TABLE 2. Performance of cows fed sodium bicarbonate during the week of fecal collections

	Diet (% sodium bicarbonate)							
	Experiment 1				Experiment 2			
Item	0	0.25	0.5	0.75	0	0.4	0.8	1.2
Dry matter intake								
lb/day	31.3	31.8	29.8	32.4	43.2	42.6	41.0	42.3
% body weight	3.7	3.7	3.5	3.8	3.4	3.4	3.3	3.4
Production								
Milk (lb/day)	44.3	43.9	44.5	45.2	70.8	67.9	69.0	68.4
Fat (%)	4.8	4.5	4.7	5.1	3.3	3.4	3.3	3.4
Protein (%)	3.8	3.8	3.7	3.7	3.1	3.2	3.1	3.1
Total solids (%)	14.5	14.1	14.2	14.6	12.2	12.1	12.1	12.3

TABLE 3. Apparent digestibility of complete mixed diets.

	Diet (% sodium bicarbonate)									
	Experiment 1					Experiment 2				
Item	0	0.25	0.5	0.75	SE*	0	0.4	0.8	1.2	SE*
					%					
Dry matter	71.9	72.0	71.5	71.5	±1.1	61.7	60.3	61.4	62.3	±2.1
Nitrogen	72.4	72.6	70.8	72.0	± .8	60.9	58.3	60.4	60.5	±2.0
Energy	71.1	71.5	70.5	70.4	±1.5	60.2	58.5	59.3	60.3	±2.3
Acid detergent fiber	47.0	48.7	46.6	46.9	±1.3	31.3	29.3	32.5	37.5	±3.9
Neutral detergent fiber	48.3	48.1	48.1	48.1	±2.4	37.5	36.4	37.0	44.4	±3.3
Cellulose	58.7	59.7	59.2	58.9	±1.6	45.0	45.7	47.5	51.4	±3.1

*SE is the standard error of the mean and indicates the amount of variation.

TABLE 4. Rumen fluid volatile fatty acids of Jersey cows two hours after feeding (experiment 1) and Holstein cows three hours after feeding (experiment 2)

	Diet (% sodium bicarbonate)							
	Experiment 1				Experiment 2			
Item	0	0.25	0.5	0.75	0	0.4	0.8	1.2
Volatile fatty acid (molar %)								
Acetic	63.5	63.1	64.6	64.2	64.4	64.4	66.3	64.8
Propionic	22.4	21.5	21.2	21.1	20.6	20.3	19.0	20.2
Butyric	12.0	13.1	12.0	12.6	12.6	12.7	12.3	12.5
Acetic:propionic ratio	2.8	2.9	3.0	3.0	3.1	3.2	3.5	3.2

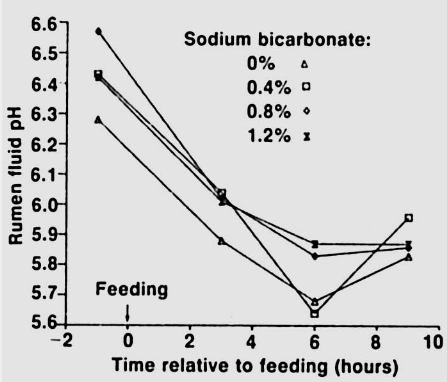

Fig. 1. The highest two levels of sodium bicarbonate provides a more stable rumen pH.

feeding followed by smaller changes until nine hours. Sodium bicarbonate at the highest two levels provided a more stable rumen environment in terms of pH. Although differences in cellulose digestibility were not significantly different (table 3), there were small improvements in cellulose digestibility observed for the 0.8 and 1.2 percent diets that may be associated with rumen pH. Rumen pH before feeding was also slightly higher for all diets containing sodium bicarbonate when compared with the control diet (no sodium bicarbonate).

In summary, adding sodium bicarbonate to complete mixed diets high in concentrate and containing chopped alfalfa hay did not affect digestibility of dietary components even though it elevated rumen pH. Milk fat also was not affected. Improved production responses have been reported with the inclusion of 0.8 percent sodium bicarbonate in the total diet dry matter or 1.5 percent in the concentrate dry matter of diets based on corn silage as the forage component. This would be approximately 0.4 to 0.5 pound sodium bicarbonate per cow per day in early lactation and 0.2 to 0.3 pound per cow per day in mid lactation. Our research indicated that when dairy rations contain alfalfa hay, there may not be as much need for supplemental sodium bicarbonate as is sometimes the case when corn silage is the only forage in the diet.

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They're more resistant than cotton to ozone and sulfur dioxide

Air pollution causes moderate

Patrick J. Temple □ Kris A. Surano

More than 90 percent of the processing tomatoes grown in the United States are raised in California's Central Valley. Much of this acreage is in San Joaquin County, directly east, downwind, of the large urban-industrial complex around San Francisco Bay. Automobile exhaust and industrial emissions mix in the atmosphere and convert to smog (ozone) through photochemical processes. Prevailing westerly winds carry the pollution into the Central Valley. Increased industrialization and urban growth in the area add to the air pollution burden already present as a result of agricultural burning. Proposed fossil-fuel-burning power plants in the Sacramento Delta could further contribute to air pollution levels in this agriculturally rich area.

