on November 1, 1977 and the chambers removed from the plots. Harvesting of the beets was begun on November 10 and concluded on November 11. The beet plant was pried loose with a two-tongued fork, the clinging dirt removed by shaking and then brushing, the whole plant weighed, the top was then chopped off and the root weighed separately. The lengths and widths of the individual beet roots were also recorded.

A 6' x 8' frame was used to delineate a subplot within each of the 12' x 12' plots. This was deemed necessary by Mr. L. M. Burtch, Chief Agronomist with Spreckles Sugar who supervised and helped with the harvest, because

---

6/ Wallihan, E. F., Agronomy Journal, 65(4), p. 659-662, 1973.

beets in "border" rows grow quite differently from those in the interior of the plot. In this experiment this was especially true for the outside control plots. Two samples of beets from each of the 6' x 8' subplots were taken to Spreckles for standard beet quality determinations.

Table 9 contains a summary of the sugar beet yields for both the whole plots and the 6' x 8' subplots. No differentiation is made here for the type of chamber (open top or conventional) in which they were grown.

In tables 10, 11 and 12, however, data for each of the chamber types is shown together with the treatment means shown in the lower half of table 9. The analyses of variance are also provided to indicate the extent and source of variation among the means.

Beet root yields presented in table 10 indicate no significant differences due to air treatment, but a very significant effect of chamber type. Significant reductions in beet yields in the 2/3rds ambient and filtered closed top chambers are probably due to the insect and mildew problems experienced in those chambers. In the open top chambers where there were not the insect and mildew problems, production was essentially the same as in the outside plots.

Similarly, sugar production results presented in table 11 were the same in all of the open top chambers, but slightly greater in the outside plots, probably the results of slightly elevated temperatures in the chambers compared with outside. Again the large reductions were associated with chamber type and insect-mildew problems, not air treatment.

Beet top weights, summarized in table 12, averaged less in the outside plots than in the chamber even though beet weights and sugar production were higher in the outside plots. It seems likely that lower mean temperatures which promote increased storage of carbohydrates are involved here.

It is interesting to note the trend towards increased top weights in the filtered open top chamber. This was the only suggestion of a response to filtered air by the sugar beets.

The effects of the treatments on sugar beet quality criteria as determined by the Spreckles beet lab are shown in table 12. Purity, expressed as a percent, is a measure of the east with which sucrose can be extracted from the beets. The nitrate ratings were on the beet roots, not the tops, and indicated lower values associated with higher gross weight of roots produced and sugar production.

Table 9. The effects of filtered and non-filtered air sugar beet yields.

Treatment	Beet Tops lbs/plot	Beet Roots lbs/plot	Tops/Root Ratio	Weight of Sucrose lbs/plot
Whole Plots (12' x 12')				
Outside Control*	124.0	412.2	.29	54.1
Ambient Chamber	177.2	370.0	.46	41.4
2/3rds Ambient Chamber	144.7	315.4	.43	33.7
Filtered Chamber	169.2	329.4	.44	37.5
Mean	153.8	356.7	.40	41.7
*Adjusted to same size (12' x 12') as other plots				
Interior Subplots (6' x 8')				
Outside Control	39.3	131	.30	17.1
Ambient Chamber	55.8	125	.45	14.0
2/3rds Ambient Chamber	45.3	108	.42	11.5
Filtered Chamber	56.1	112	.50	12.7
Mean	49.1	119	.42	13.8

Table 10. Sugar beet root yields

6 x 8 Subplots - lbs/plot

Plot	Outside	Treatments: Ambient	2/3rds Ambient	Filtered
1	142 a 142 b	[131]	[99] *	[114] *
2	122 a 113 b	[122]	[111] *	[105] **
3	138 a 132 b	(140)	(135)	(136)
Treatment Mean (closed and open)		131	115	118

[ ] = closed top

( ) = open top

* serious insect and mildew injury

** severe insect and mildew injury

Analysis of Variance[1/]

