EFFECTS OF OZONE OR SO_2 ON GROWTH AND YIELD OF RICE

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ABSTRACT

Three cultivars of rice produced commercially in California, M7, M9 and S201, were grown in pots, six plants per pot and were flooded continuously with tap water and supplied with all known mineral elements. The plants were provided with activated carbon filtered air to which ozone or SO_2 was added as a fumigant. Twenty greenhouses were divided randomly into 10 groups of two each. Twelve pots of each cultivar (36 pots/greenhouse) were fumigated as follows: ozone 0.05, 0.10, 0.15 and 0.20 ppm for 25 hrs/wk plus one treatment of 0.25 ppm for 5 hrs/wk; SO_2 0.05, 0.10, 0.15 and 0.20 ppm for 104 hrs/wk. Two greenhouses received carbon filtered air (controls).

Three successive harvests were made of one plant, one plant and four plants per pot. Parameters determined were height of plant, total dry weight, number of tillers, number of panicles, total seed weight, weight of 100 seeds, percent of sterile seeds, straw weight, number of spikelets per panicle and total biomass.

Results of the first harvest showed that ozone reduced dry weight of all cultivars but SO_2 increased this parameter with M9. The second harvest showed no effect of SO_2 but 0.20 ppm ozone reduced numbers of tillers in M9 but increased the numbers in S201.

The final harvest showed that ozone reduced seed weight, height of plant and spikelets per panicle but increased number of panicles in all cultivars and reduced straw weight in M9 and S201. It increased percent of sterile seed in these two cultivars. Seed weights were reduced 13, 30 and 24% in M7, M9 and S201, respectively, by 0.20 ppm ozone.

Sulfur dioxide at this level reduced seed weight 28 and 17% with M9 and S201, respectively, and the height was reduced in S201. SO_2 increased the number of panicles significantly in M9.

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. Cultivar M7 is less susceptible to either ozone

or SO_2 than M9 or S201. A pronounced positional effect within the chamber 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 the effects of increased SO_2 levels with existing amounts of ozone on rice production in California.

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SUMMARY AND CONCLUSIONS

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, M7, M9 and S201, were grown in pots, from 13 May to 27 September 1982 at the University of California, Riverside. Twenty greenhouses were divided randomly into 10 groups of two each. Twelve pots of each cultivar (36 pots/greenhouse) were fumigated as follows:

Ozone (ppm)	SO_2 (ppm)
0.05 - 5 hr/day, 5 day/wk	0.05 - Continuous, 5 days/wk*
0.10 " "	0.10 " "
0.15 " "	0.15 " "
0.20 " "	0.20 " "
0.25 - 5 hr/day, one day/wk	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,

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

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 (Table 1). Leaf area of S201 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 (Table 2). 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 (Table 3). 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 (Table 4).

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 (Table 5), 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 are shown in Tables 1, 3, 5, and 7 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 (Table 6). 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 (Table 7). 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. Figures 1-3 summarize the yield data from plants 1-6 of each cultivar.

Ozone at the 0.20 ppm level reduced total seed weight in all three cultivars (see Figures 1, 2 and 3) 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 this.

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.

RECOMMENDATIONS

A study similar to this work should be done using the same cultural and fumigation procedures but one which utilized combinations of dosages of ozone and SO_2. At present we have no information as to whether these pollutants interact to cause either enhanced effects, synergism, or the opposite, antagonism. The California Air Resources Board greenhouse facility located at UCR would serve admirably for this work. This information would be most vital for establishing emission levels and air quality standards for protection of this valuable crop.

BODY OF REPORT

Introduction

Rice is the major source of calories for 40% of the world's population (1). California's annual production from 525,000 acres yields 1.5 million tons valued at $255 million. U. S. production on 3,000,000 acres is 7.8 million tons. California's principal rice growing area, the Sacramento Valley, has moderately low levels of photochemical air pollution and low levels of SO_2. Oxidant level maximums exceed 0.10 ppm ozone 5-10 days/year depending upon the location. SO_2 levels are lower and are recorded at a limited number of stations. Meager information is available concerning the effects of air pollutants, ozone and/or SO_2 on the growth and yield of this major crop. Rice is produced principally in rural areas where these pollutants are well dispersed. If industrial sources emit significant amounts, the exposed population and agriculture have not had the technical ability to determine possible effects.

In 1976 Nakamura et al. (2) and Matsuoka (3) demonstrated that injury to rice, similar to "Akgare disease," was caused by photochemical oxidants. Nakamura and Ota (4) and Nakamura et al. (5) observed chlorotic flecks after episodes of high oxidant on rice leaves. Comparison between rice grown in greenhouses which received ambient or carbon filtered air showed small but nonsignificant reductions in numbers of panicles, spikelets, and percent of ripened grains. Photosynthesis and chlorophyll content of rice in ambient air was 2/3 and 1/2 of that in carbon filtered air. Daily maximum oxidant level varied from 11 to 27 parts per hundred million (pphm) many days from May to September. Nakamura et al. (6) studied physiological changes in rice fumigated with both short-term, acute treatments of 0.12-0.20 ppm ozone for 2-3 hrs and long-term exposures of 0.05-0.09 ppm from the 3-leaf stage until harvest. Short-term exposures affected enzymatic activity in young leaves but tissues recovered in 48 hours. Long-term exposures caused reduced growth and photosynthesis even at the 0.05 ppm level.

One recent study by Agrawal et al. (7) 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 not 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.

Experimental

Three cultivars of rice seed grown commercially in Central California, S210, M7 and M9, were obtained from J. N. Rutger, University of California, Davis, CA and D. Seaman, U. S. Department of Agriculture Rice Research Station, Biggs, CA. The seed was germinated beginning May 13, 1982 in flats of vermiculite and watered from the bottom with North Carolina State University nutrient solution (8) in growth chambers. After 11-14 days six seedlings each were transplanted to a clay loam soil in 25 cm dia x 25 cm ht pots. The pots were housed in greenhouses with carbon filtered air. The soil as obtained had a pH of 8.2-8.9. This was fertilized and the pH was reduced to 7.3 by addition of KCl, urea, H_3PO_4 and $ZnSO_4$. The plants were grown in soil flooded by tap water which had a pH of 7.9. Ferric sulfate was added twice to each pot, 2.0 g pot (total 4.0) to maintain the pH below or near neutrality. The additions were made 29 July 1982 and 4 weeks later. These additions maintained the pH levels from 6.75-7.00 during the remainder of the experiment.

All transplants grew well. Some minor chlorosis developed during early June on some plants of all cultivars with most of M7. Additions of extra nitrogen as urea, reduction of soil pH with HNO_3, addition of manganese or iron chelate as foliar sprays or to the soil on separate test pots failed to overcome the chlorosis quickly but, in retrospect, the weather during June was cool with overcast mornings and the low temperatures may have caused the problem because as soon as warm weather began in July, all plants developed a healthy green color.

Fumigations were begun June 10, 1982. Twenty greenhouses with activated carbon air filters were divided randomly into 10 groups of 2 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)

After one fumigation period of 5 hrs with 0.25 and 0.20 ppm ozone, considerable foliar injury occurred and the highest level was discontinued on a 5 day/wk schedule. This group was fumigated for the remainder of the growth period with 0.25 ppm ozone 5 hrs/day, one day/wk (Greenhouses 16, 19).

The fumigations were continued until September 24, 1982 with minor variations caused by equipment failure for short periods. The SO_2 levels were applied for a total of 1405 hrs; the ozone at the 4 lower levels 346 hrs and 0.25 ppm ozone for 80 hrs.

On July 6 one plant per pot was harvested (Harvest #1). Height of this plant, total dry weight, leaf area as measured with a photoelectric densitometer, number of tillers and percent injury were determined. Percent injury is an arbitrary rating of 1-10 (1 is slight chlorosis and 10 total leaf necrosis). These values are the means from 24 replicates.

Because the replicate plants (pots 7-12) grown in the center of each greenhouse during the first part of the study as shown in Figure A, were obviously taller than those in the outside circle (pots 1-6), the location

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

of plants was switched July 19 (after 39 days fumigation) to that shown in Figure B. This involved a change from outside to inside and north to south and vice versa. The plants were approaching flower formation but the panicles hadn't emerged.

On August 23 a second harvest of one plant per pot was made. The same measurements were done except the leaf area was omitted but the number of panicles per plant was recorded. On September 27 the final harvest of the remaining four plants was done, the height of each measured and the mean determined, the panicles were removed and both portions of the plant dried. Weight of straw was measured, the panicles per plant were counted and spikelets per panicle determined. The spikelets were threshed from the panicles without separating sterile seed coats and the percent sterile seeds determined. The total dry biomass was measured after which the rough rice was separated, dried to constant weight and total seed weight plus weight of 100 seeds determined.

Results

All three cultivars grew well. The foliar injury from ozone was most pronounced during the early fumigation period especially prior to Harvest 2. All cultivars responded similarly, but as higher temperatures and lower humidities occurred in the later summer less foliar effects were evident. Either older plants are less sensitive or the changes in temperature and humidity caused the effect. Cultivar M9 continued to put out green leaves after all cultivars had flowered and fruited.

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 (Table 1). Leaf area of S201 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 (Table 2). 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 (Table 3). 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 (Table 4).

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 (Table 5), 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 are shown in Tables 1, 3, 5 and 7 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 (Table 6). 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 (Table 7). 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. Figures 1-24 summarize the significant data from plants 1-6 of each cultivar. The numerical data for pots 1-6 as well as 7-12 are summarized in Appendix A, Tables A1-A10.

Ozone at the 0.20 ppm level reduced total seed weight in all three cultivars (see Figures 1, 2, and 3) by 12, 29, and 21% in cultivars, M7, M9 and S201, respectively. One hundred seed weight was also reduced in M9 and S201 (Figures 4 and 5). Percent sterility of seed in panicles was increased by ozone in cultivars M9 and S201 by 9% and 6% respectively (Figures 6 and 7). Weight of rice straw was reduced in cultivars M9 and S201 (Figures 8 and 9).

Sulfur dioxide at 0.20 ppm reduced total seed weight in the two cultivars M9 and S201 by 22 and 14%, respectively (Figures 10 and 11). Weight of one hundred seeds likewise was reduced in these cultivars (Figures 12 and 13).

Ozone reduced numbers of spikelets per panicle in all three cultivars (Figures 14, 15 and 16). Sulfur dioxide failed to cause a significant effect on this parameter. Ozone also reduced the height of plants in all cultivars (Figures 17, 18 and 19), but increased the number of panicles per plant (Figures 20, 21, and 22). Sulfur dioxide reduced the height of cultivar S201 (Figure 23), and increased the number of panicles (Figure 24). The other cultivars were unaffected.

Discussion

This study demonstrates that rice can be grown successfully in pots to flowering and fruiting if sufficient care is taken to maintain soil pH

and moisture during growth. No particular problems with insect on fungal pests were encountered.

Evaluation of the plant responses show that ozone is much more injurious per unit of pollutant than SO_2. The reductions in yield of rice were roughly similar with 0.20 ppm of the two pollutants but the plants were fumigated with SO_2 four times longer. An inverse relationship was shown between yield of seed and straw weight with the same cultivars when the outside pots were switched to inside (1-6 vs 7-12). This effect is difficult to explain but other investigators (9) have reported that guard rows of test plants upwind in the Sacramento Valley show reduced seed yield when the rice plants flower during a hot, dry period. It is proposed that this effect could have occurred in the greenhouses. Riverside has a hot, dry climate in summer and the outside rows of plants were much more exposed to the incoming air stream. With this condition either the pollen or pistil in the rice flowers could be dehydrated and thus prevent fertilization.

The present studies compare well with those of Nakamura et al. (5) who found nonsignificant reductions in seed yield, number of panicles and spikelets with similar amounts of ozone except our work shows statistical validity with all parameters and on the three cultivars tested. We didn't observe statistically valid effects on the parameters we measured with 0.08 ppm ozone as did Agrawal et al. (7) but would undoubtedly see effects of 0.50 ppm SO_2. We may have had reductions in chlorophyll and carotene at 0.08 ppm ozone if we had made these measurements.

With the present information in hand future studies could expand the present work to find out the degree of interactions of these pollutants and enable predictions of the effects of increased levels of the two pollutants on production of rice in California.

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Figure A. Location of Pots of Rice in Greenhouses 10 June - 19 July, 1982.