Some tomato cultivars are known to be highly susceptible to air pollution injury, although little is known of the effects of air pollution on tomato productivity. A major field study was begun in 1981 to determine the effects of ozone (O_3) and sulfur dioxide (SO_2), the major phytotoxic components of air pollution, on growth and yield of tomatoes. This experiment was conducted as part of the National Crop Loss Assessment Network (NCLAN) program. The objectives of NCLAN are to (1) develop dose-response equations that relate yields of major agricultural crops to exposure to ozone, sulfur dioxide, and their mixtures; and (2) use this information to assess the economic effects of air pollution on U.S. agriculture.

'Murrieta', the tomato cultivar used in these experiments, was released in 1974. Initial selection was conducted in the San Joaquin Valley, and final development

The impact of air pollution on an experimental plot in a commercial tomato field was compared with a plot enclosed in an adjacent open-top plastic chamber to which controlled amounts of pollutant gases were added.

damage to tomatoes

□ Randall G. Mutters □ Gail E. Bingham □ Joseph H. Shinn

took place at the Niagara Seed Farm in Davis. Approximately 30 percent of the tomato acreage in the San Joaquin Valley is now planted to 'Murrieta'. Any loss in yield induced by air pollution could thus have serious economic consequences for growers in the area.

Methods

The experimental site was on the southeastern edge of a 160-hectare (385-acre) commercial tomato farm near Tracy. 'Murrieta' was seeded on June 1, 1981, onto prepared single-row, false-furrow beds, and on May 17, 1982, onto prepared double-row, false-furrow beds. Seeding, cultivation, fertilization, irrigation, and pesticide applications were performed by the grower, and conformed to standard commercial practices.

Thirty-two open-top chambers, 3 meters in diameter by 2.4 meters high, were centered on randomly selected row segments on June 30, 1981, and July 14, 1982. Companion plots consisting of a 3-meter segment of row were established near each chamber to assess plot-to-plot variability across the field. Twenty-four companion plots were used in 1981 and 48 in 1982.

Plants inside the chambers were exposed to five levels of ozone and six levels of sulfur dioxide in a 5x6 factorial experiment. The control treatment (no pollutants) was replicated three times.

In 1981, ozone treatments consisted of charcoal-filtered air, nonfiltered air, and nonfiltered air plus 0.03, 0.06, and 0.07 parts per million (ppm) ozone. In 1982, ozone was added in proportion to its concentration in atmospheric air; treatments were charcoal-filtered, nonfiltered, and nonfiltered times 1.3, 1.5, and 1.6. In both years, sulfur dioxide was added to chambers at concentrations of about 0, 0.03, 0.06, 0.09, 0.12, and 0.23 ppm.

Both gases were added seven hours per day (0900 to 1600), seven days per week. In 1981, exposure to pollutant gases began on July 15, about two weeks after flower initiation, and continued until September 14. In 1982, exposures began on July 21, one week after flower initiation, and ended on October 11. Pollutant gases inside chambers were sampled three times each hour; from these figures, hourly, daily, weekly, and seasonal mean concentrations were computed. Atmospheric ozone and sulfur dioxide were monitored continuously.

TABLE 1. Effect of ozone on yield of 'Murrieta' tomato grown in opentop chambers at Tracy, California in 1981 and 1982

Ozone*	Yield†	Percent loss‡
1981		
0.012	61.4	—
0.030	61.9	—
0.062	59.4	3.3
0.085	53.1	13.5
0.102	46.6	24.1
1982		
0.012	59.5	—
0.031	56.9	4.4
0.041	51.8	12.9
0.047	50.1	15.8
0.051	47.3	20.5

* Seasonal 7-hour (0900-1600) means, ppm.
† Total fruit fresh weight, kg $ha^{-1} \times 10^{-3}$; averaged across SO_2 treatments.
‡ Relative to yield in charcoal-filtered chambers (O_3 = 0.012 ppm).

Chamber and companion plots were harvested September 15-18, 1981, and October 12-24, 1982. Fruit from each plot was sorted, counted, and weighed in the field. Harvest data were analyzed statistically, by analysis of variance and multiple regression analysis.

Yield responses

Total fruit fresh weight of 'Murrieta' was reduced by exposure to ozone at or above naturally occurring concentrations. The relationship between tomato yield and pollutant concentration was highly significant in both years (1981, r = 0.82; 1982, r = 0.68). Ozone was more injurious to tomato than sulfur dioxide. Yields in chambers averaged about 18 percent lower than in adjacent companion plots.

continued

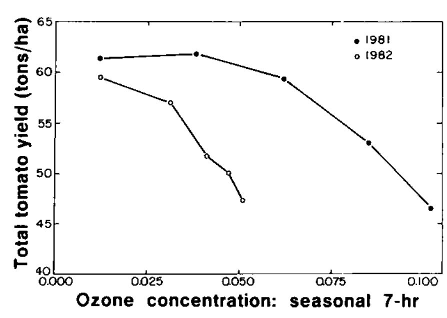

Fig. 1. In cooler, more humid weather of 1982, comparable doses of ozone caused almost twice the tomato yield reduction as in 1981.

