EPA-600/3-77-128
November 1977

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# THE EFFECTS OF OXIDANT AIR POLLUTANTS ON SOYBEANS, SNAP BEANS AND POTATOES

Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Corvallis, Oregon 97330

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# THE EFFECTS OF OXIDANT AIR POLLUTANTS ON SOYBEANS, SNAP BEANS AND POTATOES

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ARS No. 12-14-1001-185

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This study was conducted
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# FOREWORD

Effective regulatory and enforcement actions by the Environmental Protection Agency would be virtually impossible without sound scientific data on pollutants and their impact on environmental stability and human health. Responsibility for building this data base has been assigned to EPA's Office of Research and Development and its 15 major field installations, one of which is the Corvallis Environmental Research Laboratory (CERL).

The primary mission of the Corvallis Laboratory is research on the effects of environmental pollutants on terrestrial, freshwater, and marine ecosystems; the behavior, effects and control of pollutants in lake systems; and the development of predictive models on the movement of pollutants in the biosphere.

This report summarizes the results of five years of research related to the effects of photochemical oxidants on soybeans, snap beans and potatoes. The work supports CERL's mission in strengthening the scientific bases for secondary air quality standards required by the Federal Clean Air Act.

A. F. Bartsch
Director, CERL

# PREFACE

Air pollution research is conducted in the Plant Stress Laboratory to determine the effects of air pollutants on plants and to develop improved technology for minimizing and preventing damage by the use of genetic, chemical, mechanical and other methods. Both basic and mission-oriented research are required to meet the objectives. Emphasized are (1) evaluating the effects of air pollutants on crop yield and quality, (2) identifying and developing plants tolerant to pollutants, and (3) determining the mechanisms of action of air pollutants, including assessing the nature of resistance to pollutants.

The effects of photochemical oxidants on plants have been studied at Beltsville, Maryland since 1956, when studies were initiated to determine the cause of weather fleck, a leaf spot injury to tobacco. By 1959, we reported that oxidants, primarily ozone, caused weather fleck. In 1966, the research was expanded to studies of other crop and ornamental plants. By 1968, the research was underway in new laboratory and greenhouse facilities with a staff of three professionals. In 1972, some field-oriented research was initiated, using eight open-top chambers from the Environmental Protection Agency, Raleigh, North Carolina.

ABSTRACT

During the past 5 years the impact of photochemical oxidants on soybeans and snap beans in Maryland and on potatoes in Virginia and Delaware was assessed with open-top chambers. Experiments with soybeans were conducted at Queenstown, Maryland from 1973-1975. The mean yields of four selected soybean varieties grown in open-top chambers with carbon-filtered air and in plots without chambers were about the same. However, the mean yields of beans grown in chambers with nonfiltered air were significantly lower (about 20%). In experiments with snap beans at Beltsville, Maryland from 1972-1974, the bean yield from one of three varieties tested was decreased 14% by oxidants, whereas the other two varieties did not show a yield decrease. Snap beans grown in plots without chambers produced about the same as those in chambers with nonfiltered air. Results from snap bean experiments conducted in 1975 and 1976 using the circular plot design and four varieties were similar to those obtained in the first 3 years of study using row plots.

At Painter, Virginia, in 1975, three of four potato varieties showed a significant yield reduction (average 30%) in chambers with nonfiltered air as compared with filtered air. The variety Pungo yielded the same in the two different chamber environments. Mean yields for these potato varieties were about the same when grown in the plots without chambers as when grown in filtered-air chambers, but were significantly lower when grown in unfiltered chambers. However, mean yields of potatoes were not significantly different in these three environments in an experiment at Georgetown, Delaware in 1976.

In 1975, mean hourly oxidant concentrations were higher at Painter, Virginia than at Beltsville, Maryland but peak values were higher at Beltsville.

In 1976, a clear plastic tunnel-type chamber tested at Beltsville proved to be suitable for assessing air pollution impact on snap beans. The primary advantage over open-top chambers was lower oxidants in the tunnel chamber with filtered air. However, cultural practices were more difficult to perform in the tunnel chambers (1.2 m high by 9.1 m long). A chamber modification to permit easier access to the plants is suggested.

This report is submitted by the Agricultural Research Service, U.S. Department of Agriculture in fulfillment of an Interagency Agreement No. EPA-IAG-D6-0479 sponsored by the Corvallis Environmental Research Laboratory, U.S. Environmental Protection Agency. The research was completed September 30, 1976.

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ACKNOWLEDGMENT

The following persons contributed valuable aid and assistance in completing this study: Mr. Louis P. Rose, Jr. and Mr. W. C. Craig, Jr. supplied technical assistance; Mr. E. James Koch was consulted on the statistical methods and analyses; Dr. Alan Heagle, Agricultural Research Service, U.S. Department of Agriculture, Raleigh, NC provided suggestions on experimental procedure used on the 1972-1974 snap bean studies; Dr. R. E. Baldwin and Mr. Boyette Graves, Virginia Truck and Ornamentals Research Station, for conducting the experiments with potatoes at Painter, VA; and to Dr. Donald F. Fieldhouse, University of Delaware, Newark for conducting the experiment with potatoes at Georgetown, DE.

Acknowledgment is also given to the contributions of: Dr. J. P. Meiners, Chief, Applied Plant Pathology Laboratory, Beltsville, MD for suggestions on snap bean culture; Dr. Raymon Webb, Chief, Vegetable Laboratory, Beltsville, MD for "seed potatoes"; The Asgrow Seed Co., Kalamazoo, MI for seed of the snap bean varieties Astro, Bush Blue Lake 290 and Bush Blue Lake 274; and the Gallatin Valley Seed Co., Twin Falls, ID for seed of Gallatin 50.

## INTRODUCTION

In 1972, the use of "open-top" cylindrical chambers (3 m dia. and 2.4 m high) to exclude photochemical oxidants was a new approach to assessing the impact of air pollution on field-grown crops. These chambers (8) were obtained from the cooperative EPA-USDA research project at Raleigh, North Carolina. In the first study, three varieties of snap beans were grown from seedling stage to harvest in three environments: (1) chambers with carbon-filtered air, (2) chambers with nonfiltered air and (3) field plots without chambers. In 1973 and 1974, additional chambers were constructed to permit simultaneous studies on snap beans, soybeans and potatoes.

We also report here on an experiment conducted in 1976 with a tunnel-type chamber design.

## CONCLUSIONS

Experiments in Maryland and nearby locations in Virginia and Delaware during the past 5 years with open-top chambers placed over field-grown crops revealed that photochemical oxidants reduced crop productivity. The amount of the reduction depended on the crop and the varieties tested. Seasonal variability in oxidant concentrations and in environmental conditions that influenced plant growth and response to pollutants affected the results.

Mean yields of soybeans grown in chambers with nonfiltered air were reduced about 20% as compared with those grown in filtered air. Since the yields in plots without chambers were about the same as those in filtered air, a question remains as to how much the yield reductions may reflect a chamber influence on plant response to pollutants.

In studies with three snap bean varieties conducted over a 3-year period, the sensitive Bush Blue Lake 290 variety showed a 14% reduction in yield attributable to oxidants. Yields of the other two varieties were not significantly reduced. Studies conducted during 1975-1976 gave similar results. However, BBL 274, which was added to the experiment, showed about the same yield reduction as BBL 290. BBL 274 is more widely planted than BBL 290. Snap bean yields were about the same in plots without chambers as in chambers with nonfiltered air.

At Painter, Virginia in 1975, yields of three of four potato varieties tested were reduced significantly (30%) in chamber plots with nonfiltered as compared with filtered air. However, mean yield of potatoes in a similar experiment at Georgetown, Delaware in 1976 was not reduced by air pollutants. Potatoes produced higher yields in field plots without chambers than in chambers.