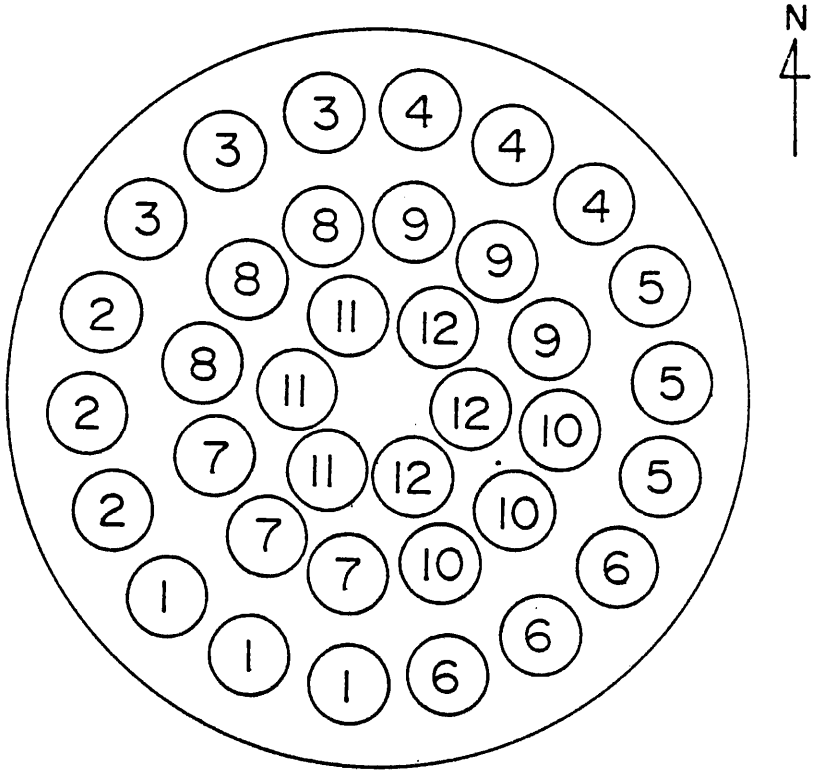
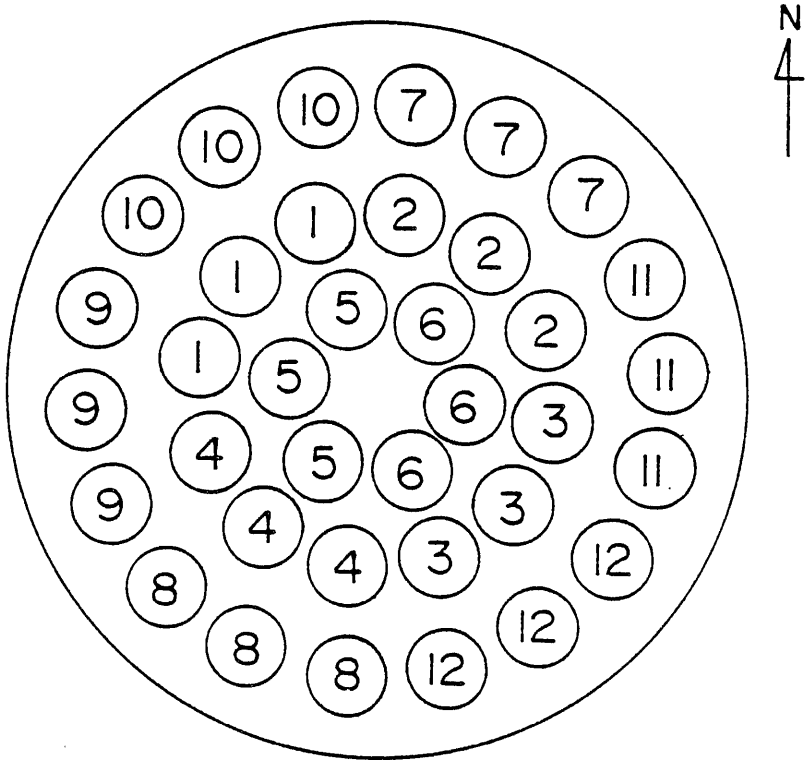


Figure B. Location of Pots of Rice in Greenhouses 19 July - 27 Sept. 1982. Pots relocated North to South and from outside to center



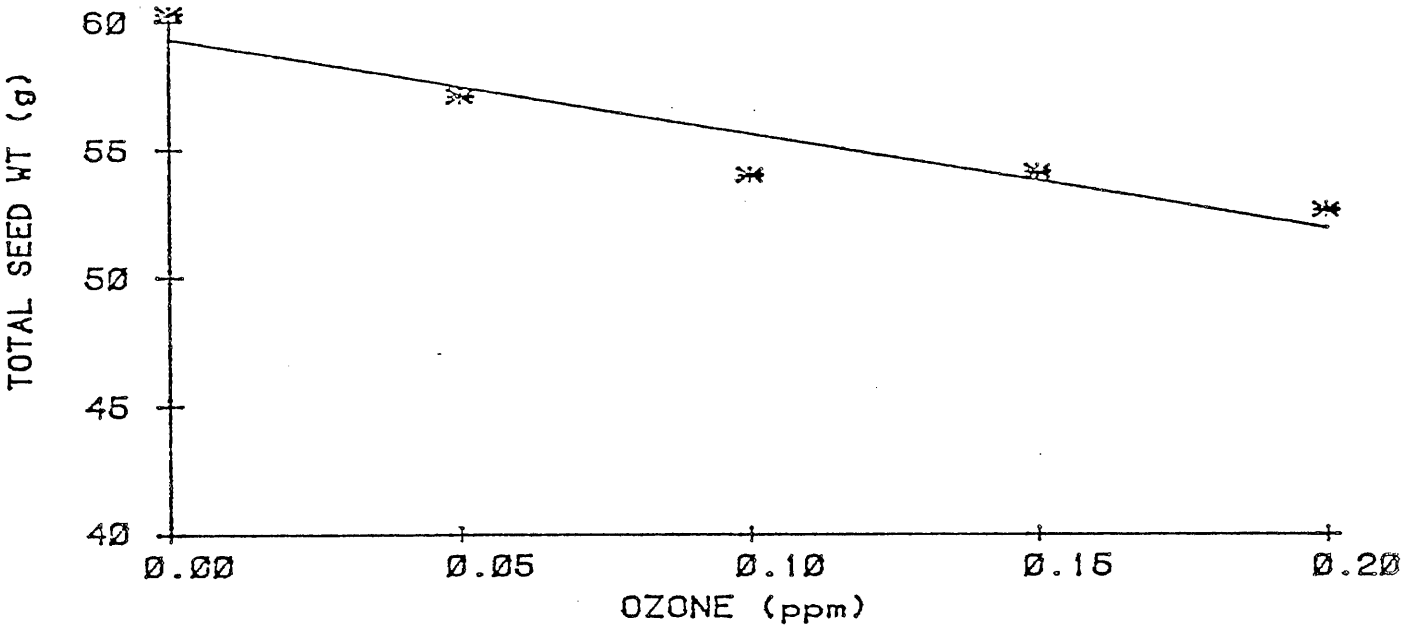


Figure 1. Total seed weight of rice cultivar M7 = -36.9 x + 59.3, r^2 = .086, Sy.x = 8.7, n = 60. Each (*) represents the mean of 12 plants.

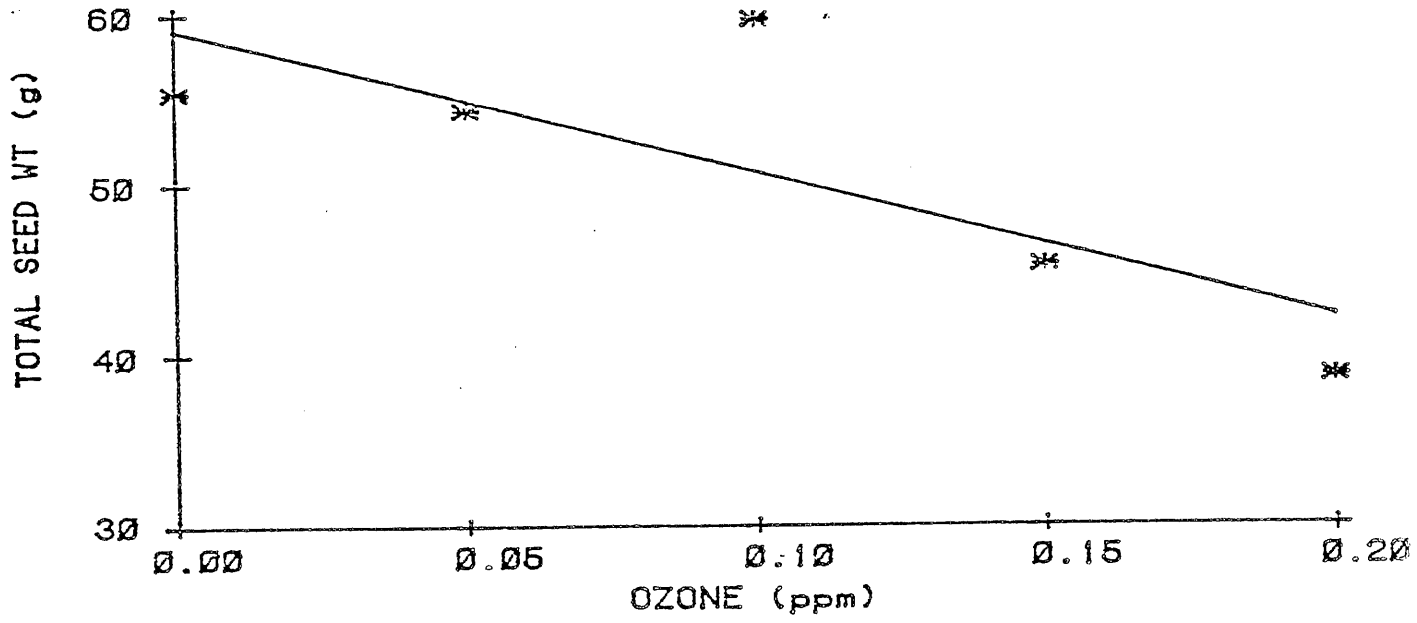


Figure 2. Total seed weight of rice cultivar M9 = -84.6 x + 59.1, r^2 = .213, Sy.x = 11.7, n = 60. Each (*) represents the mean of 12 plants.

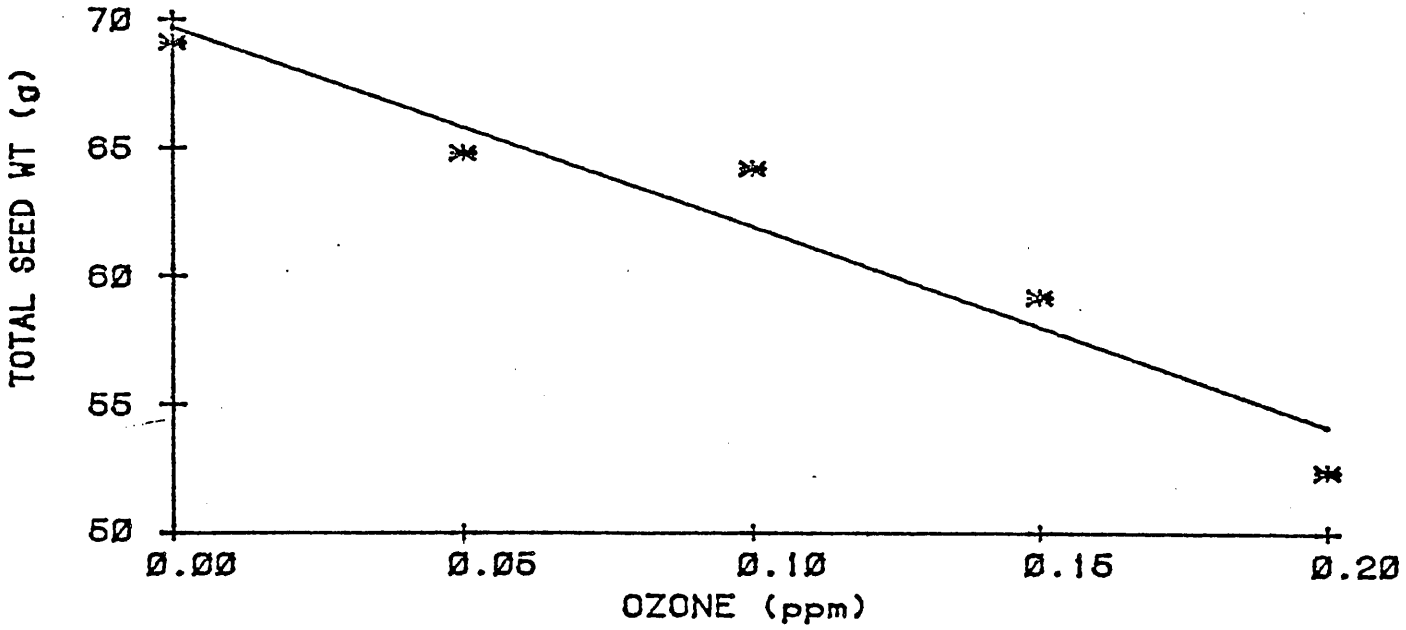


Figure 3. Total seed weight of rice cultivar S201 = -77.7 x + 69.7 r^2 = .331, Sy.x = 7.9, n = 60. Each (*) represents the mean of 12 plants.