In 1982, atmospheric concentrations of ozone reduced tomato yield 4.4 percent relative to yields in charcoal-filtered chambers (table 1). A seasonal seven-hour mean concentration of 0.051 ppm reduced tomato yield over 20 percent relative to charcoal-filtered chambers. In 1981, atmospheric levels of ozone had no apparent effect on tomato yield, but yields were reduced at concentrations above 0.062 ppm. The same seasonal mean concentration of ozone had approximately twice the effect in reducing yield in 1982 as in 1981 (fig. 1). These results were similar to those reported earlier for cotton (*California Agriculture,* September-October 1983).

The 1981 growing season was typical of the Central Valley: high temperatures, low humidity, and little cloud cover. In contrast, the summer of 1982 was cooler, cloudier, and more humid than normal. In 1982, cooling degree-days were 36 percent lower and precipitation 7.5 cm greater than in 1981. Under these conditions, tomatoes were more susceptible to ozone injury and yield reductions were greater in 1982 than in 1981.

In contrast to ozone, sulfur dioxide had no effect on tomato yield, except at concentrations far higher than would be expected in the Central Valley. In addition, sulfur dioxide did not interact with ozone to produce greater yield losses than would be expected of the two pollutants acting alone.

Conclusions

The difference in response of tomatoes to air pollution in 1981 and 1982 was attributed primarily to cooler, more humid growing conditions in 1982, which made plants more susceptible to ozone injury. Tomatoes were very resistant to sulfur dioxide, and there were no interactions between the two pollutants.

These results indicate that tomatoes are more resistant than cotton to yield losses caused by air pollution. However, levels of ozone prevalent in the Central Valley can reduce yield of 'Murrieta' tomato under certain environmental conditions.

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The economic effects of air pollution on annual crops

Richard E. Howitt □ Thomas W. Gossard □ Richard M. Adams

For both consumers and producers, the effects of ozone on agriculture are substantial

The adverse effects of air pollution on California agriculture have been a source of concern for at least three decades. The reasons for concern are California's specialized and highly valued crop production, the documented sensitivity of some crops to air pollution, and the high levels of air pollutants in such major production regions of the state as the South Coast and San Joaquin Valley. This combination of potentially sensitive crops and relatively high concentrations of harmful pollutants suggests that air pollution may be reducing crop yields, with economic effects on both producers and consumers.

Early attempts to assess these effects, either in physical terms, such as reduced crop yields, or in economic terms, such as reduced revenues, were hindered by a lack of biological information linking yields to changes in pollution levels (dose-response data). More information has become available in recent years, as a result of state- and federally-funded research on crop dose-responses to air pollution. Further, the ability to translate these physical changes in yields into economic consequences has improved through the development of detailed economic models of the California agricultural sector. These models can account for a wide range of agronomic and economic conditions critical to the accurate assessment of the effects of environmental change.

This study uses both newly acquired dose-response data and a large-scale economic mathematical programming model to assess the economic effect of ozone on the production of several important annual crops. Ozone is the most pervasive and harmful plant air pollutant found in California. The dose-response information is used to predict changes in yields expected from changes in ozone levels in agricultural regions. These yield changes in turn are used in the economic model to account for price effects, substitution of cropping activities, and differential impacts on producers and consumers. The model, known as the California Agricultural Resources Model (CARM) measures the economic effects of ozone-induced crop yield changes for major annual crops within 14 production regions of the state. The results suggest that even modest changes in ozone levels have substantial economic consequences.

CARM finds the cropping activity that maximizes the sum of consumers' and producers' surplus for 44 annual and perennial crops in all 14 production regions. These surpluses, used by economists to estimate the benefits of alternative policies, are related to the intersection of the supply and demand curves at the equilibrium price. Conceptually, they measure the benefits of a competitive market free of government interference, monopoly power, and outside influences.

With CARM, the impacts of current and alternative ozone levels on crop production are determined through the yield adjustments predicted by the dose-response data. Specifically, for the base run, the model includes yields for various crops in each of the 14 regions realized under actual atmospheric (base) ozone conditions for 1978. The yield effect, measured as changes from these actual yields resulting from differing ozone levels, is then entered into CARM to determine associated changes in cropping activities (acreage), total production, market prices, and economic surplus. Ozone levels in parts per million (ppm) of 0.04 (an improvement in air quality from the actual), 0.05 (a slight degradation in air quality), and 0.08 (a significant degradation) were specified. The levels were based on a seasonal seven-hour average between 9 a.m. and 4 p.m.

The dose-response data are derived primarily from the U.S. Environmental Protection Agency's (EPA) National Crop Loss Assessment Network (NCLAN) program. The NCLAN data are used to estimate crop yields for field corn, cotton (see *California Agriculture,* September-October 1983), grain sorghum, irrigated wheat, dry beans, lettuce, and processing tomatoes (see accompanying article) under alternative ozone levels. Yield response data for an eighth crop — alfalfa hay — were taken from another source.

To more fully account for the effect of ozone on annual crops and make the