EFFECTS OF OZONE OR SO_2 ON GROWTH AND YIELD OF RICE

Executive Summary

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EXECUTIVE SUMMARY

California's annual production of rice is 1.5 million tons valued at $255 million. The principal rice growing area, the Sacramento Valley, has some air pollution. Photochemical oxidants exceed 0.1 parts per million (ppm) as ozone 5-10 days per year. Sulfur dioxide levels are lower. Meager information is available as to the effects of ozone and/or SO_2 on this crop.

Most of the work has been done in Japan. In 1976 Nakamura et al. (1) and Matsuoka (2) demonstrated that injury to rice, similar to "akgare disease," was caused by photochemical oxidants. Nakamura and Ota (3) and Nakamura et al. (4) observed chlorotic flecks after episodes of high oxidant on rice leaves. One recent study by Agrawal et al. (5) showed that continuous fumigation of rice with 0.08 ppm ozone or 0.50 ppm SO_2 reduced chlorophyll and carotenoids. A combination of one-half of each of these concentrations caused pigment reductions of the same magnitude as would have occurred if the separate reductions with the original concentrations had occurred thus indicating a synergistic effect of the two pollutants.

The present study was done to compare the effects of SO_2 or ozone on three varieties of rice grown commercially in California, to find out their sensitivity to these pollutants and to provide information as to what the burning of fossil fuels containing sulfur such as coal in rice growing areas would do to the performance and yield of this crop.

Three cultivars of rice produced commercially in California, M7, M9 and S201, were grown in pots, six plants per pot, from 13 May to 27 September 1982 at the University of California, Riverside. The pots were flooded continuously with tap water and supplied with all known mineral elements. No pest problems occurred. The plants were housed in open-top plastic greenhouses and provided with activated carbon filtered air to which ozone or SO_2 was added from 10 June to 24 September 1982. Twenty greenhouses were divided randomly into 10 groups of two each. Twelve pots of each cultivar (36 pots/greenhouse) were fumigated as follows:

Greenhouse No.	Ozone (ppm)
1,9	0.05 - 5 hr/day, 5 day/wk
2,15	0.10 " "
11,13	0.15 " "
10,14	0.20 " "
16,19	0.25 - 5 hr/day, one day/wk
	SO_2 (ppm)
3,20	0.05 - Continuous, 5 days/wk*
4,6	0.10 " "
8,18	0.15 " "
12,17	0.20 " "
5,7	Control (Carbon Filtered Air)

These levels of SO_2 were applied for a total period of 1405 hrs. Ozone was applied at the four lower levels for 346 hrs and at 0.25 ppm for 80 hrs.

On 6 July (First Harvest) one plant from each pot was harvested. Height of plant, total dry weight, leaf area, number of tillers and percent leaf area injured were determined. On 19 July the outer circle of pots in the circular greenhouses (pots 1-6) were relocated in the center and the center pots moved to the periphery. A second harvest was made of one plant 23 August and a final harvest of 4 plants 27 September 1982. The same parameters were measured in the second harvest except leaf area and percent injury were omitted and number of panicles recorded. The final harvest measured dry weight of seed, 100 seed wt, straw weight, percent sterile seeds in addition to measurements made on the second harvest.

Results From All Plants. The results of the first harvest, with treatments of each cultivar evaluated separately, showed that 27 days of ozone fumigation reduced significantly the height and dry weight of all cultivars at one or more of the concentrations used. Leaf area of S201

*Monday 9:00 - Friday 17:00 o'clock, weekly.

and number of tillers of M7 also were reduced. Sulfur dioxide increased height, dry weight and total leaf area of M9 at intermediate concentrations and leaf area of M7. Numbers of tillers were reduced with M7, degree of leaf injury was unaffected. All statistical evaluations of data in the tables were done by Duncan's Multiple Range Test with a level of 0.05 considered significant.

At the second harvest, after 72 days fumigation, ozone had no overall effect on plant growth. Ozone at 0.20 ppm reduced the number of tillers on M9, but increased the tillers on M7 and S201. Sulfur dioxide had no statistical effect at all levels.