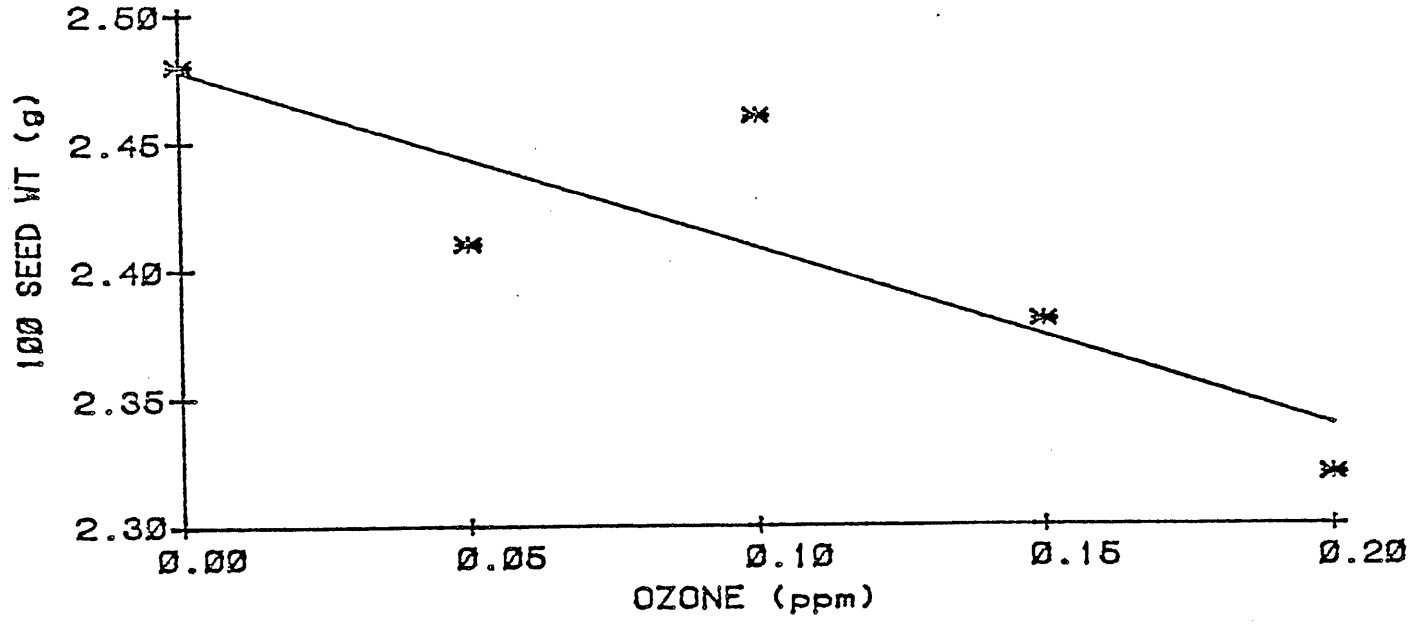


Figure 4. One hundred seed weight of rice cultivar M9 = -.693 x + 2.48, r^2 = .160, Sy.x = .114, n = 60. Each (*) represents the mean of 12 plants.

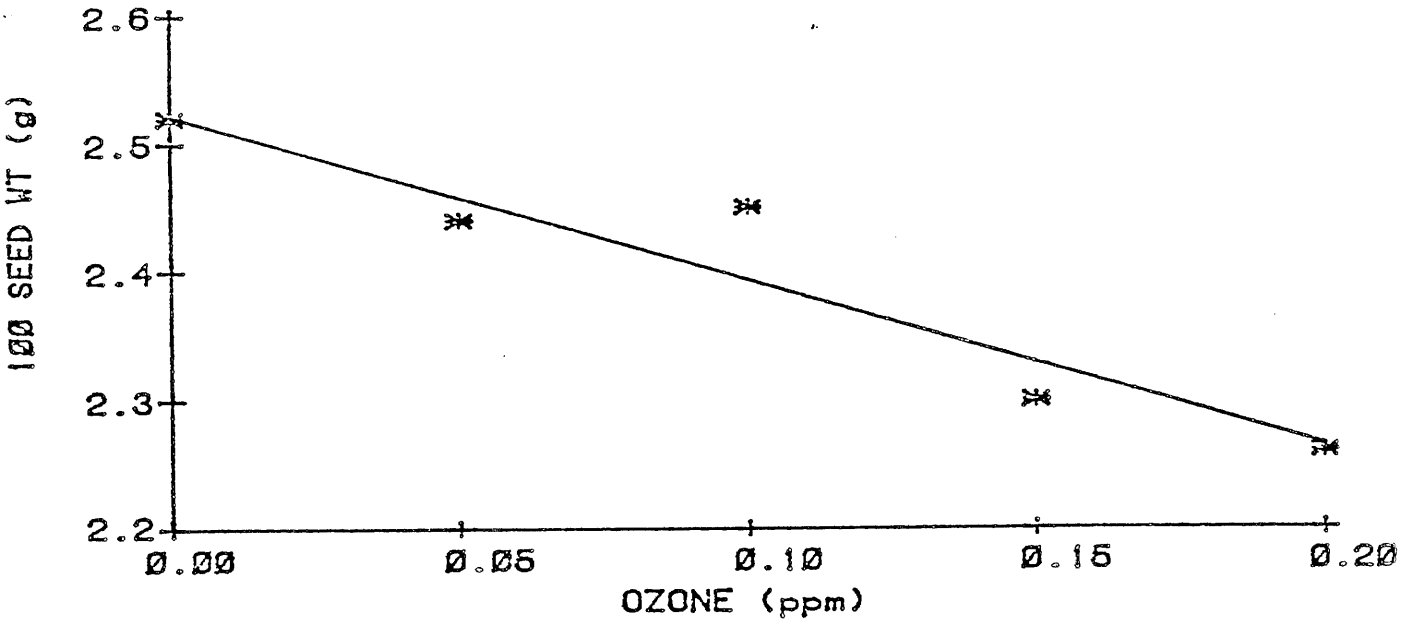


Figure 5. One hundred seed weight of rice cultivar S201 = -1.28 x + 2.52, r^2 = .380, Sy.x = .118, n = 60. Each (*) represents the mean of 12 plants.

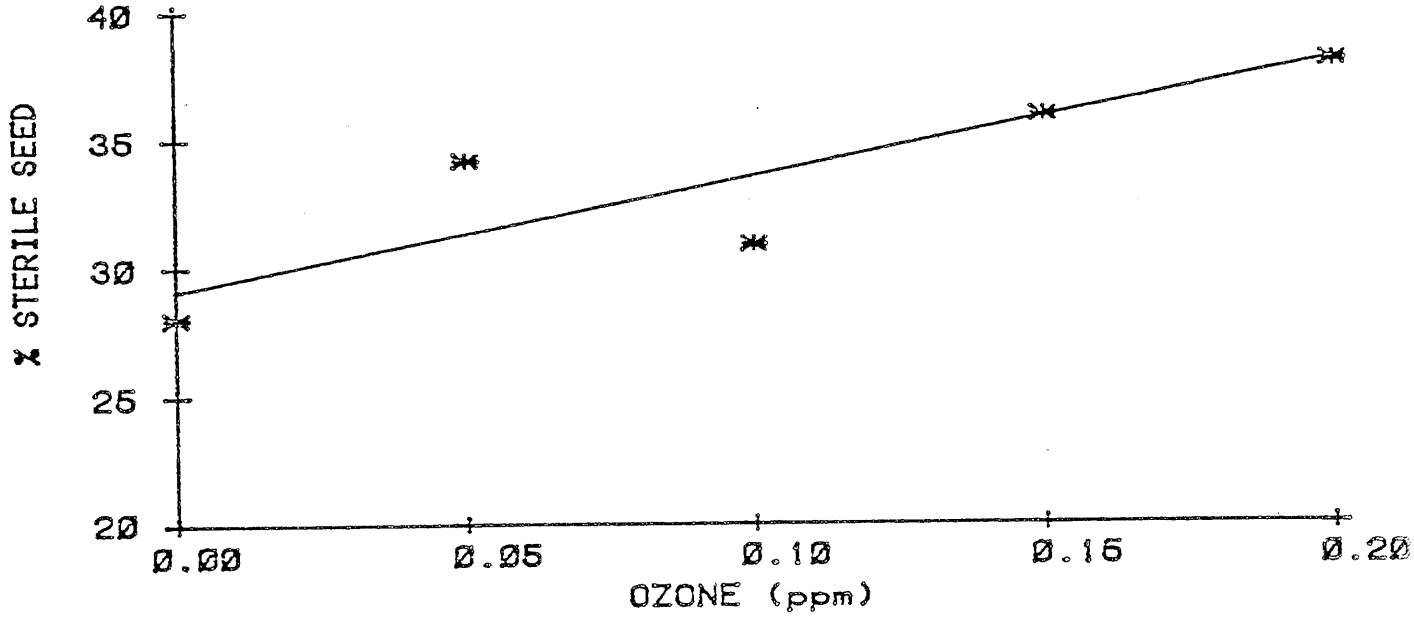


Figure 6. Percent sterility (arcsin) of rice cultivar M9 = 45.0 x + 29.1, r^2 = .108, Sy.x = 9.3, n = 60. Each (*) represents the mean of 12 plants.

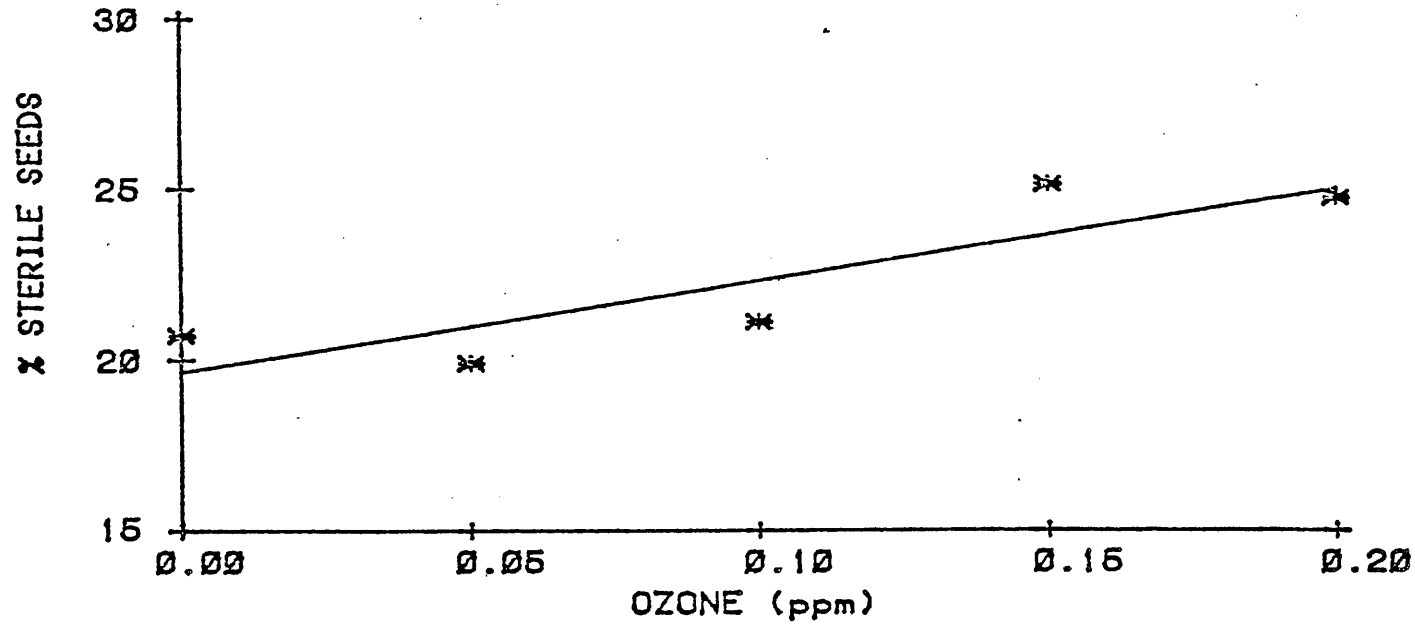


Figure 7. Percent sterility (arcsin) of rice cultivar S201 = 26.7 x + 19.6, r^2 = .113, Sy.x = 5.4, n = 60. Each (*) represents the mean of 12 plants.