Oxidant concentrations at Painter, Virginia and Beltsville, Maryland were very similar during the summer of 1975. Peak concentrations were higher at Beltsville but mean concentrations were higher at Painter.

A tunnel-type chamber (1.2 m high x 9.1 m long) tested in 1976 on snap beans maintained a lower oxidant level in the filtered air than did adjacent open-top chambers, but was too low to allow necessary cultural practices to be easily performed.

## RECOMMENDATIONS

New approaches are needed to resolve questions raised by the results obtained with open-top chambers. Results with snap beans seem adequate, perhaps because with these smaller plants the chamber effects per se were minimized. The open-top chambers should be tested with other species. Known low levels of pollutants, especially ozone, should be added to some chamber treatments. Experience with the chambers at other locations in the country would be beneficial. Chamber modification should be considered along with other approaches, such as use of chemical protectants on sensitive and tolerant varieties, for assessing the impact on air pollutants on field-grown crops.

## SECTION I

## OPEN-TOP CHAMBERS

### MATERIALS AND METHODS

#### SOYBEANS

An experiment was designed to answer the question "What is the effect of oxidant air pollutants on the yield and quality of soybeans in eastern Maryland?" It was started in 1973 and continued in 1974 and 1975. The varieties selected for the study were York, Dare, Cutler, and Clark. The experiment was conducted at the Maryland University Research Farm at the Wye Institute, Queenstown, Maryland, on a Mattapox silt loam with pH of 6.4. Fertilizer (0-15-30) at 342 kg/ha and a herbicide, trifluralin (α,α,α-trifluoro-2,6-dinitro-*N*, *N*-dipropyl-*p*-toluidine), at 1.1kg active ingredient/ha were incorporated preplant. Supplemental irrigation was provided as needed to prevent severe wilting.

The sources of variation for the analysis of variance are shown in Table 1.

TABLE 1. SOURCES OF VARIATION FOR THE ANALYSIS OF VARIANCE IN A SOYBEAN EXPERIMENT USING OPEN-TOP CHAMBERS, QUEENSTOWN, MD

| MAIN EFFECTS | ANALYSIS OF VARIANCE | |
|---|---|---|
| Environments | Sources | Degrees of Freedom |
| | Total | 95 |
| Filtered air | Replications | 3 |
| Nonfiltered | Environments (E) | 2 |
| Ambient | Error a | 6 |
| Varieties | Varieties (V) | 3 |
| York | V X E | 6 |
| Dare | Positions (P) | 3 |
| Cutler | P X E | 6 |
| Clark | Error b | 18 |
| Positions (quadrants) | Rows (R) | 1 |
| NE, NW, SE, SW | R X E | 2 |
| | R X V | 3 |
| Rows | R X E X V | 6 |
| Outer | R X P | 3 |
| Inner | R X P X E | 6 |
| | Error c | 27 |

The environmental treatments were arranged as four replications of a randomized complete block design with the positions and varieties forming a 4 x 4 Latin square as a split plot for each environment and the rows within a position treated as split-split plots within this Latin square. Because of the cylindrical chamber design (3 m dia. x 2.4 m high) three rows 75 cm apart were arranged in circles. Each plot was divided into equal quarters, referred to as positions in the analysis of variance. Thus, each quarter had a long outer row of 1.8 m, and a short inner row of 0.6 m. Varieties were assigned to quadrants using a separate randomized 4 x 4 Latin square for each of the three environmental treatments. Three seeds were placed in each site spaced 5 cm apart in each row. After 10 days, seedlings were thinned to one per site. Chambers were placed over plants on designated plots. Four chambers received air drawn through activated carbon (filtered air) and four received air not filtered through carbon. Ambient air plots without chambers represented field conditions.

The open-top field chamber with a krene coating was identical to that described by Heagle, et al. (1). Air under pressure enters the base of the chamber through many 2.5-cm-diameter holes in the inner wall of the krene coating, and circulates around the plants before escaping through the top of the chamber. The air blower assembly was similar in design to that described by Mandl, et al. (2). Air flow rates were about 1 km/hr above the plants in the plot centers when external wind conditions were calm. Each chamber was covered with a coarse mesh net to minimize wind turbulence.

For more information on the microenvironment conditions in the open-top chambers, see the Appendix.

Each plant was harvested separately, bagged, identified, and dried in the greenhouse for 14 days. Seeds were removed, weighed, and reported as yields in g/plant for each row.

## SNAP BEANS

The 1975 and 1976 open-top field chamber experiments conducted at Beltsville, Maryland with snap beans involved circular plots similar to those described for soybeans (Figure 1). Each plot consisted of two circular rows 76 cm apart. In 1972, 1973, and 1974, however, the beans were grown in three row plots which were parallel and spaced 76 cm apart (Figure 2). Each year the plants were spaced 5 cm apart and all plots had border rows.

Plants were harvested at the proper stage for processing, except in 1975 they were harvested a few days early because of damage caused by heavy rains. In 1972, 1973, and 1974, five groups of 5 plants each

Figure 1. Open-top chambers in place over circular plots with four snap bean varieties in each of four quadrants and similar plots without chambers, 1975-1976. Border row around chambers as well as plots without chambers.

Figure 2. Open-top chambers in place over row plots (3 varieties) and plots without chambers, 1972-1974. Note complete field cover in 1974.

were harvested for each variety. In 1975 and 1976, all plants were harvested. Data included green weight of plants and green and dry weights of pods. For some crops, mature and immature pods, stem length, and leaf and stem weights were recorded.

Bush Blue Lake 290, Gallatin 50 and Astro were used throughout the 5 years. BBL 290 and Gallatin 50 are processing-type beans and Astro is a fresh market bean. In 1975 and 1976, Bush Blue Lake 274 was added, since 4 varieties could be tested with the new plot design. BBL 274 is a processing type more widely grown than BBL 290.

Each year, an early (mid-May to mid-July) and a late crop (late-July to late-Sept.) were planted. Beans normally mature 55-60 days after seeding. Oxidant leaf injury was noted as it developed during the season.

## POTATOES

In 1971, photochemical oxidants damaged potato crops on the Eastern Shore of Virginia (3); consequently, studies with open-top chambers were initiated in 1973 at Painter, Virginia and continued to 1976 when they were moved to Georgetown, Delaware. The experimental design used with potatoes also involved circular plots with a different variety planted in each quadrant. At Painter, Virginia the varieties were Pungo, LaChipper, Superior and Norchip. Each plot contained 8 plants of each variety, with plants spaced 30 cm apart. The outside row contained six plants of each variety and the inside row, two plants of each. Cultural practices were similar to those used for crop production in the area. Each of the three environments (filtered air chamber, nonfiltered air chamber and plots without chambers) were replicated twice.

In 1976 at Georgetown, Delaware, only two potato varieties were planted: Norland, which is sensitive to oxidants, and Superior, which is relatively tolerant. Each environment was replicated four times.

Oxidants were monitored with Mast Ozone Meters at Beltsville and Queenstown, Maryland, and at Painter, Virginia to obtain hourly averages and daily maximum concentrations.

## RESULTS AND DISCUSSION

### SOYBEANS

Brief summaries of the soybean studies have been published (4, 5). There was no significant variety x environment interaction. Differences in mean seed yields between the filtered and nonfiltered chambers were greatest in 1973 and least in 1974 (Table 2). Yields were lowest in 1975. Mean seed yields for soybeans grown in carbon-filtered chambers and in plots without chambers were not significantly different (Table 3). Mean seed yields for the varieties grown in nonfiltered air chambers were reduced significantly (about 20%) compared to the other two environments.