The results from the final harvest after 107 days fumigation were analyzed statistically by combining all values from four plants per pot, from pots 1-12, for an analysis of variance. These results showed that ozone at 0.20 ppm reduced significantly total seed weight, 100 seed weight, straw weight and height of plant plus increasing seed sterility and number of panicles per plant on cultivar M9. Other ozone levels caused similar effects in some cases for this cultivar. For S201, 0.20 ppm ozone caused the same effects as for M9, except the percent of sterile seeds and straw weight were the same as the control, statistically. For M7 0.20 ppm ozone level of ozone also reduced height of plant and increased number of panicles. The results with 0.25 ppm ozone were included for comparative purposes only because the period of exposure was one day/week, one-fifth that of the other levels.

At the final harvest sulfur dioxide also reduced growth and yield of rice, but the effects were not as great as with ozone. With 0.20 ppm sulfur dioxide M9 showed significant reductions in total seed weight, weight of 100 seeds and plant height plus increased seed sterility. Lower sulfur dioxide levels showed the same effects in some cases. For S201, 100 seed weight and plant height were reduced at 0.20 ppm sulfur dioxide. The cultivar M7 showed no effects at 0.20 ppm sulfur dioxide but increased seed sterility at 0.10 ppm sulfur dioxide and increased height but decreased number of panicles at 0.15 ppm SO_2.

Total yield of seed was greater with S201, less with M7 and least with M9 at all pollutant levels. This observation was inherent in the cultivars with our cultural conditions.

Results From Center Plants. Because the pots were switched in position after 30 days fumigation and because the greater height of plants in pots 7-12 persisted throughout the study, comparisons were made of the variability of the above-mentioned measurements between pots 1-6 and 7-12. These evaluations showed that the data from pots 1-6 were less variable within treatments and showed greater statistical differences between treatments than pots 7-12. Use of the results from 1-6 gave somewhat greater statistical significance of treatment vs response even though the replication was reduced by one-half. Total seed weight, height and straw weight were significantly less with 0.20 ppm ozone with all cultivars with these replicates whereas only M9 and S201 showed these differences when all replicates were considered.

Because of reduced variability of the pots 1-6, the 7-12 numbered replicates were considered as a "guard row" and the most valid results are considered to be those from pots 1-6. These were evaluated statistically by the prediction equation y = a (conc) + b which is calculated by the linear regression of the dependent variable "y" on the independent variable "concentration." The equation describes the least-squares best fit of a straight line with y as the dependent variable, concentration as the independent variable, a as the slope and b as the intercept.

Ozone at the 0.20 ppm level reduced total seed weight in all three cultivars by 12, 29, and 21% in cultivars M7, M9 and S201, respectively. One hundred seed weight was also reduced in M9 and S201. Percent sterility of seed in panicles was increased by ozone in cultivars M9 and S201 by 9% and 6% respectively. Weight of rice straw was reduced in cultivars M9 and S201.

Sulfur dioxide at 0.20 ppm reduced total seed weight in the two cultivars M9 and S201 by 22 and 14%, respectively. Weight of one hundred seeds likewise was reduced in these cultivars.

Ozone reduced numbers of spikelets per panicle in all three cultivars. Sulfur dioxide failed to cause a significant effect on this parameter. Ozone also reduced the height of plants in all cultivars, but increased the number of panicles per plant. Sulfur dioxide reduced the height of cultivar S201, and increased the number of panicles. The other cultivars were unaffected by sulfur dioxide.

These results show that ozone is much more toxic per unit of pollutant than SO_2. Roughly equal effects were produced by one-fourth the total exposure to ozone. A pronounced positional effect within the chambers occurred. Plants in the center yielded better than those on the periphery. Reduced pollination is suspected because of the constant flow of incoming air. Further work should explore the interactions of these two pollutants on rice so that environmental planners can predict what the effects of increased SO_2 levels with existing amounts of ozone would be on rice production in California.

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