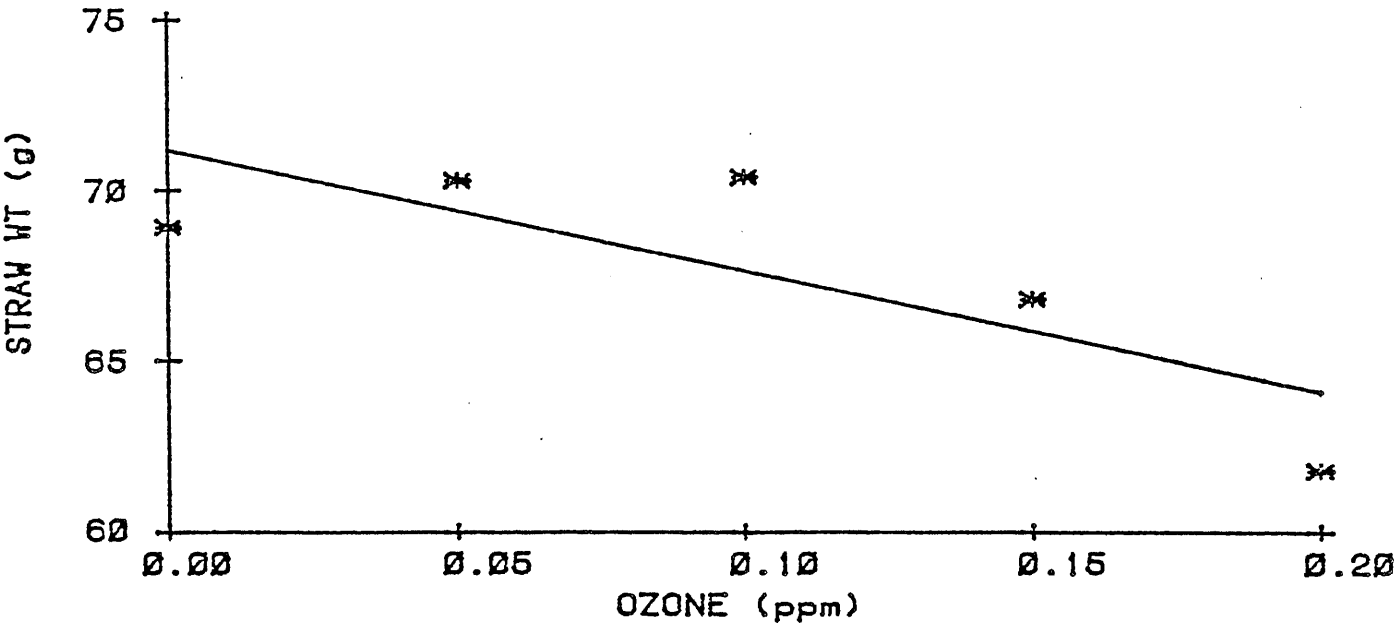


Figure 8. Straw weight of rice cultivar M9 = -65.3 x + 55.9, r^2 = .075, Sy.x = 8.9, n = 60. Each (*) represents the mean of 12 plants.

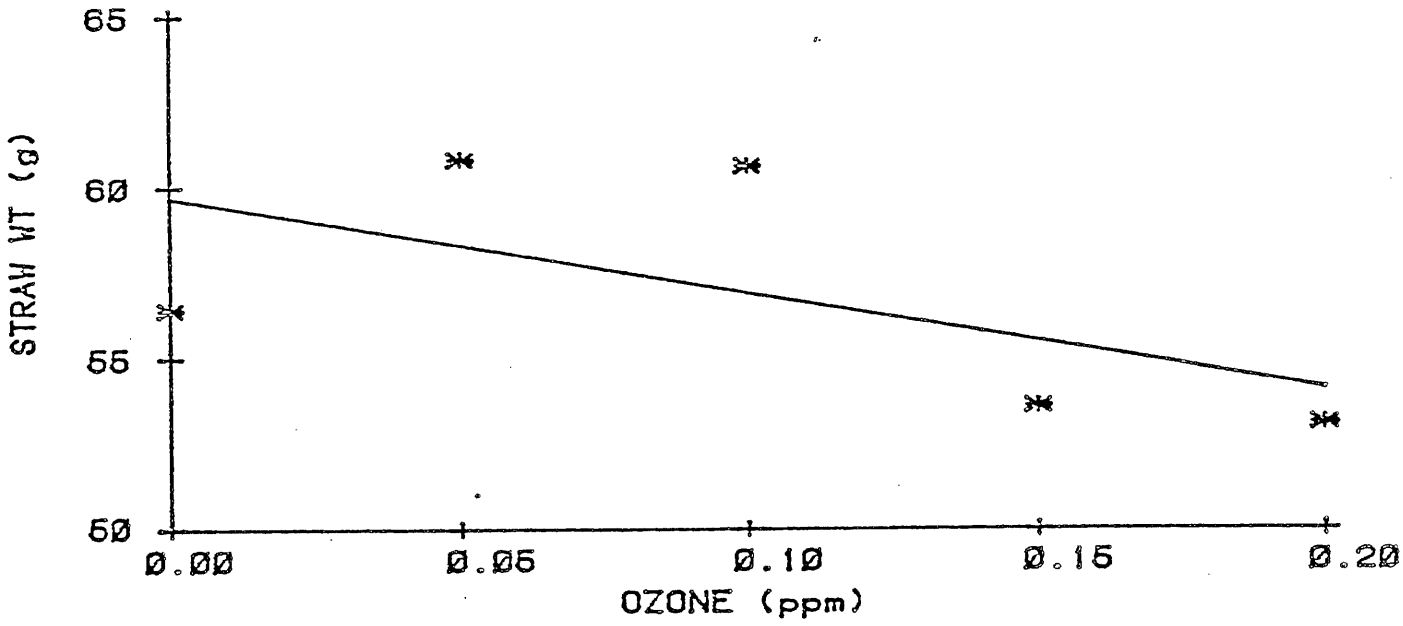


Figure 9. Straw weight of rice cultivar S201 = -47.2 x + 67.7, r^2 = .079, Sy.x = 6.8, n = 60. Each (*) represents the mean of 12 plants.

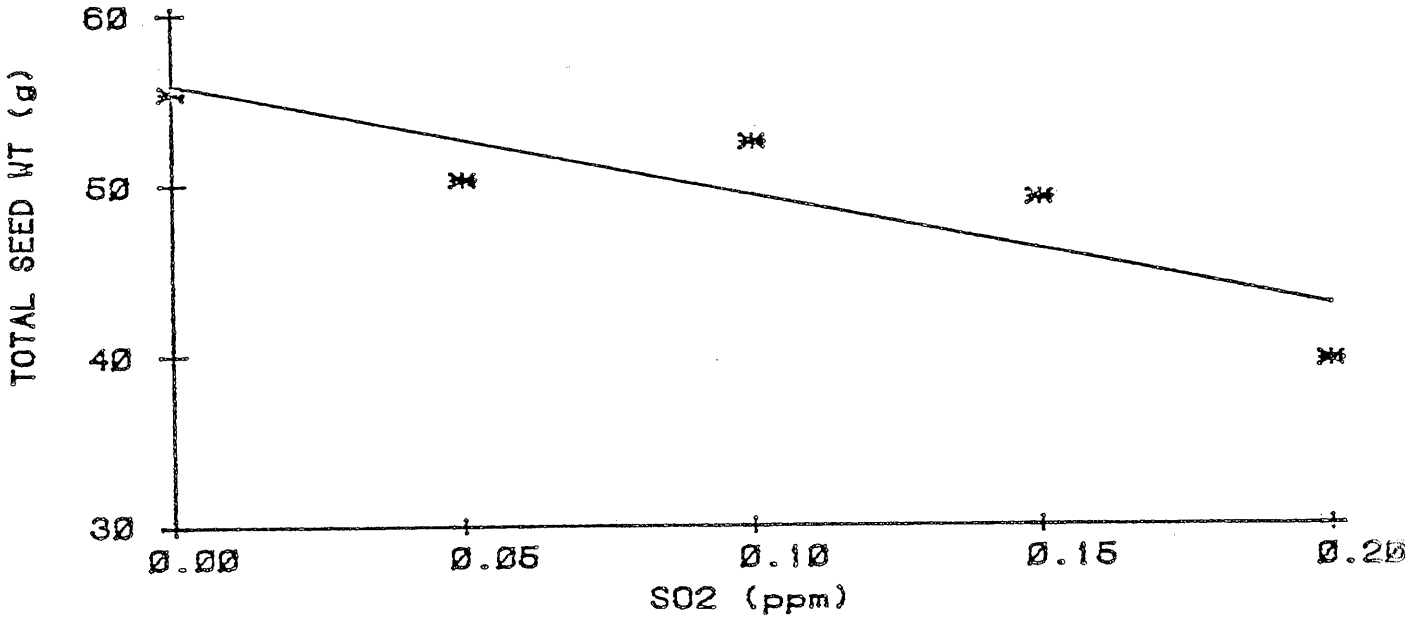


Figure 10. Total seed weight of rice cultivar M9 = -65.3 x + 55.9, r^2 = .133, Sy.x = 12.0, n = 60. Each (*) represents the mean of 12 plants.

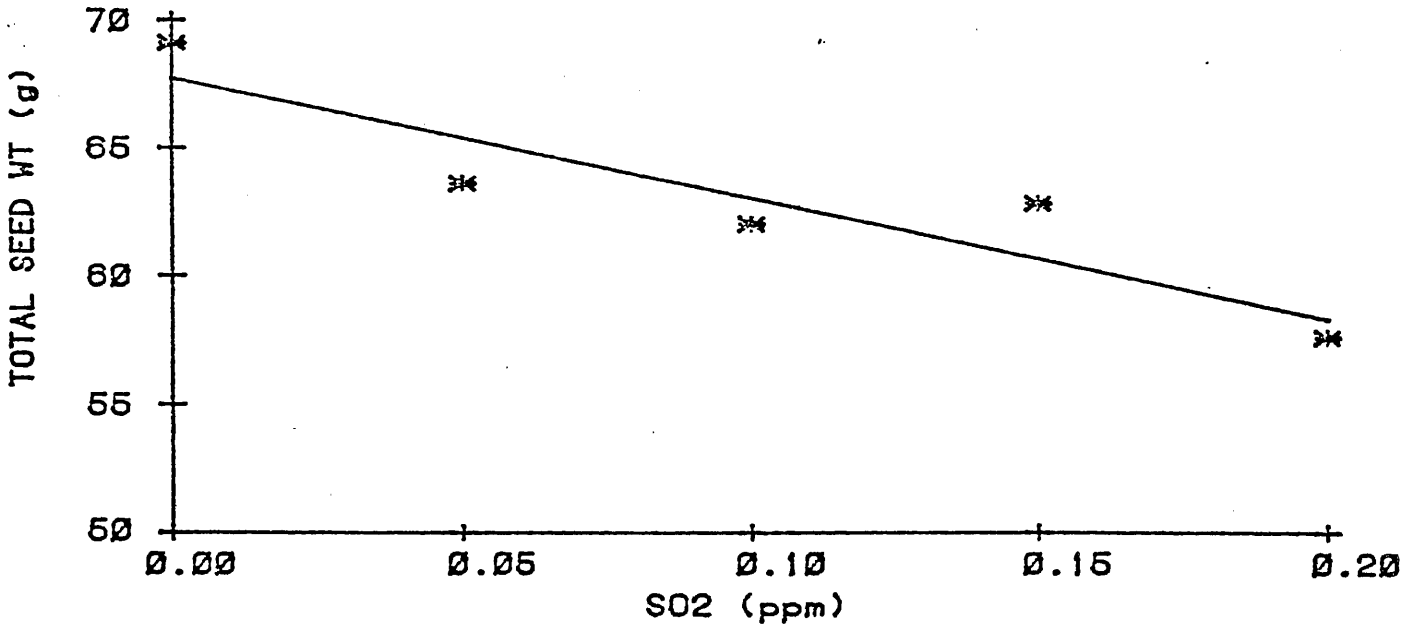


Figure 11. Total seed weight of rice cultivar S201 = -47.2 x + 67.7 r^2 = .205, Sy.x = 6.7, n = 60. Each (*) represents the mean of 12 plants.