### SNAP BEANS

Only summary information on the first 2 years of snap bean experiments has been published (6, 7). Over the 3-year period (1972-1974), Gallatin 50 produced significantly greater (7%) weight of green pods in carbon-filtered air than in plots without chambers. The data also showed a higher yield (not statistically significant) for this variety in chambers with nonfiltered than with filtered air (Table 4). We cannot explain this response. The lower yields in plots without chambers may be due in part to more leaf diseases in these plots. BBL 290 and Gallatin 50 were more susceptible to leaf diseases than was Astro. Astro was also the most tolerant to oxidants, as evidenced by the similar yields in the three environments.

In 1975, snap beans were first grown in circular plots and compared with those grown in previous years in row plots (Figures 1 and 2). Photochemical oxidants did not reduce yields of either the early or late crops that year (Tables 5 and 6). In the early crop, the chamberless plots produced higher yields than chamber plots because of severe drought late in June. Physical measurements have shown that plants in chambers have greater moisture stress. When the early crop plants were half grown, moisture stress was sufficient to induce wilting, especially in the chamber plots. The drought was followed by heavy rains (about 21 cm during a week). The soil became waterlogged, resulting in root damage and most pods in contact with soil developing rot. Plants were harvested a few days early to minimize the damage. Actually 1/3 to 1/2 of the pods were under size ( 7 cm or less). Before the harvest was complete (2 days) the plants were severely wilted, indicating root damage. The replications harvested last had significantly lower green pod weight due to loss of the moisture content. Under these environmental conditions Gallatin 50 produced significantly more green weight of beans than the other

TABLE 2. SUMMARY OF RESULTS IN 1973, 1974, AND 1975 WITH SOYBEANS IN THREE ENVIRONMENTS: CHAMBERS WITH FILTERED AIR, CHAMBERS WITH NONFILTERED AIR AND PLOTS WITH NO CHAMBERS AT QUEENSTOWN, MARYLAND

| Year | Yield per plant - environment [a]: Chambers nonfiltered air (NF) | Chambers filtered air (F) | No chambers | Ave. | NF/F x100 |
|---|---|---|---|---|---|
| | g | g | g | g | % |
| 1973 | 21.5 b | 30.4a | 31.1a | 27.7a | 70.7 |
| 1974 | 19.9 bc | 21.8 b | 21.2 b | 21.0 b | 91.3 |
| 1975 | 14.0 d | 16.9 cd | 18.1 bc | 16.3 c | 82.8 |
| Average | 18.5 b | 23.0a | 23.5a | | |

[a]Values not followed by the same letter are significantly different at 5% level, Duncan's multiple range test.

TABLE 3. SUMMARY OF 3 YEARS' RESULTS WITH 4 SOYBEAN VARIETIES IN 3 ENVIRONMENTS AT QUEENSTOWN, MARYLAND

| Variety | Yield per plant - environment: Chambers nonfiltered air (NF) | Chambers filtered air (F) | No chambers | Ave. | NF/F x100 |
|---|---|---|---|---|---|
| | g | g | g | g | |
| Dare | 21.3 | 27.0 | 25.2 | 24.5a | 78.9 |
| York | 19.5 | 22.4 | 26.7 | 22.9a | 87.1 |
| Cutler | 17.9 | 22.1 | 21.2 | 20.4 b | 81.0 |
| Clark | 15.2 | 20.6 | 20.7 | 18.8 b | 73.8 |
| Average [a] | 18.5 b | 23.0a | 23.5a | | |

[a]Values not followed by the same letter are significantly different, Duncan's multiple range test.

TABLE 4. SUMMARY OF RESULTS WITH SNAP BEANS IN 1972, 1973, AND 1974 (TWO CROPS EACH YEAR) IN THREE ENVIRONMENTS UTILIZING OPEN-TOP CHAMBERS AT BELTSVILLE, MARYLAND

| Character and variety | Yield per plant in three environments [1 2]: Chambers nonfiltered air (NF) | Chamber filtered air (F) | No chamber | NF/F x100 |
|---|---|---|---|---|
| | g | g | g | |
| Plant green wt. | | | | |
| BBL 290 | 108.8 c | 125.8a | 109.6 c | 86.5 |
| Astro | 118.9ab | 123.2ab | 120.8ab | 96.5 |
| Gal. 50 | 121.4ab | 117.4b | 109.0 c | 103.4 |
| Pods green wt. | | | | |
| BBL 290 | 57.4 d | 66.9a | 57.9 cd | 85.8 |
| Astro | 58.1 cd | 59.9 cd | 60.2 cd | 97.0 |
| Gal.50 | 65.3ab | 62.1 bc | 57.7 d | 105.2 |
| Pods dry wt. | | | | |
| BBL 290 | 5.5 de | 6.8a | 4.9 f | 80.9 |
| Astro | 5.9 cd | 6.1 bc | 5.5 de | 96.7 |
| Gal. 50 | 6.5ab | 6.1 bc | 5.4 e | 106.6 |

[1]Four replications (plots) of each environment with 5 groups of 5 plants each harvested of each variety in each plot. Each value is the average performance in 6 experiments; i.e., 3 years and 2 crops each year.

[2]Values not followed by the same letter are significantly different at 5% level, Duncan's multiple range test.

TABLE 5. PRODUCTION OF 4 VARIETIES OF SNAP BEANS IN 3 ENVIRONMENTS, EARLY CROP 1975, BELTSVILLE

| Character Variety | Yield per plant - environment [a] Chambers nonfiltered | Chambers filtered | No chambers | NF/F x100 |
|---|---|---|---|---|
| | g | g | g | |
| **Plant green wt.** | | | | |
| BBL 290 | 84.3 def | 87.5 cde | 95.2 c | 96.3 |
| Astro | 81.8 ef | 78.1 f | 95.8 c | 104.7 |
| Gal. 50 | 109.7 b | 105.1 b | 118.6a | 104.4 |
| BBL 274 | 93.6 c | 92.3 cd | 104.0 b | 101.4 |
| **Pods fresh wt.** | | | | |
| BBL 290 | 37.9 de | 40.5 cd | 49.1 bc | 93.6 |
| Astro | 23.6 f | 22.0 f | 36.5 de | 107.3 |
| Gal. 50 | 55.4 b | 54.7 b | 68.0a | 101.3 |
| BBL 274 | 31.2 ef | 29.0 ef | 43.1 cd | 107.6 |
| **Pods dry wt.** | | | | |
| BBL 290 | 2.95 cde | 2.75 cdef | 3.46 bc | 105.8 |
| Astro | 2.18 ef | 2.03 f | 3.01 cd | 107.4 |
| Gal. 50 | 4.02ab | 4.21a | 4.38a | 95.5 |
| BBL 274 | 2.46 def | 2.48 def | 3.15 cd | 99.2 |

[a]Values not followed by the same letter are significantly different at 5% level, Duncan's multiple range test.

TABLE 6. PRODUCTION OF 4 VARIETIES OF SNAP BEANS IN 3 ENVIRONMENTS, LATE CROP 1975, BELTSVILLE

| Character<br>Variety | Yield per plant - environment [a]<br>Chambers nonfiltered air (NF) | Chambers filtered air (F) | No chambers | NF/F x100 |
|---|---|---|---|---|
| | g | g | g | |
| Plant green wt. | | | | |
| BBL 290 | 75.5 d | 85.0 abcd | 80.0 cd | 88.8 |
| Astro | 95.2 abc | 86.0 abcd | 82.9 abcd | 110.7 |
| Gal. 50 | 91.0 abcd | 86.0 abcd | 81.7 bcd | 105.8 |
| BBL 274 | 87.5 abcd | 97.5 ab | 93.2 abc | 89.7 |
| Pods fresh wt. | | | | |
| BBL 290 | 32.7 abcd | 38.1 a | 32.9 abcd | 85.8 |
| Astro | 31.7 abcd | 33.3 abcd | 19.8 e | 95.2 |
| Gal. 50 | 36.8 ab | 34.3 abc | 25.0 cde | 107.2 |
| BBL 274 | 27.3 bcde | 30.4 abcd | 23.6 de | 89.8 |
| Pods dry wt. | | | | |
| BBL 290 | 2.56abc | 2.89a | 2.51abc | 88.6 |
| Astro | 2.37abcd | 2.42abc | 1.43 e | 97.9 |
| Gal. 50 | 2.73ab | 2.49abc | 1.84 cde | 109.6 |
| BBL 274 | 1.95 cde | 2.09 bc | 1.68 de | 93.3 |

[a]Values not followed by the same letter are significantly different at 5% level, Duncan's multiple range test.

varieties.

