Open-cone-top chambers (frustra) control ozone concentrations in smog study.

Smog damage to cotton in the San Joaquin Valley

Patrick J. Temple □ O. Clifton Taylor □ Larry A. Benoit
Chris A. Reagan □ Robert W. Lennox

Photochemical air pollution (smog) is harmful to California agriculture, as has been widely recognized since the 1940s, when growers in the Los Angeles Basin reported silvering, bronzing, and other discolorations on leafy crops such as lettuce, spinach, and Swiss chard. Severe smog injury on these crops rendered the produce unmarketable or greatly reduced its value.

Since these initial observations, researchers have characterized the air pollutants responsible for plant damage, described injury symptoms and identified the plant species most severely affected, and studied the effects of smog on plant growth and development. It is now known that ozone is the major component of smog responsible for plant injury, and that many important crop plants in California, including cotton, are susceptible to ozone injury.

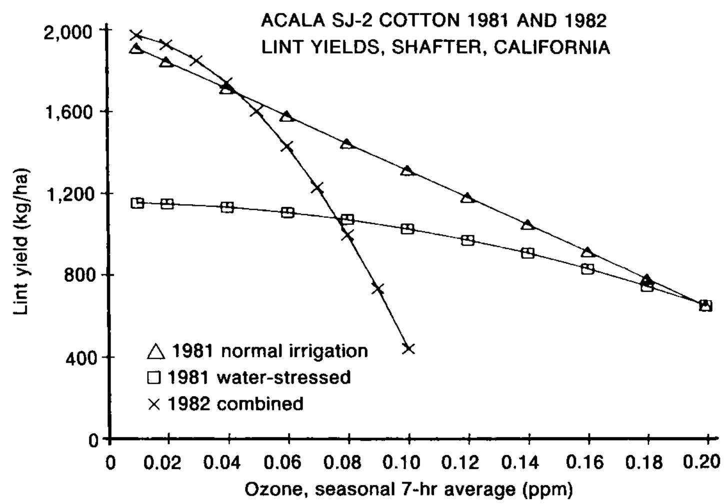
Economic losses to California agriculture from air pollution have been roughly estimated at $100 million to $500 million yearly. Such estimates, based on visible injury symptoms, are at best guesswork, because relatively little is known of the effects of ozone and other air pollutants on crop losses in the field. Even less is known of how these losses, in turn, affect economic returns to the grower.

Ozone injury symptoms on cotton have been observed in the San Joaquin Valley since the 1950s. Field experiments comparing growth of cotton in filtered and nonfiltered greenhouses have shown consistently greater yields from plants grown in filtered air (R.F. Brewer and G. Ferry, *California Agriculture*, June 1974). However, these experiments were not designed to provide the detailed dose-response data necessary for an economic assessment of crop losses to ozone.

Crop loss assessment

In 1980, major air pollution research centers around the United States joined with the U.S. Environmental Protection Agency to form the National Crop Loss Assessment Network (NCLAN). The goal of NCLAN was to determine, as accurately as possible under existing technology, the economic consequences of air pollution to U.S. agriculture. The first step was to quantify the effects of ozone and other air pollutants, alone and in mixtures, on productivity and yield of major agronomic crops in the field. This information would then be applied to an economic model of farm income and to data on ambient (outdoor) air concentrations of pollutants to assess the economic impact of air pollution on agriculture. The assessment could provide a basis for establishment of federal or local air quality standards

Ozone injury to cotton reduced yield 15 to 20 percent.



In 1981, water stress reduced yields, but ozone caused little change. In 1982, below-normal irrigation caused no significant difference (data combined), but ozone severely reduced yields.

for ozone or other air pollutants.

Because California is preeminent in U.S. agriculture and relatively high ozone levels are prevalent in some of its agricultural areas, two NCLAN field sites were established in the state. Crops to be evaluated include cotton, tomato, lettuce, barley, and alfalfa. In this report, we discuss the results of a two-year study on Acala SJ-2 cotton.

Experiment

The NCLAN field site was operated by the Statewide Air Pollution Research Center, University of California, Riverside, at the U.S. Department of Agriculture Cotton Research Station at Shafter, in the cotton growing region of Kern County. Station field personnel prepared the site for cotton planting using standard cultural practices for the area. Planting densities, row spacings, and fertilizer and pesticide applications also followed standard practices. Plant populations were thinned to 30,000 per acre in 1981 and 21,000 per acre in 1982. The field was divided into 30 plots, each of which included six rows of cotton 20 feet long. Half the plots received the normally recommended rates of furrow irrigation. In 1981, the other plots received 20 percent less water, and in 1982, 15 percent less than the recommended rate.

Twenty-four cylindrical open-top chambers, 10 feet in diameter by 8 feet high, were centered on randomly selected plots when plants were 60 days old. These chambers were designed to maximize control of ozone concentrations around the plants and to minimize environmental changes caused by the chambers themselves. The chambers were also equipped with cone-tops (frustra) that reduced diluting effects of outside air entering the chambers on windy days.

The 24 chambers were divided randomly into six ozone treatments at two levels of soil moisture with two replications each. Treatments in 1981 were: (1) full charcoal filtration of all air entering the chambers; (2) half-filtered; (3) ambient air, in which ozone concentrations inside the chamber were about the same as those in outside plots; (4) ambient plus 0.03 parts per million (ppm) of added ozone; (5) ambient plus 0.06 ppm ozone; (6) ambient plus 0.10 ppm ozone. In 1982, concentrations in the ambient-plus-ozone chambers were controlled by a proportional controller, which automatically added one-third, two-thirds, or full ambient concentration of ozone to the ambient ozone entering the chambers.