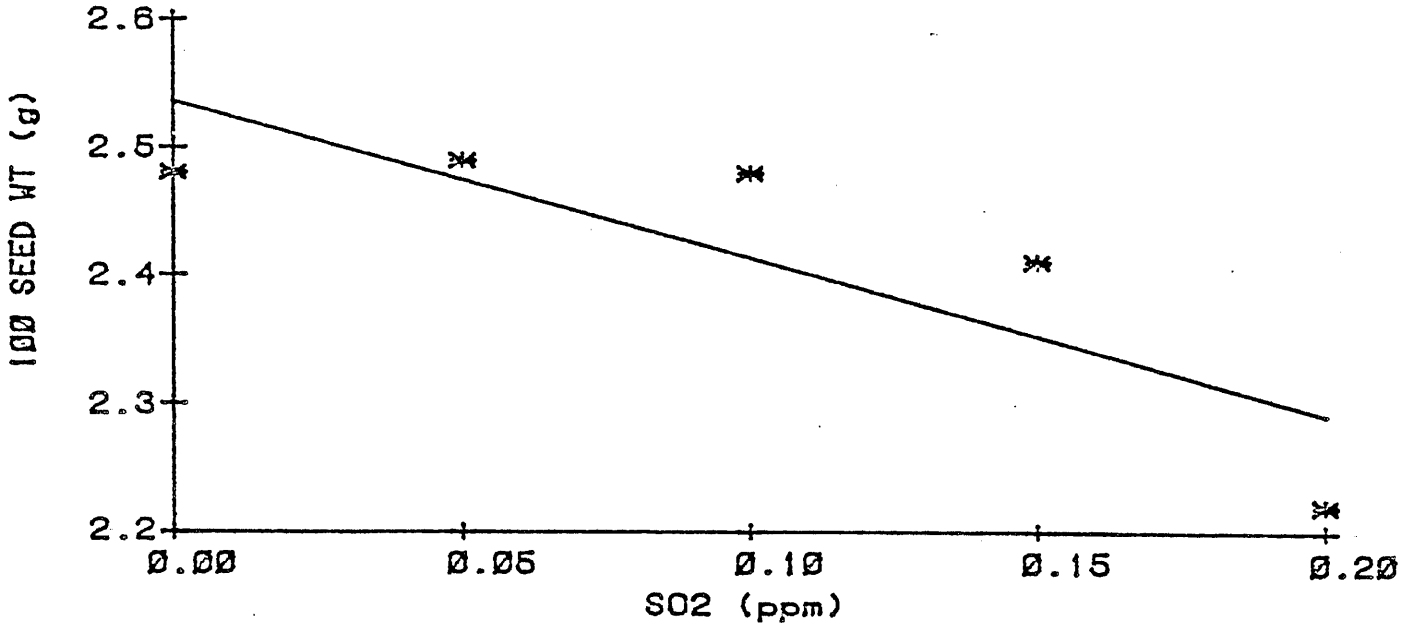


Figure 12. One hundred seed weight of rice cultivar M9 = -1.22 x + 2.54, r^2 = .120, Sy.x = .238, n = 60. Each (*) represents the mean of 12 plants.

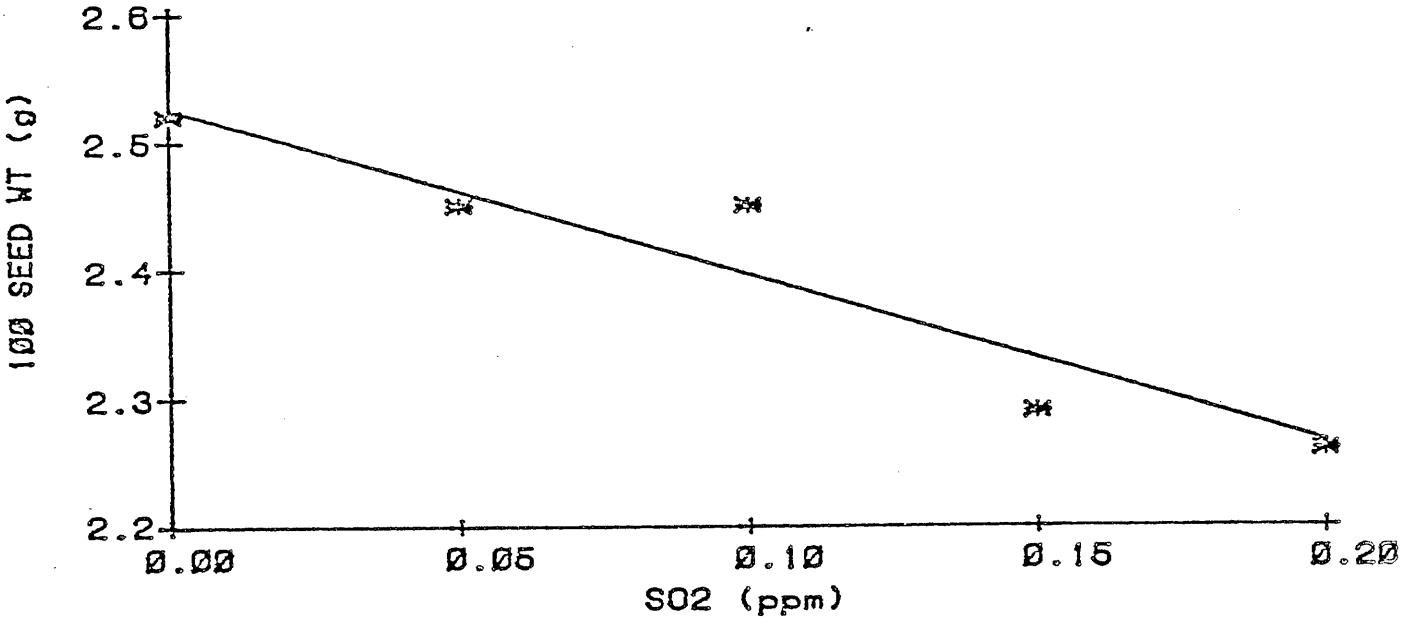


Figure 13. One hundred seed weight of rice cultivar S201 = -1.35 x + 2.53, r^2 = .499, Sy.x = .097, n = 60. Each (*) represents the mean of 12 plants.

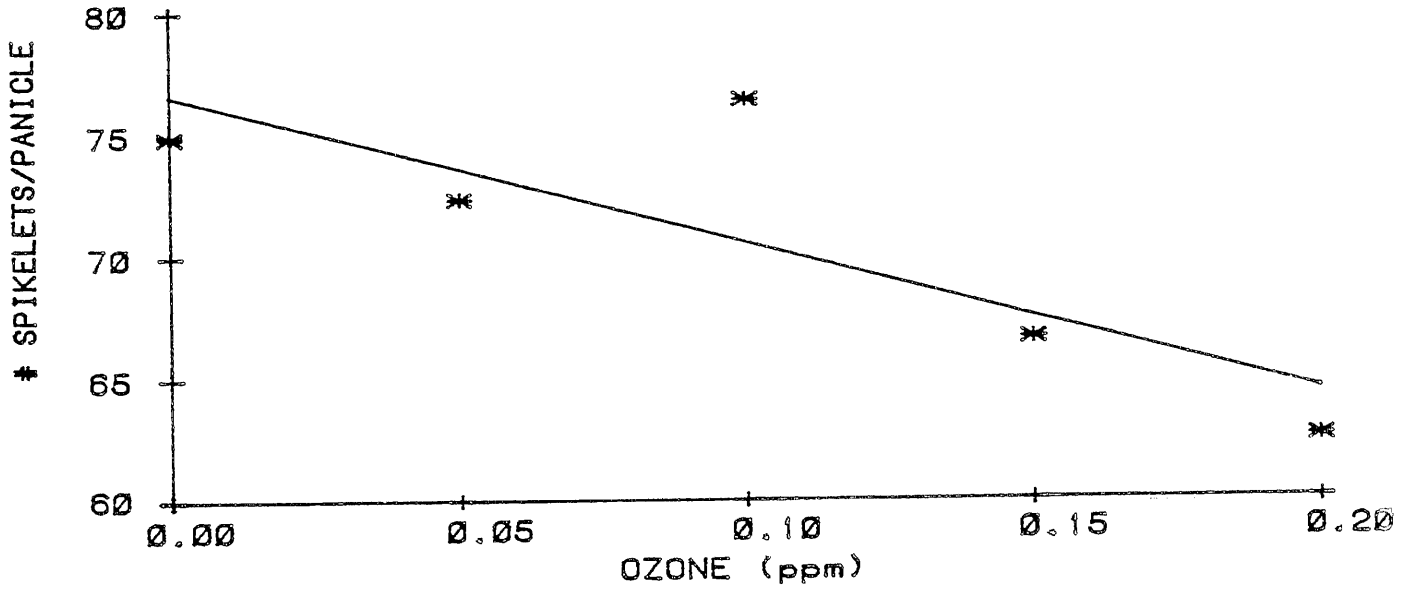


Figure 14. Number of spikelets per panicle of rice cultivar M7 = -60.77 x + 76.59, r^2 = .059, Sy.x = 17.3, n = 300. Each (*) represents the mean of 60 panicles.

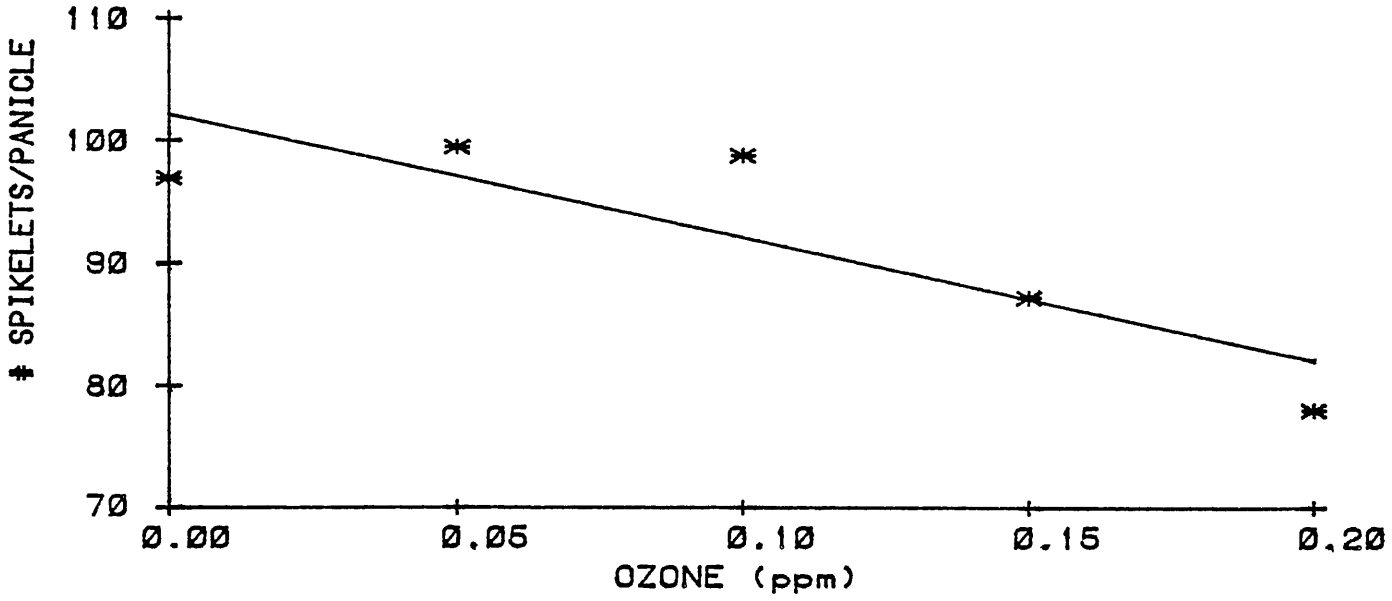


Figure 15. Number of spikelets per panicle of rice cultivar M9 = -100.33 x + 102.1, r^2 = .107, Sy.x = 20.6, n = 300. Each (*) represents the mean of 60 panicles.