The experiment with the late bean crop was on a new location having lighter textured soil and better drainage. Plant growth was good, until heavy rains late in September caused some damage. As with the early crop, green pods were harvested a few days before they were ready for processing or marketing. Oxidant concentrations during September were relatively low. Yields were similar for all varieties (Table 6). Astro, however, produced significantly less in the no-chamber plots than in chamber plots. Yields in the outside rows were significantly higher than in the inside rows. There was also a significant position effect. In the unfiltered chambers, plots in the southwest quadrant produced more than those in the northwest or southeast quadrant.

1976 Early Crop

In 1976 the experimental plantings were in circular plots. Bean yields for the early crop were similar for all environments (Tables 7 and 8). The plants in filtered air had significantly more leaves than plants in the chamberless plots (Table 8). The ratio of leaves to stems and the percent dry matter in pods were significantly higher in all chamber plots than in the plots without chambers, indicating a chamber effect.

The performance by each variety is shown by data in Table 9. BBL 290 produced significantly less plant green weight and less leaf and stem weight than the other varieties. The reduced weights may be due to the greater susceptibility of BBL 290 to a virus disease which was apparently prevalent in several Eastern States during June. The virus was either plant stunt virus or yellow mosaic virus according to J. P. Meiners, Agricultural Research Service, USDA, Beltsville, Maryland. It stunted the plants to various extents and even killed some plants.

1976 Late Crop

In the late crop, the chamber experiments indicated that photochemical oxidants reduced the plant growth of Astro and BBL 274 significantly (Table 10). Pod yields of BBL 274 were reduced 22%. In filtered air BBL 274 produced almost double the bean yield of BBL 290. BBL 290 yields were reduced by rust, which was especially severe in the field plots without chambers. Because of the rust, differences in the yields of BBL 290 in filtered and nonfiltered air were not significant, even though the variety is more sensitive to oxidants than the other varieties. Other research has shown that rust lesions give localized protection from oxidant injury (8).

TABLE 7. INFLUENCE OF ENVIRONMENT ON SNAP BEAN YIELDS WITH 4 VARIETIES EARLY CROP 1976, BELTSVILLE

| Character and Variety | Yield per plant-environment[a] | | | NF/F x100 |
|---|---|---|---|---|
| | Chamber nonfiltered air (NF) | Chamber filtered air (F) | No chamber | |
| | g | g | g | |
| Plant green wt. | | | | |
| BBL 290 | 114.4 d | 132.8 bcd | 126.9 cd | 86.1 |
| Astro | 164.6a | 168.7a | 156.4ab | 97.6 |
| Gal. 50 | 170.8a | 145.7abc | 161.6ab | 117.2 |
| BBL 274 | 162.7a | 175.4a | 174.6a | 92.8 |
| Pods green wt. | | | | |
| BBL 290 | 59.1 b | 65.9ab | 62.1ab | 89.7 |
| Astro | 59.0 b | 65.1ab | 59.3 b | 90.6 |
| Gal. 50 | 78.2ab | 64.7ab | 72.1ab | 120.8 |
| BBL 274 | 71.9ab | 82.6a | 76.0ab | 87.0 |
| Pods dry wt. | | | | |
| BBL 290 | 6.22a | 7.00a | 6.00a | 88.9 |
| Astro | 5.98a | 6.56a | 5.50a | 91.2 |
| Gal. 50 | 7.51a | 6.36a | 6.11a | 118.1 |
| BBL 274 | 6.16a | 7.18a | 6.09a | 85.8 |

[a] Values not followed by same letter are significantly different at 5% level, Duncan's multiple range test.

TABLE 8. COMPARISON OF SNAP BEAN PRODUCTION - THREE ENVIRONMENTS, EARLY CROP 1976

| Character | | Yield per plant-environment[a] Chamber nonfiltered air (NF) | Chamber filtered air (F) | No chamber | NF/F x100 |
|---|---|---|---|---|---|
| Plant green wt. | g | 153.1 a | 155.7 a | 154.9 a | 98.3 |
| Pods green wt. | g | 67.0 a | 69.6 a | 67.4 a | 97.1 |
| Pods dry wt. | g | 6.47a | 6.78a | 5.92a | 95.4 |
| Leaves/plant | g | 68.5 ab | 71.4 a | 63.2 b | 95.9 |
| Stems/plant | g | 57.6 a | 62.0 a | 60.9 a | 92.9 |
| Ratio, leaves/stem | | 1.20a | 1.15a | 1.04 b | 104.3 |
| Pods, % dry matter | | 9.78a | 9.77a | 8.81 b | 100.1 |

[a] Values not followed by the same letter are significantly different at 5% level, Duncan's multiple range test.

TABLE 9. COMPARISON OF 4 VARIETIES OF SNAP BEANS IN AIR POLLUTION FIELD STUDIES, EARLY CROP 1976

| Character | | Variety[a] | | | |
|---|---|---|---|---|---|
| | | BBL 290 | Astro | Gal. 50 | BBL 274 |
| Plant green wt. | g | 124.7 b | 163.2 a | 159.4 a | 170.9 a |
| Pods green wt. | g | 62.4 b | 61.1 b | 71.7 ab | 76.8 a |
| Pods dry wt. | g | 6.41a | 6.01a | 6.66a | 6.48a |
| Leaves/plant | g | 51.6 c | 78.2 a | 69.4 b | 71.5 ab |
| Stems/plant | g | 49.0 b | 66.9 a | 61.5 a | 63.2 a |
| Ratio, leaves/stem | | 1.05a | 1.17a | 1.14a | 1.15a |
| Pods, % dry matter | | 10.17a | 9.86a | 9.37 b | 8.41 c |

[a] Values not followed by the same letter are significantly different at 5% level, Duncan's multiple range test.

TABLE 10. INFLUENCE OF ENVIRONMENT ON YIELDS OF 4 SNAP BEAN VARIETIES LATE CROP 1976, BELTSVILLE

| Character and Variety | Yield per plant-environment[a] Chamber nonfiltered air (NF) | | Chamber filtered air (F) | | No chamber | | NF/F x100 |
|---|---|---|---|---|---|---|---|
| | g | | g | | g | | |
| Plant green wt. | | | | | | | |
| BBL 290 | 70.0 | ef | 81.0 | e | 64.1 | f | 86.3 |
| Astro | 102.9 | cd | 122.3 | b | 97.9 | d | 84.1 |
| Gal. 50 | 114.9 | bc | 119.8 | b | 95.2 | d | 95.9 |
| BBL 274 | 112.8 | bc | 143.8 | a | 108.0 | bcd | 78.4 |
| Pods green wt. | | | | | | | |
| BBL 290 | 31.5 | e | 35.5 | e | 18.5 | f | 88.7 |
| Astro | 51.2 | bcd | 57.1 | bc | 48.4 | cd | 89.4 |
| Gal. 50 | 59.7 | b | 59.6 | b | 47.9 | d | 100.2 |
| BBL 274 | 54.7 | bcd | 70.1 | a | 52.7 | bcd | 78.0 |
| Pods dry wt. | | | | | | | |
| BBL 290 | 2.69 | e | 3.00 | e | 1.47 | f | 89.7 |
| Astro | 4.60 | bcd | 4.91 | b | 4.01 | cd | 93.7 |
| Gal. 50 | 4.85 | b | 4.79 | bc | 3.87 | d | 101.3 |
| BBL 274 | 4.57 | bcd | 5.85 | a | 4.11 | bcd | 78.1 |

[a] Values not followed by the same letter are significantly different at 5% level, Duncan's multiple range test.