Factor	d.F.	SS	Variance	F calc.	F required .05	F required .01	Significance[2/]
Total	449	2512.9					
Plot Type	2	48.7	24.35	4.43	3.02	4.68	+
Treatments (Closed Top)	2	17.8	8.90	1.62	"	"	NS
Treatments (Open Top)	2	0.4	0.20	0.04	"	"	NS
Reps (Closed Top)	1	5.2	5.20	.95	3.87	6.70	NS
Reps (Outside Plots)	5	21.6	4.32	0.79	2.26	3.11	NS
Error	440	2419.2	5.50				

1/ Using Table of F from Statistical Methods; G. W. Snedecor, Collegiate Press, Iowa, 1937.

2/ Significant at .05 = +, at .01++.

Table 11. Sugar production - sugar beets, 1977

6 x 8 Subplots - lbs/plot

All Plots Considered

Plot	Outside	Ambient	2/3rds Ambient	Filtered
1	17.1 a 16.1 b	13.6	10.4 *	11.4 *
2	16.6 a 17.7 b	12.6	9.1 *	11.2 **
3	18.6 a 16.6 b	15.9	15.1	15.6
Treatment‡ Mean	17.1	14.0	11.5	12.7

□ = closed top

○ = open top

* serious insect and mildew injury

** severe insect and mildew injury

‡ Mean values listed except for Outside Plots represent average for two closed and one open top unit.

Analysis of Variance 1/

Factor	d.F.	SS	Variance	F calc.	F required .05	F required .01	Significance
Total	14	119.6					
Plot Type	2	102.6	51.3	20.9	19.0	99.0	
Treatments (Closed Top)	2	11.2	5.6	2.3	"	"	NS
Treatments (Open Top)	2	0.3	.15	0.06	"	"	NS
Reps (Closed Top)	1	0.5	.25	0.01	2.0	4999	NS
Reps (Outside Subplots)	5	3.1	.62	0.25	19.3	99.3	NS
Error	2	4.9	2.45				

1/ Using Table of F from Statistical Methods, G. W. Snedecor, Collegiate Press, Iowa, 1937.

Table 12. Sugar beet top weights

6 x 8 subplots - lbs/plot

Plots Considered

Plot	Outside	Ambient	2/3rds Ambient	Filtered
1	41.0 a 42.2 b	[51.3]	[39.0] *	[44.2] *
2	42.5 a 35.0 b	[49.2]	[47.7] *	[59.5] **
3	34.5 a 41.2 b	(54.2)	(49.2)	(64.7)
Treatment Mean‡	39.4	51.6	45.3	56.1

☐ = closed top

○ = open top

* serious insect and mildew injury

** severe insect and mildew injury

‡ Except for outside plots the mean values represent the average for two closed and one open top unit.

Analysis of Variance[1/]

Factor	d.F.	SS	Variance	F calc.	F required .05	F required .01	Significance
Total	449	3187.5					
Plot Type	2	372.0	186.0	27.96	3.02	4.68	++
Treatments (Closed Top)	2	5.5	2.7	0.40	"	"	NS
Treatments (Open Top)	2	16.7	8.3	1.24	"	"	NS
Reps (Closed Top)	1	9.9	9.9	1.48	3.87	6.70	NS
Reps (Outside Subplots)	5	11.8	2.4	0.36	2.26	3.11	NS
Error	327	2949.9	6.7				

1/ Using Table of F from Statistical Methods, G. W. Snedecor, Collegiate Press, Iowa, 1937.

Table 13. Effects of air quality on sugar beet quality

Treatment	Percent Sucrose	"Purity"*	Nitrate** Content
Outside Control	13.13	84.8	1.9
Ambient Chamber	11.20	80.1	3.4
2/3rds Ambient Chamber	10.70	80.1	3.4
Filtered Chamber	11.37	82.1	3.1

*"Purity" - A measure of the ease with which sucrose can be extracted.