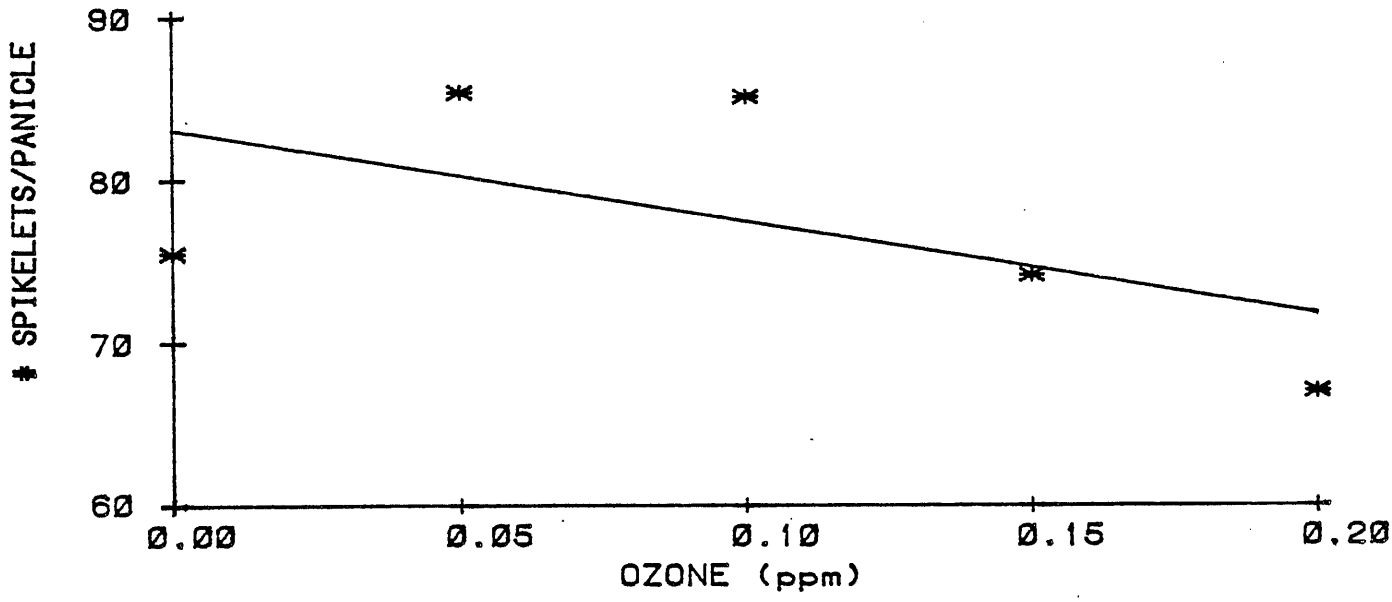


Figure 16. Number of spikelets per panicle of rice cultivar S201 = -56.57 x + 83.07, r^2 = .033, Sy.x = 21.6, n = 300. Each (*) represents the mean of 60 panicles.

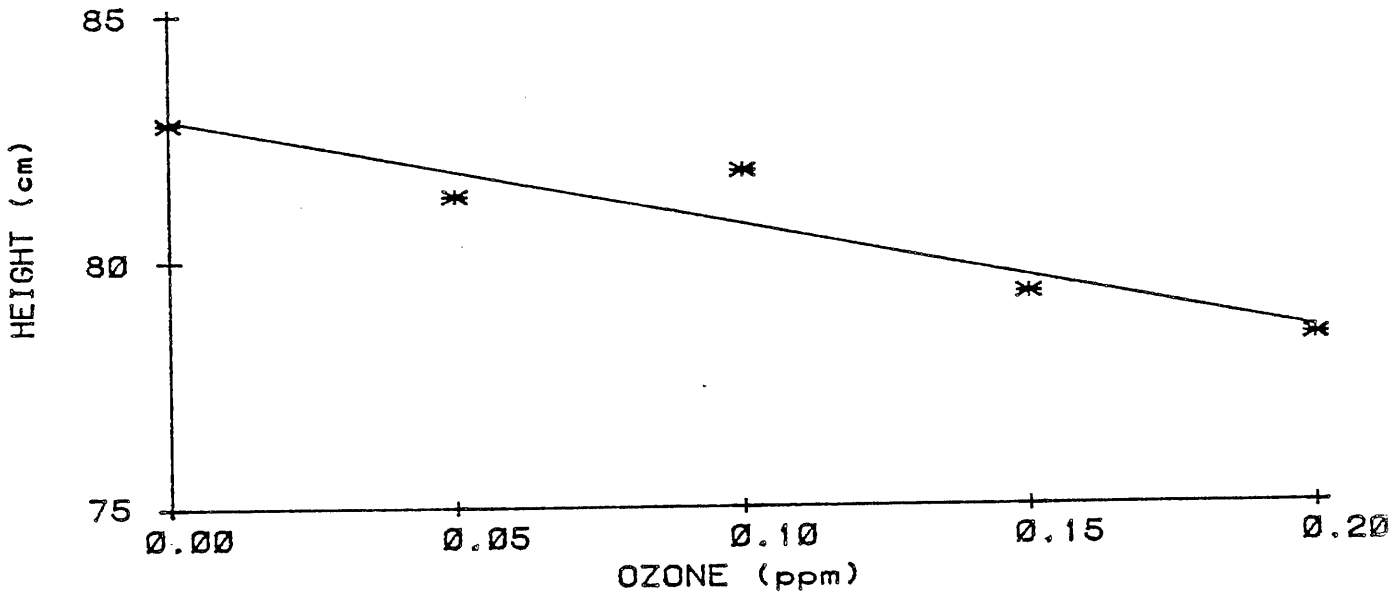


Figure 17. Height of rice cultivar M7 = -21.71 x + 82.88, r^2 = .103, Sy.x = 4.6, n = 240. Each (*) represents the mean of 48 plants.

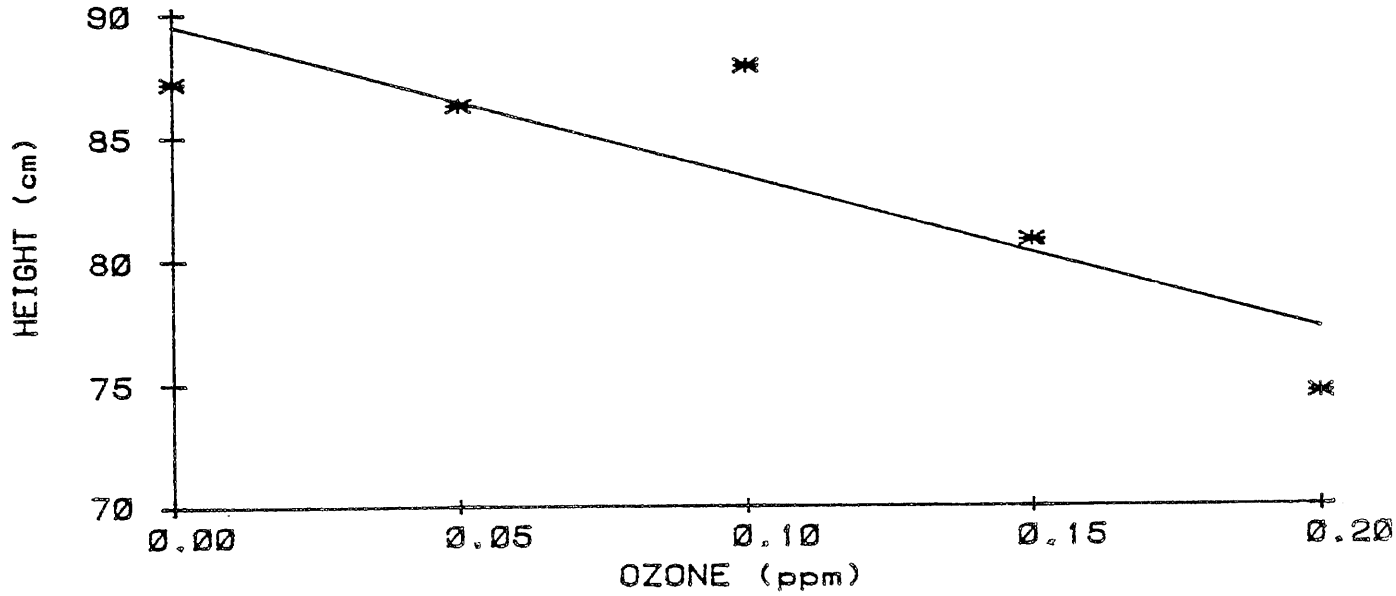


Figure 18. Height of rice cultivar M9 = -61.54 x + 89.53, r^2 = .365, Sy.x = 5.8, n = 240. Each (*) represents the mean of 48 plants.

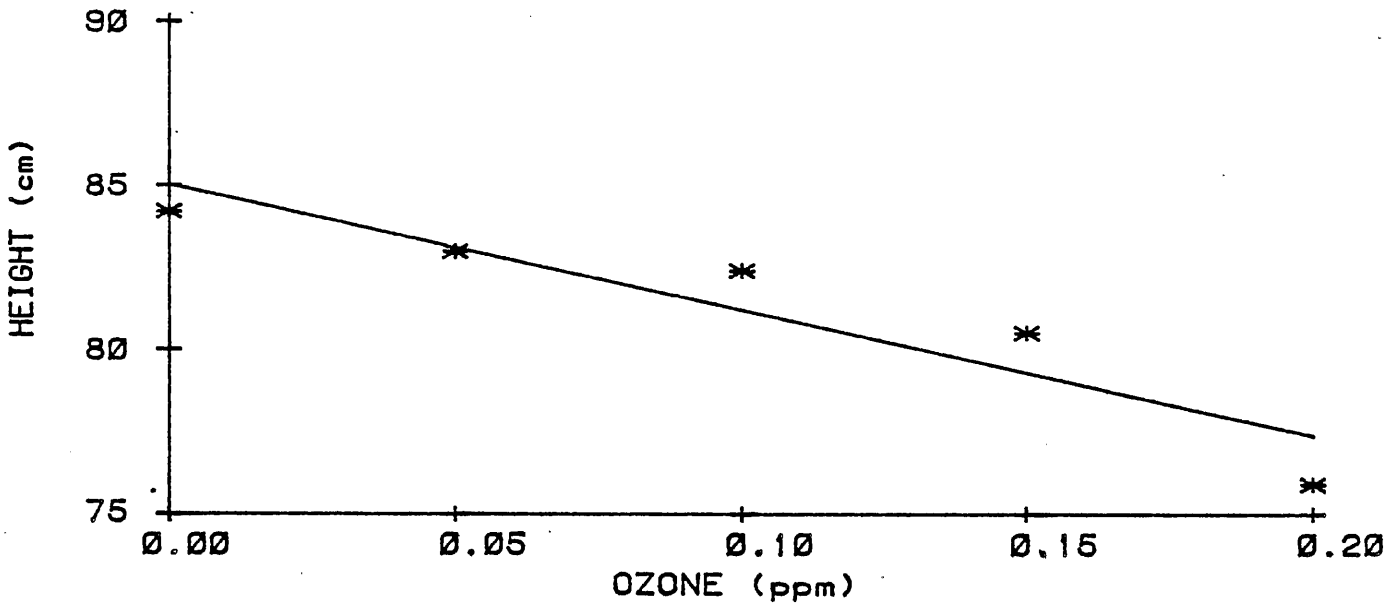


Figure 19. Height of rice cultivar S201 = -38.20 x + 85.02, r^2 = .315, Sy.x = 4.0, n = 240. Each (*) represents the mean of 48 plants.