Average green weights of plants and pods, and weights of mature pods and leaves were significantly higher in the chambers with filtered air than in chambers with nonfiltered air or in plots without chambers (Table 11). As might be expected, oxidants depressed leaf weights more than bean yields, 24% vs 11% respectively. Although BBL 274 showed the greatest yield reduction due to oxidants, it still had the highest yields in all environments (Table 12). Gallatin 50 had significantly more immature pods (<10 cm) than the other varieties.

The data for the 1975 and 1976 studies using the new circular experimental design are summarized in Table 13. Although the statistical treatment of the combined data is not complete, the results indicate that oxidants depressed the yields of BBL 290 an average of 10%, whereas Gallatin 50 produced more in chambers with nonfiltered air than in the filtered air. Thus, the experimental design using circular rows gave results very similar to those obtained with row plots (Table 4).

POTATOES

Summary data for the 1975 study at Painter are presented (Table 14). Yield reductions attributable to oxidants average 24 percent. Pungo, the most tolerant variety, produced about the same yields in all environments. The yield of Superior was reduced 41%. At harvest, Pungo had significantly more vine weight in the filtered air. Perhaps if the harvest had been delayed, the greater vine weight of Pungo would have resulted in more tuber weight in the filtered air, as happened with the other varieties.

At Georgetown in 1976, yields of the two potato varieties did not differ significantly in the three environments (Table 15). Seasonal oxidant concentrations were relatively low. Although oxidant-induced leaf injuries developed in July, especially on Norland in the nonfiltered chambers and in plots without chambers, they apparently were not sufficient to reduce tuber yield.

TABLE 11. COMPARISON OF SNAP BEAN PRODUCTION IN THREE ENVIRONMENTS, LATE CROP 1976

| Character[1] | | Yield per plant-environment: Chamber nonfiltered air (NF) | Chamber filtered air (F) | No chamber | NF/F x100 |
|---|---|---|---|---|---|
| Plant green wt. | g | 100.1 b | 116.8 a | 91.3 b | 85.7 |
| Pods green wt. | g | 49.3 b | 55.6 a | 41.9 c | 88.7 |
| Pods dry wt. | g | 4.18a | 4.64a | 3.37 b | 90.0 |
| Pods mature | g | 44.2 b | 49.6 a | 35.2 b | 89.1 |
| Pods immature | g | 4.4 b | 5.3 ab | 6.0 a | 83.0 |
| Stem length (cm) | | 38.7 ab | 43.8 a | 34.9 b | 88.4 |
| Leaves/plant | g | 43.3 b | 57.3 a | 43.3 b | 75.6 |
| Stems/plant | g | 21.7 a | 27.4 a | 24.3 a | 79.2 |
| Ratio, leaves/stem | | 2.10a | 2.10a | 1.81a | 100.0 |
| Pods dry matter | % | 8.48a | 8.33a | 8.03a | 100.8 |

[1] Values followed by a different letter are significantly different at 5% level, Duncan's multiple range test.

TABLE 12. COMPARISON OF 4 VARIETIES OF SNAP BEANS IN AIR POLLUTION FIELD STUDIES, LATE CROP 1976[a]

| Character | | Yield per plant-variety | | | |
|---|---|---|---|---|---|
| | | BBL 290 | Astro | Gal. 50 | BBL 274 |
| Plant green wt. | g | 71.7 c | 107.7 b | 110.0 b | 121.5 a |
| Pods green wt. | g | 28.5 c | 52.3 b | 55.7 ab | 59.2 a |
| Pods dry wt. | g | 2.39 b | 4.51a | 4.50a | 4.84a |
| Pods mature | g | 22.5 c | 49.3 ab | 47.3 b | 53.0 a |
| Pods immature | g | 5.3 b | 3.0 c | 7.6 a | 5.1 b |
| Stem length (cm) | | 35.7 b | 39.1 a | 41.1 a | 40.6 a |
| Leaves/plant | g | 43.5 b | 46.7 ab | 47.5 ab | 54.2 a |
| Stems/plant | g | 21.0 b | 25.5 ab | 24.1 ab | 27.2 a |
| Ratio, leaves/stem | | 2.14a | 1.87 b | 1.99ab | 2.00ab |
| Pods dry matter | % | 8.28 b | 8.59a | 8.11 b | 8.15 b |

[a] Values not followed by the same letter are significantly different at 5% level, Duncan's multiple range test.

TABLE 13. PRODUCTION OF 4 SNAP BEAN VARIETIES IN NONFILTERED AIR CHAMBERS AS PERCENT OF PRODUCTION IN CARBON-FILTERED AIR, 1975 AND 1976

| | 1975 | | 1976 | | |
|---|---|---|---|---|---|
| Variety | Early | Late | Early | Late | Ave. |
| | % | % | % | % | |
| BBL 290 | 93.6 | 85.8 | 89.7 | 88.7 | 89.5 |
| Astro | 107.3 | 95.2 | 90.6 | 89.4 | 95.6 |
| Gal. 50 | 101.3 | 107.2 | 120.8 | 100.2 | 107.4 |
| BBL 274 | 107.6 | 89.8 | 87.0 | 78.0 | 90.6 |
| Average | 102.5 | 94.5 | 97.0 | 89.1 | |

TABLE 14. YIELD OF FOUR POTATO VARIETIES IN THREE ENVIRONMENTS AT PAINTER, VIRGINIA, 1975[a b]

| Variety | Tuber yield per plant-environment[c] | | | NF/F x 100 |
|---|---|---|---|---|
| | Nonfiltered air (NF) | Carbon-filtered air (F) | No chambers | |
| | g | g | g | |
| Pungo | 375.9abc | 364.4abc | 379.3abc | 103.1 |
| LaChipper | 249.9 c | 419.8abc | 553.3a | 59.5 |
| Superior | 301.3 bc | 516.8a | 565.5a | 58.3 |
| Norchip | 440.3abc | 491.8ab | 509.6ab | 89.5 |
| Average | 341.8 b | 448.2ab | 501.9a | 76.3 |

[a]Eight plants per plot. Two replications.

[b]Cooperation of Dr. R. Baldwin and Mr. B. Graves, Truck Crops Substation, Eastern Shore, Painter, Va.

[c]Values not followed by the same letter are significantly different at the 5 percent level, Duncan's multiple range test.

TABLE 15. YIELD OF TUBERS FOR TWO VARIETIES IN THREE ENVIRONMENTS AT GEORGETOWN, DELAWARE, IN 1976[a]

| Character Variety | Tuber yield per plant in environments[b] Chamber nonfiltered air (NF) | Chamber filtered air (F) | No chamber | NF/F x 100 |
|---|---|---|---|---|
| Tuber wt./g | | | | |
| Norland | 878.6 | 943.1 | 990.4 | 93.2 |
| Superior | 910.3 | 845.8 | 837.6 | 107.6 |
| Plant wt./g | | | | |
| Norland | 138.9 | 131.4 | 88.9 | 105.7 |
| Superior | 215.9 | 170.3 | 115.8 | 126.8 |
| Tuber no. | | | | |
| Norland | 11.8 | 13.8 | 12.1 | 85.5 |
| Superior | 12.1 | 12.1 | 9.9 | 100.0 |

[a]Cooperation University of Delaware, Dr. D. Fieldhouse.