Ozone was generated by electrical spark discharge and was added for seven hours per day (0900 to 1600 Pacific Daylight Time), seven days per week, for 10 weeks in 1981 and 14 weeks in 1982. Ozone concentrations inside each chamber were monitored five times each hour, and the hourly average ozone concentration was recorded on a computer-operated data acquisition system. Ambient ozone concentrations were monitored continuously at canopy height in one of the open plots.

Open cotton bolls were harvested on October 10 to 13, 1981, and October 20 to 21, 1982. Data were collected on number and weight of open bolls and number of green bolls. Samples were ginned at the research station, and weights of lint and seed were recorded for each sample. Lint quality was analyzed at the station fiber laboratory.

Weather played a major role in determining how SJ-2 cotton responded to ozone. The summer of 1981 was typically hot and dry with many days over 100°F. In 1982, the summer was unusually cool and humid for the San Joaquin Valley: accumulated degree days above 60°F and pan evaporation (potential evaporative demand) averaged 20 percent lower in June, July, and August than in the same months of 1981. Ozone levels in 1982 averaged about half those in 1981, particularly in the ozone-added treatments. Ambient ozone averaged 37 percent lower in 1982 than in 1981.

Effects of ozone on lint production of field-grown Acala SJ-2 cotton in open-top chambers at Shafter, California

Treatment*	1981 Ozone†	1981 Lint yield‡	1981 Yield reductions§	1982 Ozone†	1982 Lint yield‡	1982 Yield reductions§
	ppm	lb/acre	%	ppm	lb/acre	%
Full-filtered	0.018	1,670	—	0.012	1,830	—
Half-filtered	0.044	1,552	7.1	0.031	1,862	—
Ambient ozone	0.072	1,330	20.3	0.044	1,557	14.9
Ozone-added (1)	0.111	995	40.4	0.065	1,017	44.4
Ozone-added (2)	0.143	984	41.1	0.077	987	46.1
Ozone-added (3)	0.183	697	58.2	0.092	626	65.8

NOTE: Plots received recommended rates of irrigation.
* Ozone-added treatments in 1981 were (1) ambient levels (A) + 0.03 ppm ozone; (2) A + 0.06 ppm ozone; (3) A + 0.10 ppm ozone. In 1982, ozone-added treatments were (1) A + ⅓A; (2) A + ⅔A; (3) 2 × A.
† Seasonal 7-hour average (0900-1600 P.D.T.).
‡ Average of two chambers (1 lb/acre = 1.12 kg/ha).
§ Relative to full-filtered chambers.

Yield responses to ozone

The plants subjected to water stress responded differently in the two years. In 1981, yields were severely reduced in those plots, and the plants showed comparatively little response to ozone (see graph). In 1982, differences in yield between water-stressed and normal irrigation plots were slight, and plants under both water regimes showed severe reductions in yield with increasing concentrations of ozone.

In normally irrigated plots in 1981, exposure to ambient ozone reduced lint yields by 20 percent relative to yields in full-filtered chambers. Yields were reduced up to 58 percent at the highest ozone concentration (see table). In 1982, full-filtered chambers given normal irrigation averaged 1,830 pounds per acre of lint. Cotton grown in ambient ozone chambers averaged 1,557 pounds per acre, a 15 percent reduction in yield. Yields were reduced by 66 percent at the highest ozone levels, which were only half those of 1981. No effect on fiber quality was found in any ozone treatment.

The greater susceptibility of SJ-2 cotton to ozone in 1982 was attributed to the cooler, more humid growing conditions. Under high evaporative demand, as during the summer of 1981, plants can wilt rapidly in late morning or early afternoon; stomates (pores in leaves through which plants exchange gases with the air) close and gas exchange is reduced. In 1982, evaporative demand was lower; plants rarely wilted, and stomates remained open all day. More ozone could enter leaves during mid- or late-afternoon when ozone levels were highest, as compared with 1981 conditions, when stomates may have been closed. Thus, despite much lower ozone concentrations in 1982, yield reductions in the two years were comparable. Ozone-added treatments began several weeks earlier in 1982 than in 1981, during boll initiation and early development; this may have contributed to the large yield reductions at the highest ozone concentrations in 1982.

The results of this two-year study on the response of field-grown cotton to ozone indicate that cotton production in the San Joaquin Valley may be reduced up to 15 to 20 percent each year as a result of prevailing ozone levels in the valley. The amount of crop loss was influenced by ozone concentrations, soil moisture, and by climatic conditions that may suppress or enhance the ozone effects.

Patrick J. Temple is Assistant Research Plant Physiologist, O. Clifton Taylor is Horticulturist and Professor of Plant Science, and Larry A. Benoit, Chris A. Reagan, and Robert W. Lennox are Staff Research Associates, Statewide Air Pollution Research Center, University of California, Riverside.
This research was supported by the U.S. Environmental Protection Agency, the California Producers Cotton Seed Distributors, and the Kern County members of Western Oil and Gas Association. Staff at the USDA Cotton Research Station and the UC Cooperative Extension, Kern County, office provided valuable advice and assistance.