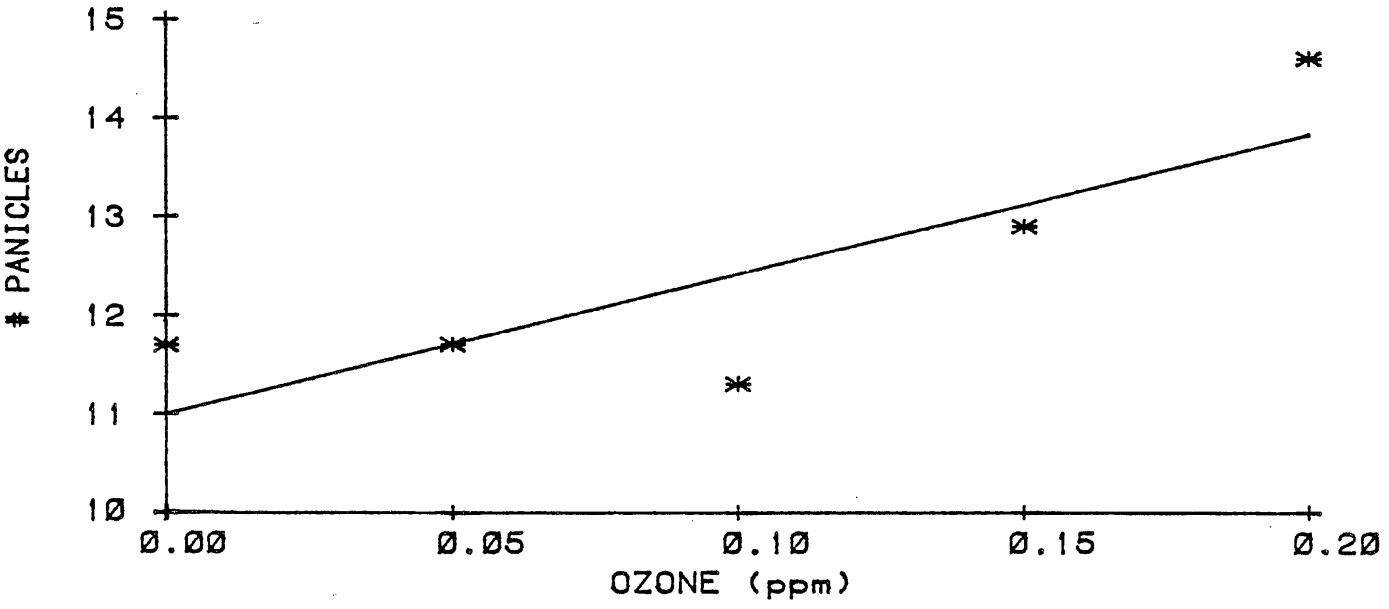


Figure 20. Number of panicles per plant of rice cultivar M7 = 14.13 x + 11.01, r^2 = .134, Sy.x = 2.6, n = 240. Each (*) represents the mean of 48 plants.

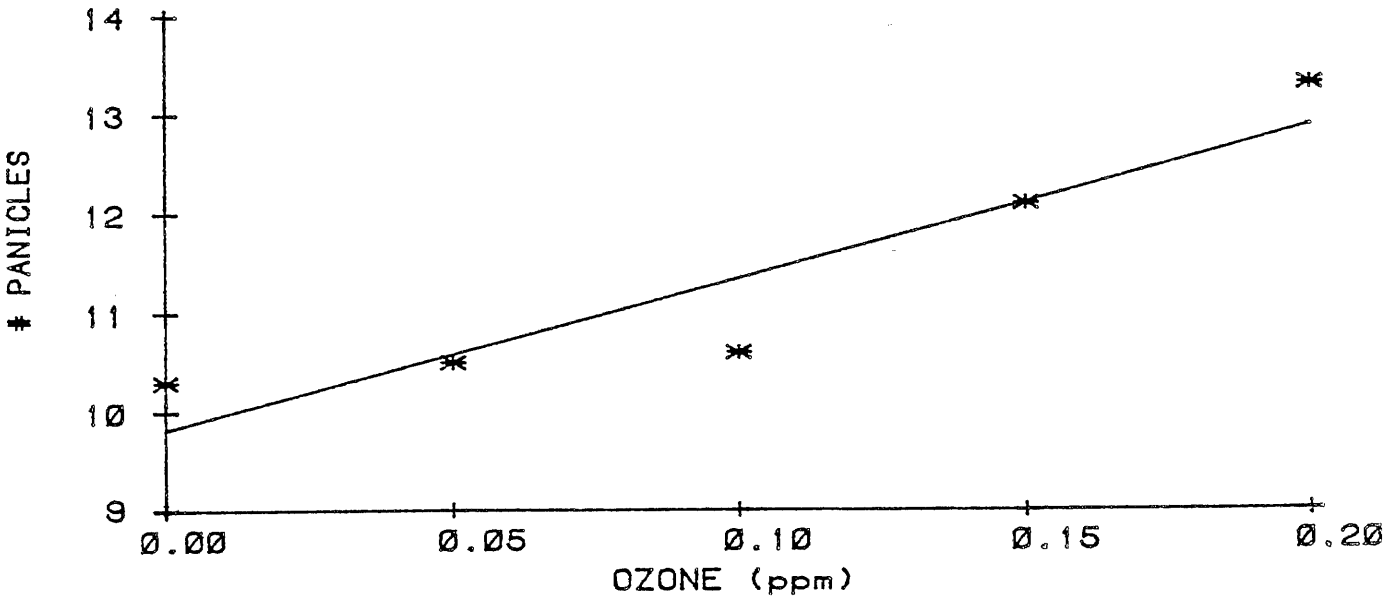


Figure 21. Number of panicles per plant of rice cultivar M9 = 15.33 x + 9.82, r^2 = .146, Sy.x = 2.6, n = 240. Each (*) represents the mean of 48 plants.

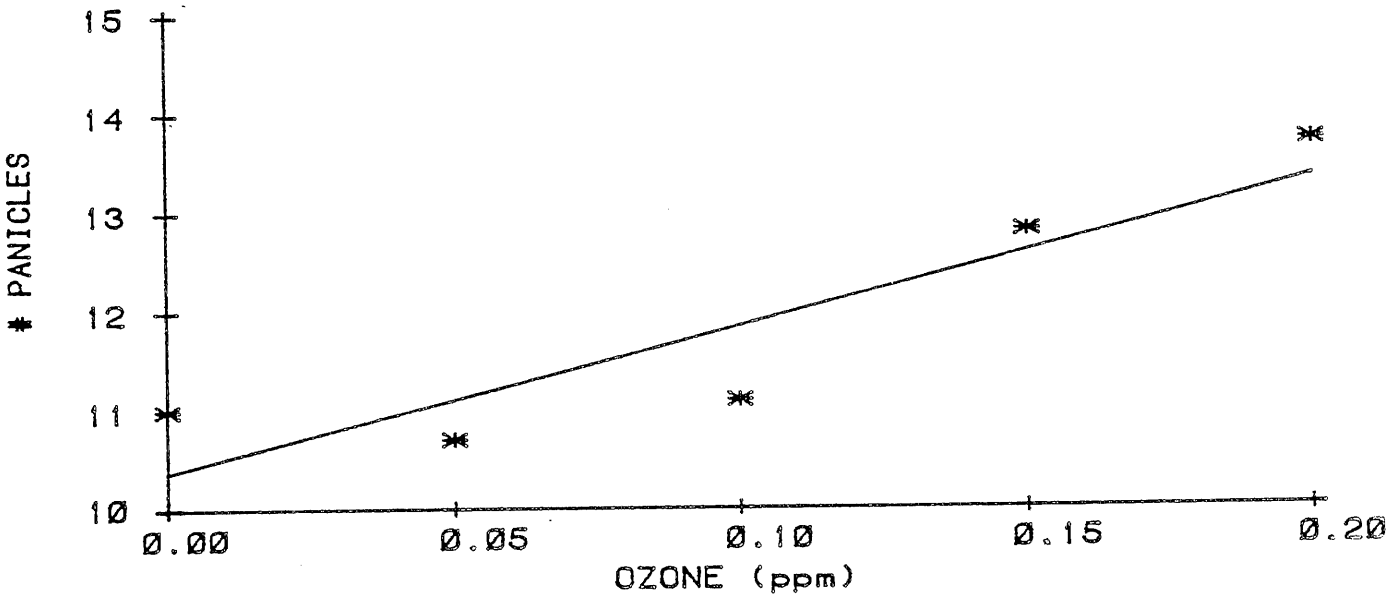


Figure 22. Number of panicles per plant of rice cultivar S201 = 14.79 x + 10.36, r^2 = .146, Sy.x = 2.5, n = 240. Each (*) represents the mean of 48 plants.

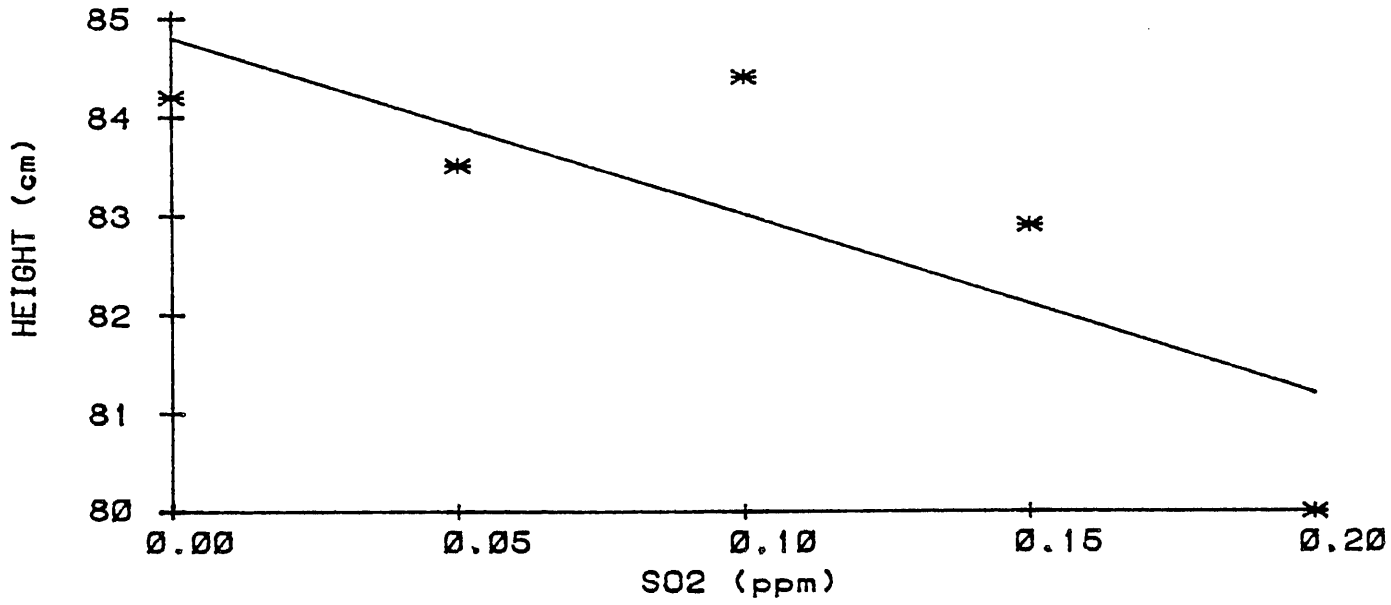


Figure 23. Height of rice cultivar S201 = -18.00 x + 84.80, r^2 = .094, Sy.x = 4.0, n = 240. Each (*) represents the mean of 48 plants.

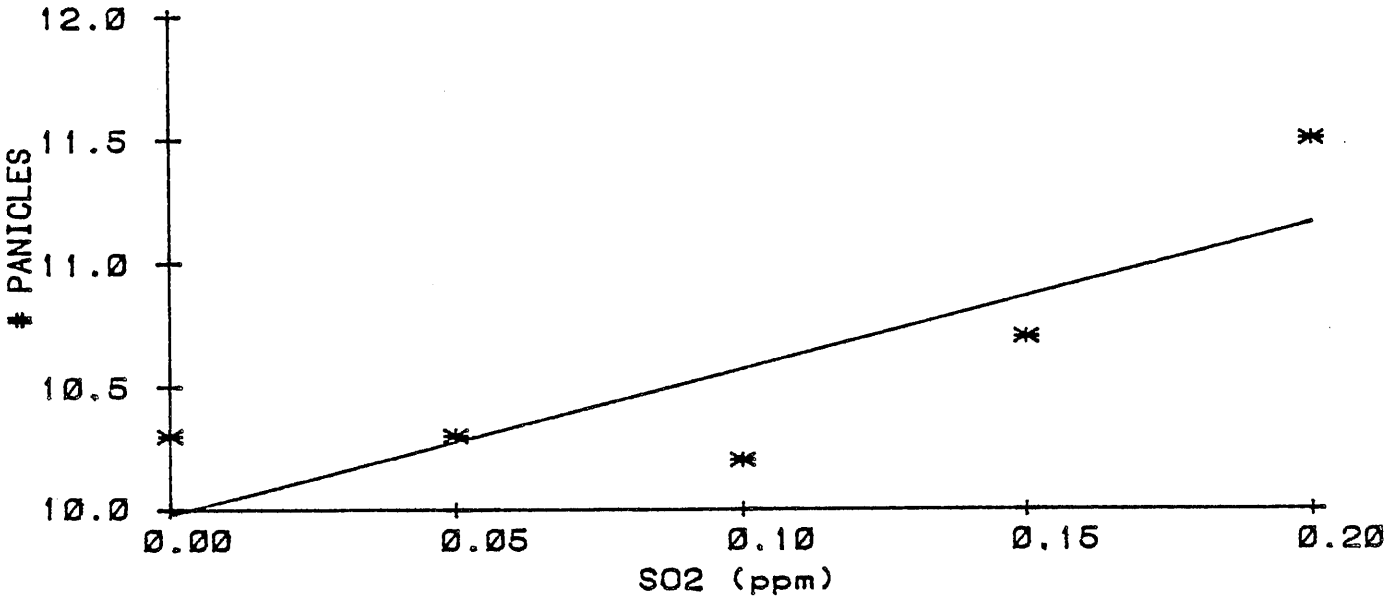


Figure 24. Number of panicles per plant of rice cultivar M9 = 5.92 x + 9.98, r^2 = .027, Sy.x = 2.5, n = 240. Each (*) represents the mean of 48 plants.