[b]Based on F tests in the analysis of variance tuber production in the different environments were not significantly different.

## SECTION II

## OXIDANT VALUES COMPARISON AT BELTSVILLE, MARYLAND AND PAINTER, VIRGINIA 1975

Oxidants were monitored with Mast ozone sensors throughout 1975 at Beltsville, Maryland and during May through September at Painter, Virginia. A sulfur dioxide ($SO_2$) scrubbing column was used at Beltsville but not at Painter, Virginia. Some experience with $SO_2$ scrubbers at Painter indicated no $SO_2$ interference. The 1975 oxidant data at Painter and Beltsville were representative of those obtained in other years.

The mean oxidant values in 1975 were higher at Painter, Virginia than at Beltsville for May - September (Table 16). However, the maximum hourly values were higher at Beltsville (17.0 pphm, July 31, 4 p.m. at Beltsville, and 11.7 pphm, July 31, 1 p.m. at Painter). The mean hourly concentration was highest at 3 p.m. (5.0 pphm) at Beltsville and at 4 p.m. (5.1 pphm) at Painter, Virginia.

In each month, May through September (Table 17), the oxidant concentration was 5 pphm or greater for more hours at Painter (729 hours) than at Beltsville (469 hours). However, the concentration was 10 pphm or greater for only 2 hours during the season at Painter compared to 42 hours at Beltsville. Previous experience indicates that several hours at an oxidant concentration of 5 pphm by Mast is a threshold value for causing visible injury to sensitive plants. At 10 pphm, the oxidant injury to vegetation is much more prevalent and we sometimes refer to the situation as an air pollution episode.

The frequency distribution of the oxidant values from 9 a.m. to 8 p.m. and 9 p.m. to 8 a.m. for May through September are presented in Tables 18 and 19, respectively. In the daytime period, oxidant peak values were higher at Beltsville. However, the oxidant value with greatest frequency was 4.5 pphm for Painter, Virginia, as compared with 1.5 pphm for Beltsville, Maryland. No values at Painter were as low as 0.5 pphm.

Oxidant values during the 9 p.m. to 8 a.m. period reached the same maximum, 8.5 pphm, at the two locations; but in general, oxidants were higher also during this 12-hour period at Painter than at Beltsville. The oxidant value of greatest frequency was 1.5 pphm at Beltsville, as compared with 2.5 pphm at Painter.

TABLE 16. AVERAGE AND MAXIMUM HOURLY OXIDANT VALUES AT BELTSVILLE, MARYLAND, AND PAINTER, VIRGINIA, MAY - SEPTEMBER 1975

| Month | Oxidant value (Mast - pphm) Mean | | Maximum | |
|---|---|---|---|---|
| | Maryland | Virginia | Maryland | Virginia |
| May | 2.67 | 3.67 | 11.2 | 9.0 |
| June | 2.98 | 3.39 | 12.4 | 8.3 |
| July | 3.17 | 3.47 | 17.0 | 11.7 |
| August | 3.28 | 3.78 | 14.0 | 10.8 |
| September | 1.90 | 2.90 | 7.3 | 6.8 |

TABLE 17. OXIDANT LEVELS EQUAL TO OR GREATER THAN 5 AND 10 pphm AT BELTSVILLE, MARYLAND, AND PAINTER, VIRGINIA, MAY - SEPTEMBER 1975

| Month | Hours 5 pphm or greater | | Hours 10 pphm or greater | |
|---|---|---|---|---|
| | Maryland | Virginia | Maryland | Virginia |
| May | 57 | 138 | 2 | 0 |
| June | 119 | 139 | 7 | 0 |
| July | 125 | 165 | 16 | 1 |
| August | 143 | 227 | 17 | 1 |
| September | 25 | 60 | 0 | 0 |
| Total | 469 | 729 | 42 | 2 |

TABLE 18. FREQUENCY DISTRIBUTION OF MEAN HOURLY OXIDANT VALUES, 9:00 A.M. TO 8:00 P.M., MAY - SEPTEMBER 1975, AT BELTSVILLE, MARYLAND, AND PAINTER, VIRGINIA

| Oxidant Value (pphm) | Percentage at indicated oxidant values | |
|---|---|---|
| | Maryland | Virginia |
| 17.5 | .02 | .00 |
| 16.5 | .02 | .00 |
| 15.5 | .02 | .00 |
| 14.5 | .05 | .00 |
| 13.5 | .02 | .00 |
| 12.5 | .23 | .00 |
| 11.5 | .30 | .06 |
| 10.5 | .30 | .06 |
| 9.5 | .56 | .54 |
| 8.5 | .87 | 1.53 |
| 7.5 | 1.15 | 4.90 |
| 6.5 | 2.78 | 12.51 |
| 5.5 | 5.35 | 19.00 |
| 4.5 | 8.77 | 21.12 |
| 3.5 | 14.74 | 20.83 |
| 2.5 | 21.14 | 15.10 |
| 1.5 | 36.09 | 4.37 |
| 0.5 | 7.58 | .00 |
| | 100.00 | 100.00 |

TABLE 19. FREQUENCY DISTRIBUTION OF MEAN HOURLY OXIDANT VALUES, 9:00 P.M. TO 8:00 A.M., MAY - SEPTEMBER 1975, AT BELTSVILLE, MARYLAND, AND PAINTER, VIRGINIA

| Oxidant Value (pphm) | Percentage at indicated oxidant values | |
|---|---|---|
| | Maryland | Virginia |
| 8.5 | .02 | .18 |
| 7.5 | .35 | .06 |
| 6.5 | .71 | .54 |
| 5.5 | 1.11 | 3.70 |
| 4.5 | 3.11 | 9.98 |
| 3.5 | 10.41 | 16.61 |
| 2.5 | 23.50 | 26.22 |
| 1.5 | 43.63 | 24.07 |
| 0.5 | 17.16 | 18.64 |
| | 100.00 | 100.00 |

# SECTION III

## TUNNEL-TYPE CHAMBERS

Research results of the past 5 years have shown that open-top chambers supplied with either carbon-filtered or nonfiltered air are useful in assessing the impact of oxidant air pollution on crops. However, even with low windspeeds, some unfiltered air enters from the open top and mixes with filtered air within the chamber. Consequently, the chamber's efficiency in protecting the enclosed plants from oxidants is reduced. The above is not a problem with a long tunnel-type chamber having an open end. Such a chamber was designed and tested with snap beans during 1976.

## MATERIALS AND METHODS

Two tunnel-type chambers (1.5 m wide, 1.2 m high, and 9.1 m long) were made using 4 mil, clear polyethylene plastic supported at 1.8-m intervals with six U-shaped, 1.8-cm-diameter, tubular aluminum supports. The supports were set in larger pipe (1 m x 2.5 cm diameter) driven about 0.5 m into the ground. Both edges of the plastic were placed in 10-cm-deep trenches running the length of the chambers. The edges were covered with soil until the plastic was stretched uniformly over the supports. At one end, a 2-m length of the plastic was shaped into a cone to permit attachment to a 46-cm-diameter duct from the blower. To help straighten the air flow entering the chamber, two pieces of plastic "egg crate" (1.2 m x 1.2 m x 1.2 cm) with 1.2-cm square openings were set upright 15 cm apart and attached to the first section of tubular aluminum supporting the plastic. The other end of the chamber was open, although a buffer shield was erected about 0.5 m from the open end to prevent high winds from blowing into the tunnel. Each chamber had one row of an oxidant-sensitive cultivar of snap bean, Bush Blue Lake 290, and a row containing a tolerant cultivar, Astro. The rows were 76 cm apart. Seeds were planted July 27 and the chambers were put in place August 18 after the seedlings were thinned to 5-cm spacings and the first cultivation was done. Plants were watered by drip irrigation using Dupont Viaflow tubing on each side of the two rows. When the chambers were first set in place, the plants had one fully expanded trifoliate. On August 25 the beans were sidedressed with 560 kg/ha of 10-6-4 fertilizer. The sidedressing was applied to help correct a nitrogen deficiency and reduce the irregularity in bean growth caused by differences in previous cropping of the plot land. Plants were harvested on September 27, and data were taken on each plant. In addition, the plants between each set of metal supports were kept separate so the yields could be determined on a plot (5) as well as a plant basis.