**Nitrate Ratings: 1 = low, 4 = high.

CONCLUSIONS

Results of these experiments permit the following conclusions:

1. Sugar beets growing under central San Joaquin Valley conditions do not respond positively to removal of ozone from the air in which they are grown. The only suggestion of a response was somewhat greater top growth in filtered air but root weights and sugar production were not affected. (These conclusions are confirmed by a July, 1978 report from studies with sugar beets by the California Department of Food and Agriculture which showed no correlation between ozone dose and sugar beet yields or sugar content.)
2. Sugar beet root growth and sugar production are very poorly related to top growth. This would suggest that moderate leaf damage due to ozone or PAN would not necessarily reduce crop yields so long as the damaging episodes were infrequent. This would be especially true if leaf damage occurred late in the growth season when the sizeable beet root is a potential source of energy for producing replacement foliage.
3. Open top growth chambers more nearly approach outdoor growing conditions than do closed top conventional greenhouse type structures and therefore results obtained in air pollution tests using this type of chamber should more nearly represent the field situation.

4. Plastic covered igloo-shaped open top structures provided nearly twice as much growing area compared with silo-shaped units with no significant difference in air intrusion or light distribution. Forced ventilation from below helped prevent intrusion of non-filtered air into filtered units.
5. The sugar beet plants exposed to ambient ozone concentrations in these tests were about three weeks old (second leaf stage) when the greenhouses were installed over them. The effects, therefore, of any ambient oxidants on the newly emerged beet plants which later received oxidant-free carbon filtered air are not known.

(NOTE) After this report was prepared results of an ozone dose study with sugar beets by the Department of Food and Agriculture[1/] was released indicating the following"

> "Ozone dose was not correlated with sugar beet yield or soluble solids content. The analysis and evaluation of the 1977 field data did not detect ozone specific responses. This crop was therefore labelled ozone resistant and no loss function provided."

1/ Mackenzie, Jake. Supplement to Air Pollution Crop Loss Manual, Division of Pest Management, Environmental Protection and Worker Safety, California Department of Food and Agriculture, July 31, 1978.

GRAPE EXPERIMENT

Two rows of Thompson Seedless grapes (76 vines) were pruned uniformly in February of 1978 to leave 6 canes with a total of 72 buds on each vine. Prunings from these vines which included last year's fruiting canes as well as one year old canes in excess of the 6 left to fruit were weighed and measured. Lengths and weights of these canes were recorded for each vine and the data subjected to a standard analysis of variance. To determine the optimum number of vines per unit the data was analyzed for variance between individual vines, adjoining pairs of vines, and triplets. Results of these analyses follow.

A total of 354 canes from 59 vines which could be used in future air pollution experiments were included in the analyses which are summarized in tables 14 and 15.

Table 14. Statistical analysis of variation in Thompson Seedless grapevines pruned February 14, 1975.

Source	DF	SS	MS	F
Total	353	3,718.59	-	
Between vines	58	695.76	11.996	1.17 (NS at .25)
Between canes	295	3,022.83	10.247	

Table 15. Probability of random differences using 1 to 3 vines per unit.

Vines/unit	Mean wt/vine kg	Standard deviation kg	Probability of random difference* 5%	10%	15%
1	4.47	.785	-	-	1.17 to 1
2	4.50	.482	-	1.86 to 1	5.25 to 1
3	4.64	.242	2 to 1	20 to 1	99 to 1

*Using Fishers Table of X to determine probability (P) based on value of $\frac{X}{\sigma}$, where X = $\pm$ variation from mean and σ = the standard deviation (Statistical Technique in Agr. Research, McGraw Hill, 1939).

CONCLUSIONS

Assuming no more than 3 chambers per treatment and a desire to detect 10 percent differences with a confidence of .05 (20 to 1 odds), it would appear necessary to enclose at least 3 vines in each chamber. Fruit yields will be obtained from these uniformly pruned vines in August or September, 1978 and the data similarly analyzed before final design plans are made for the comtemplated experiment with grapes.