## RESULTS

On sunny days when the bean plants were small, air temperature in the center of the chamber was 3 to 6° C above ambient. On cloudy, days the chamber temperature was about the same as ambient. After plants were in bloom, the chamber temperature above the plant canopy was about the same as ambient, even on sunny days. This was probably due to the cooling effects of the moisture transpired from the plants and soil, and to the increased air speed through the chamber as the plant canopy filled more of the chamber. When the plants were in full bloom, they occupied about half of the chamber space.

Plant green weight was significantly greater in filtered air than nonfiltered air (about 20%) for both the susceptible and tolerant varieties (Tables 20 and 21). The green weight bean yield was significantly greater (17%) in filtered air for the susceptible variety but not for the tolerant variety (difference 13%). The susceptible variety was severely injured by bean rust, especially in the ambient chamberless plots. There was very little rust in the chambers. Bean yields of BBL 290 in the chamberless plots were only a third of those in filtered air. By contrast, the oxidant-tolerant variety Astro was also quite rust tolerant. Its yield was significantly greater in the no-chamber plot than in the nonfiltered chamber plot.

Correlation coefficients were highly significant when comparing pod dry weight and green weight and pod weight with plant weight for both varieties in the three environments (Table 22). As might be expected, the correlation was very high between pod green and dry weights ($>r = .97$). Lowest correlation between pod and plant weights was in the no-chamber plots for the oxidant- and rust-susceptible variety Bush Blue Lake 290.

## DISCUSSION

Tunnel-type chambers keep oxidant concentrations lower around the vegetation than do open-top chambers. In the nonfiltered air chambers, plant weights of even the oxidant-tolerant variety, Astro, were reduced nearly the same (about 20%) as for the oxidant-susceptible variety. Although both varieties of beans grew well in the chambers, Astro produced more beans in the no-chamber plots than in the chambers.

A disadvantage with the tunnel-type chambers is the difficulty in cultivating the soil and applying insecticides within the chamber. We may be able to correct this by cutting the chamber top along one side so the top can be periodically opened for access. The chamber could be closed by taping the cut edges together onto a metal base fastened between the six frames that support the plastic.

TABLE 20. EFFECTS OF AMBIENT OXIDANTS ON A SUSCEPTIBLE AND A TOLERANT SNAP BEAN VARIETY GROWN IN TUNNEL-TYPE CHAMBERS[a]

| Variety | Environment | Plant green weight | Pods green weight | Pods dry weight |
|---|---|---|---|---|
| | | g | g | g |
| Susceptible, Bush Blue Lake 290 | | | | |
| | Nonfiltered chamber | 93.4 c | 47.4 bc | 4.12 b |
| | Filtered chamber | 119.5a | 57.5a | 4.84ab |
| | No chamber | 51.6 d | 17.4 d | 1.53 c |
| Tolerant, Astro | | | | |
| | Nonfiltered chamber | 101.1 bc | 42.8 c | 3.97 b |
| | Filtered chamber | 125.5a | 49.4abc | 4.37ab |
| | No chamber | 110.0ab | 54.9ab | 5.13a |

[a]Values not followed by the same letter are significantly different at the 5 percent level, Duncan multiple range test.

TABLE 21. BEAN PRODUCTION IN TUNNEL-TYPE CHAMBERS WITH NONFILTERED AIR AND IN NO-CHAMBER PLOTS AS PERCENT OF PRODUCTION IN FILTERED AIR[a]

| Variety | Environment | Plant green weight | Pods green weight | Pods dry weight |
|---|---|---|---|---|
| | | % | % | % |
| Susceptible, Bush Blue Lake 290 | | | | |
| | Nonfiltered air chamber | 78 | 83 | 85 |
| | Filtered air chamber | 100 | 100 | 100 |
| | No chamber | 43 | 30 | 32 |
| Tolerant, Astro | | | | |
| | Nonfiltered air chamber | 81 | 87 | 91 |
| | Filtered air chamber | 100 | 100 | 100 |
| | No chamber | 88 | 111 | 117 |

[a]See Table 20 for weights and statistical significance.

TABLE 22. CORRELATION COEFFICIENTS FOR TWO SNAP BEAN VARIETIES IN THREE ENVIRONMENTS IN STUDIES WITH TUNNEL-TYPE CHAMBERS[a]

| Environment and Parameter Measured | Bush Blue Lake 290 | | | Astro | | |
|---|---|---|---|---|---|---|
| | Plant green wt. | Pods green wt. | Pods dry wt. | Plant green wt. | Pods green wt. | Pods Dry wt. |
| Nonfiltered air chamber | | | | | | |
| Plant green wt. | 1.00 | | | 1.00 | | |
| Pods green wt. | .97 | 1.00 | | .94 | 1.00 | |
| Pods dry wt. | .96 | .99 | 1.00 | .94 | .99 | 1.00 |
| Filtered air chamber | | | | | | |
| Plant green wt. | 1.00 | | | 1.00 | | |
| Pods green wt. | .97 | 1.00 | | .90 | 1.00 | |
| Pods dry wt. | .94 | .97 | 1.00 | .86 | .98 | 1.00 |
| No chamber | | | | | | |
| Plant green wt. | 1.00 | | | 1.00 | | |
| Pods green wt. | .89 | 1.00 | | .98 | 1.00 | |
| Pods dry wt. | .86 | .99 | 1.00 | .96 | .99 | 1.00 |

[a]All correlations are significant at 1 percent level.

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APPENDIX

## MICROENVIRONMENT IN OPEN-TOP CHAMBERS

Abstract

Air flow, light, temperature, pollutant concentration, and soil moisture parameters were measured on sunny and cloudy days in open-top field chambers on snap bean, potato, and soybean plots. Chamber air blowers produced air flow in the chambers of about 0.5 m $sec^{-1}$ (1 mph). Gusty winds increased chamber ventilation because of air entering from the top. During periods of high solar lighting, photosynthetically active radiation (PAR) in shaded areas within the chambers were 50-60% of the intensities of the brightest parts of the chambers. On cloudy days, light and temperatures inside and outside the chambers were about the same. Chamber temperatures were closely related to solar radiation, ventilation rates, and ground cover. Chamber filters (charcoal) removed 80% or more of the oxidants passed through them; however, on windy days oxidant concentrations within filtered air chambers averaged about 50% of the ambient levels due to ingress from the open top. Chamber "rainshadows" and "light shadows" affected the soil moisture as did plant age and condition which affected the evapotranspiration potential.

Periodic measurements made during the summer months allow the following general statements to be made about the microenvironmental conditions within the open-top chambers:

Wind- and Air-Flow Parameters:

The ambient wind direction during the summertime was from the northwest. During gusty periods, the leeward (southeastern) portion of the chamber interiors received more ventilation than the windward side due to downdrafts of ambient gusts entering the chambers from the top. During calm periods, the interior ventilation resulted essentially from the chamber air-blower input. Wind speeds above the plants produced by the blowers were approximately 0.5 m $sec^{-1}$ throughout most of the chamber interior, but decreased to about 0.25 m $sec^{-1}$ near the center portion. Very near the chamber walls where jet streams entered from the inlet duct holes, wind speeds of 2-8 m $sec^{-1}$ were measured. Within 1/2 meter of the duct walls the jet streams merged providing more generalized chamber flows. Below the plant canopy surface level, ventilating wind speeds decreased to about 0.1-0.3 m $sec^{-1}$ near the ground. Air flow characteristics of the chambers are shown by Figure 3.

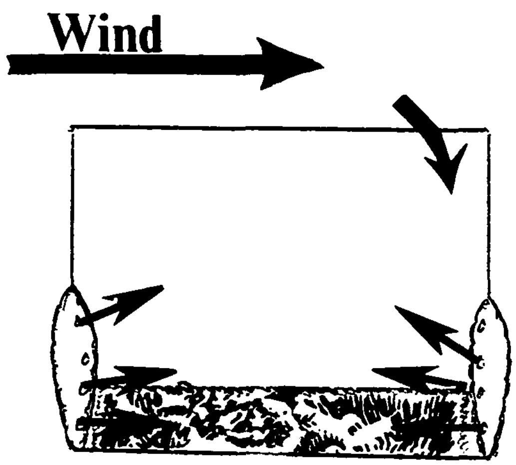


Figure 3. Chamber ventilation. Air delivery through double-walled duct. Gusty ambient winds increase internal ventilation. Air movement in the vegetation canopy is damped.

Light:

Light intensities were highest in the northern parts of the chamber interiors. Substantial shading of the southerly portions occurred during periods of direct solar lighting. The shaded areas changed as the sun's angle rotated. Solar insolation was least where chamber bracings or the double thicknesses of the lower half of the plastic chamber walls cast visible shadows. Light intensities in the most extensively shaded areas (measured above the plants) were reduced to ca. 50-60% of the light intensities in the "unshaded" areas during periods of high incident sunlight. Light intensities in the brightest parts of the chambers were 70-90% of the intensities measured outside the chambers. During overcast periods light intensities, resulting from diffuse skylight, were essentially the same throughout the chamber cross sections and closely approximated outside light intensities.

Below the plant canopy surfaces, light intensities decreased rapidly. Less than 5-10% of the photosynthetically active radiation ($\lambda$: 400-700 m$\mu$) reached the ground for dense canopies.

Temperature:

Temperatures within the chambers were closely related to chamber light intensities. During high solar radiation and calm periods, maximum temperature gradients of 6° C were measured over (near) bare, dry ground across the chambers between the most shaded and brightest locations. Chamber temperatures varied from several degrees centigrade (<4° C) above ambient temperatures in "hot spots" to 1-3° C below ambient temperatures in shaded parts. During periods of low light (overcast skies), temperature varied little over the cross section.

Plant canopies effectively dissipate absorbed solar energy through evapotranspiration. Therefore, temperature gradients are expected to be less over vegetation than over dry "black-body" surfaces. Vertical temperature gradients as high as 3° C were measured over closed plant canopies. Temperatures are expected to be highest near the canopy surface (just below the mean canopy surface level), decreasing above and below this plane. Soil temperatures (measured at 5-cm depths) were often 4° C or more lower than air temperatures above the canopy. Temperatures of rapidly transpiring leaves were typically ca. 1° C less than surrounding air temperatures. During gusty periods (wind gust above 0.5-1.5 m $sec^{-1}$), air entering the chambers from the top reduced temperature gradients within the chambers to more nearly the ambient wind temperatures.

Pollutant Concentrations:

Oxidant concentrations were essentially the same in nonfiltered chambers and the ambient air. Filtered air chambers showed an average reduction of about 50% in the oxidant levels (averaged over the chambers at the 1/2- to 1-m height) during a moderately breezy day. Oxidant concentrations within the chambers ranged from ca. 1 pphm to 4.1 pphm during a period when ambient levels were 5.2 pphm. The concentrations above 1 pphm were due to gusts of air bringing oxidants into the chambers. The chamber air filters allowed oxidant concentrations of 1 pphm to pass through (i.e., they were about 80% efficient in cleansing oxidants from the air entering through the chamber blower system).

Soil Moisture:

Soil moisture measurements made with soil moisture blocks showed that soils in the southern parts of the chambers typically contained more moisture than did soil in the northern parts. Two possible factors may have contributed to this: (1) the southern parts of the chambers may have received more rainfall due to "rainshadows" caused by the average angle by which rainfall entered the chambers, and (2) light shadows cast across the southern parts during high light conditions may have reduced transpiration rates of shaded plants. Also, soil moisture was higher in soils where soybean plants were senescing than in soil where plants were actively growing. Lower transpiration rates of senescing plants caused less depletion of the soil moisture.

| TECHNICAL REPORT DATA *(Please read Instructions on the reverse before completing)* | | |
|---|---|---|
| 1. REPORT NO. EPA-600/3-77-128 | 2. | 3. RECIPIENT'S ACCESSION NO. |
| 4. TITLE AND SUBTITLE The Effects of Oxidant Air Pollutants on Soybeans, Snap Beans and Potatoes | | 5. REPORT DATE November 1977 |
| | | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) H.E. Heggestad, R.K. Howell and J.H. Bennett | | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Plant Stress Laboratory, Plant Physiology Institute, Northeastern Region, Agricultural Research Service, U.S. Dept. of Agriculture, Beltsville, Maryland 20705 | | 10. PROGRAM ELEMENT NO. 1AA602 |
| | | 11. CONTRACT/GRANT NO. IAG-D6-0479-1 |
| 12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Corvallis Environmental Research Laboratory Corvallis, Oregon 97330 | | 13. TYPE OF REPORT AND PERIOD COVERED Final |
| | | 14. SPONSORING AGENCY CODE EPA/600/02 |
| 15. SUPPLEMENTARY NOTES | | |

16. ABSTRACT

During the past 5 years the impact of photochemical oxidants on soybeans and snap beans in Maryland and on potatoes in Virginia and Delaware was assessed with open-top chambers. Experiments with soybeans were conducted at Queenstown, MD from 1973-1975. The mean yields of four selected soybean varieties grown in open-top chambers with carbon-filtered air and in plots without chambers were about the same. However, the mean yields of beans grown in chambers with nonfiltered air were significantly lower (about 20%). In experiments with snap beans at Beltsville, MD from 1972-1974, the bean yield from one of three varieties tested was decreased 14% by oxidants, whereas the other two varieties did not show a yield decrease. Snap beans grown in plots without chambers produced about the same as those in chambers with nonfiltered air. Results from snap bean experiments conducted in 1975 and 1976 using the circular plot design and four varieties were similar to those obtained in the first 3 years of study using row plots.

At Painter, VA, in 1975, three of four potato varieties showed a significant yield reduction (average 30%) in chambers with nonfiltered air as compared with filtered air. The variety Pungo yielded the same in the two different chamber environments. Mean yields for these potato varieties were about the same when grown in the plots without chambers as when grown in filtered-air chambers, but were significantly lower when grown in unfiltered chambers. However, mean yields of potatoes were not significantly different in these three environments in an experiment at Georgetown, Delaware in 1976.

In 1975, mean hourly oxidant concentrations were higher at Painter, VA than at Beltsville, MD but peak values were higher at Beltsville.

In 1976, a clear plastic tunnel-type chamber tested at Beltsville proved to be suitable for assessing air pollution impact on snap beans. The primary advantage over open-top chambers was lower oxidants in the tunnel chamber with filtered air.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Plant Effects<br>Photochemical Oxidants<br>Soybeans<br>Snap beans<br>Potatoes | Yields<br>open-top chambers<br>tunnel-type chambers | 02/D |

| 18. DISTRIBUTION STATEMENT | 19. SECURITY CLASS *(This Report)* | 21. NO. OF PAGES |
|---|---|---|
| Release to Public | Unclassified | 49 |
| | 20. SECURITY CLASS *(This page)* Unclassified | 22. PRICE |

EPA Form 2220-1 (9-73)



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