Table 1. Effect of ozone on 3 varieties of rice (harvest #1)*

Cultivar	Ozone ppm	Height cm	Total dry weight g	Total leaf area cm^2	# of tillers	Injury**
M7	.00	42.0 y	4.58 y	338.6	20.9 wx	10.
	.05	42.1 y	4.78 y	390.8	18.5 yz	11.6
	.10	39.9 z	4.77 y	390.1	19.5 xyz	12.3
	.15	39.5 z	4.34 yz	405.8	20.7 wxy	19.7
	.20	41.0 yz	3.54 z	357.4	17.9 z	31.0
	.25	42.0 y	4.31 yz	368.9	21.8 w	20.4
M9	.00	45.6 y	5.52 wx	483.1 xyz	15.9	8.3
	.05	45.2 y	6.22 w	539.2 x	16.8	14.0
	.10	43.0 z	5.16 xy	452.2 yz	17.5	10.9
	.15	41.6 z	4.50 yz	446.6 yz	16.7	20.1
	.20	41.8 z	4.01 z	418.5 z	15.9	24.5
	.25	42.8 z	4.65 yz	506.2 xy	16.2	18.4
S201	.00	44.5 y	6.82 x	562.2 y	19.1	16.5
	.05	43.8 yz	5.87 y	477.8 z	19.1	14.8
	.10	43.2 yz	5.38 yz	451.9 z	18.9	16.7
	.15	42.6 z	4.78 z	443.7 z	17.8	25.2
	.20	42.7 yz	4.60 z	434.3 z	18.2	32.4
	.25	42.4 z	4.91 z	415.6 z	16.8	24.3

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

**Means from arcsin transformation.

Table 2. Effect of sulfur dioxide on 3 varieites of rice (harvest #1)*

Cultivar	SO_2 ppm	Height cm	Total dry weight g	Total leaf area cm^2	# of tillers	Injury**
M7	.00	42.0	4.58	338.6 z	20.9 y	10.6
	.05	42.6	6.08	491.9 x	18.6 yz	11.5
	.10	41.7	5.03	385.3 yz	17.0 z	11.1
	.15	43.7	5.94	516.9 x	18.6 yz	12.0
	.20	42.5	4.91	466.6 xy	17.8 z	11.0
M9	.00	45.6 z	5.52 z	483.1 z	15.9	8.3
	.05	48.7 y	7.33 y	593.7 y	16.9	13.1
	.10	48.5 y	7.49 y	571.3 y	17.2	14.2
	.15	47.5 yz	7.51 y	577.3 y	18.0	10.2
	.20	47.3 z	6.88 z	523.3 yz	17.2	11.8
S201	.00	44.5	6.82	562.2	19.1	16.5
	.05	45.0	7.23	538.2	18.1	13.8
	.10	43.5	6.66	511.4	18.5	12.8
	.15	45.6	7.36	583.4	18.1	14.8
	.20	44.4	6.98	564.5	18.8	15.2

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

**Means from arcsine transformation.

Table 3. Effect of ozone on 3 varieties of rice (harvest #2)*

Cultivar	Ozone (ppm)	Height cm	Total dry weight g	# of tillers		Injury**	# of panicles
M7	.00	83.3	23.6	12.9	yz	25.6	8.90
	.05	83.7	24.1	14.2	xy	27.9	9.55
	.10	82.6	22.0	12.7	yz	27.3	9.20
	.15	80.1	19.5	11.8	z	32.8	9.15
	.20	76.1	17.0	14.5	x	34.3	8.85
	.25	80.4	20.4	12.3	z	31.3	8.55
M9	.00	89.3	27.8	13.5	y	28.1	8.35
	.05	87.0	25.3	12.4	yz	29.7	7.75
	.10	85.4	24.2	12.2	yz	30.3	8.40
	.15	81.1	22.6	11.8	z	35.2	9.10
	.20	74.7	18.7	11.6	z	35.7	8.85
	.25	84.3	25.3	12.7	yz	31.9	9.35
S201	.00	83.9	24.3	11.8	z	28.0	8.10
	.05	84.4	25.0	12.8	xyz	29.0	8.60
	.10	83.0	23.4	12.8	xyz	30.4	8.75
	.15	79.0	20.5	12.3	yz	33.3	9.10
	.20	75.7	20.0	14.0	x	39.2	10.00
	.25	79.2	23.6	13.8	xy	30.1	9.90

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

**Means from arcsin. transformation.

Table 4. Effect of sulfur dioxide on 3 varieties of rice (harvest #2)*

Cultivar	SO_2 ppm	Height cm	Total dry weight g	# of tillers	Injury**	# or panicles
M7	.00	83.3	23.6	12.9	25.6	8.90
	.05	84.8	22.7	11.3	32.9	8.45
	.10	84.1	24.0	11.6	29.7	8.55
	.15	85.1	23.5	11.6	32.8	8.10
	.20	80.6	21.9	12.0	32.8	8.80
M9	.00	89.3	27.8	13.5	28.1	8.35
	.05	90.2	28.1	11.3	31.8	8.60
	.10	89.4	27.8	11.9	31.9	8.85
	.15	86.2	26.9	11.2	30.1	8.65
	.20	85.7	27.2	12.1	31.3	9.30
S201	.00	83.9	24.3	11.8	28.0	8.10
	.05	83.6	23.1	9.9	31.5	7.70
	.10	84.3	25.1	10.5	34.3	8.35
	.15	82.2	25.5	12.0	31.2	8.55
	.20	80.5	23.9	11.0	32.2	8.50

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

**means from arcsine transformation.

Table 5. Effect of ozone on 3 varieties of rice (final harvest)*

Pots 1-12

Cultivar	Ozone ppm	Total seed weight*** g	100 seed weight g	% of sterile seeds**	Straw weight*** g	Height cm	# of panicles
M7	.00	53.9	2.37	22.5	68.1	82.7 y	12.0 z
	.05	52.5	2.37	26.1	68.8	82.4 y	11.6 z
	.10	51.8	2.35	25.3	71.3	82.5 y	11.5 z
	.15	50.0	2.35	27.6	67.8	80.5 y	12.8 y
	.20	51.5	2.29	25.2	64.1	79.4 z	14.3 x
	.25	51.1	2.32	25.9	69.5	81.3 yz	12.0 yz
M9	.00	46.7 y	2.42 y	34.4 z	79.8 y	86.3 x	10.6 yz
	.05	43.4 y	2.37 yz	42.2 y	82.9 y	85.0 x	10.8 z
	.10	45.0 y	2.39 yz	41.9 y	82.4 y	86.4 x	10.9 z
	.15	36.1 z	2.38 yz	44.8 y	80.7 y	80.6 y	12.6 y
	.20	33.9 z	2.31 z	44.4 y	71.8 z	75.4 z	14.1 x
	.25	35.3 z	2.40 yz	44.5 y	83.6 y	81.2 y	11.7 yz
S201	.00	61.9 y	2.52 y	27.9	65.5 xyz	83.7 w	10.8 z
	.05	56.0 z	2.45 y	27.5	71.4 x	82.7 wx	11.1 z
	.10	57.9 y	2.49 y	28.6	71.0 x	82.9 w	11.2 z
	.15	53.9 z	2.36 z	38.1	62.8 yz	80.3 xy	12.7 y
	.20	53.4 z	2.31 z	27.5	59.4 z	76.7 z	13.6 y
	.25	53.2 z	2.48 y	30.9	68.3 xy	79.6 y	11.6 z

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

**Means from arcsin transformation.

***Calculated per pot (4 plants).

Table 6. Effect of sulfur dioxide on 3 varieites of rice (final harvest)*
Pots 1-12

Cultivar	SO_2 ppm	Total seed weight*** g		100 seed weight g		% of sterile seeds**		Straw weight*** g		Height cm		# of panicles	
M7	.00	53.9		2.37		22.5	z	68.1		82.7	z	12.0	y
	.05	49.5		2.32		27.4	yz	68.2		83.8	yz	10.7	z
	.10	48.9		2.36		30.3	y	67.6		84.6	yz	11.3	yz
	.15	50.1		2.35		26.5	yz	65.9		84.8	y	11.0	z
	.20	51.2		2.30		26.4	yz	67.8		83.3	yz	11.6	yz
M9	.00	46.7	y	2.42	y	34.4	z	79.8		86.3	y	10.6	yz
	.05	38.5	yz	2.42	y	43.6	y	86.0		85.7	y	10.4	z
	.10	40.3	yz	2.40	y	41.4	y	78.1		86.8	y	10.4	z
	.15	36.7	z	2.37	y	43.1	y	85.8		85.3	y	10.7	yz
	.20	32.1	z	2.26	z	46.6	y	78.2		83.4	z	11.4	y
S201	.00	61.9		2.52	y	27.9	yz	65.5	z	83.7	y	10.8	
	.05	56.5		2.47	y	27.6	yz	64.1	z	82.9	yz	10.3	
	.10	56.2		2.47	y	33.7	y	74.5	y	84.4	y	11.0	
	.15	60.3		2.37	z	24.7	z	63.5	z	83.4	y	10.6	
	.20	55.7		2.31	z	25.0	z	59.3	z	81.1	z	10.7	

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

**Means from arcsin transformation.

***Calculated per pot (4 plants).

Table 7. Effect of ozone and sulfur dioxide on 3 varieties of rice (final harvest)*

Total biomass (g)

Cultivar	Ozone ppm	Pots # 1-6	Pots # 7-12	SO_2 ppm	Pots # 1-6	Pots # 7-12
M7	.00	126.63	135.33	.00	126.63 y	135.33
	.05	125.88	137.38	.05	113.69 z	138.91
	.10	124.96	142.03	.10	119.62 yz	134.77
	.15	120.45	135.24	.15	116.85 yz	131.17
	.20	118.16	132.56	.20	118.18 yz	134.03
	.25	127.56	131.93			
M9	.00	134.35 xy	143.12 y	.00	134.35 y	143.12
	.05	132.70 xy	142.18 y	.05	131.68 y	147.38
	.10	140.61 x	142.71 y	.10	132.23 y	132.41
	.15	123.63 yz	139.25 yz	.15	134.12 y	142.02
	.20	112.52 z	126.20 z	.20	116.48 z	134.57
	.25	126.17 y	140.39 yz			
S201	.00	132.81 xy	140.29 yz	.00	132.81 y	140.29
	.05	134.48 x	140.51 yz	.05	128.65 yz	132.51
	.10	133.17 xy	144.54 y	.10	132.18 y	150.66
	.15	121.45 yz	132.53 yz	.15	123.19 yz	141.95
	.20	110.51 z	128.43 z	.20	118.17 z	131.87
	.25	127.43 xy	135.17 yz			

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

APPENDIX A

Table A1. Effect of ozone on 3 varieties of rice (final harvest)

pots 1-6

Cultivar	Ozone ppm	Total seed weight *** g	100 seed weight g	% of sterile seeds **	Straw weight *** g	Height cm	# of panicles
M7	.00	60.3 y	2.40	18.9	58.5 z	82.8 x	11.7 yz
	.05	57.1 yz	2.38	21.8	60.5 yz	81.3 xy	11.7 yz
	.10	54.0 yz	2.39	22.9	60.4 yz	8.8 xy	11.3 z
	.15	54.1 yz	2.38	21.9	57.9 z	79.3 yz	12.9 y
	.20	52.6 z	2.32	22.5	57.2 z	78.4 z	14.6 x
	.25	54.2 yz	2.45	21.5	64.8 y	80.5 xyz	12.6 y
M9	.00	55.4 y	2.48 y	28.0 z	68.9 y	87.2 x	10.3 z
	.05	54.3 y	2.41 yz	34.2 yz	70.3 y	86.3 x	10.5 z
	.10	59.6 y	2.46 yz	30.9 yz	70.4 y	87.9 x	10.6 z
	.15	45.2 z	2.38 yz	36.9 y	66.8 yz	80.8 y	12.1 xy
	.20	38.7 z	2.32 z	38.0 y	61.8 z	74.6 z	13.3 x
	.25	42.0 z	2.45 yz	36.7 y	72.0 y	81.9 y	11.0 yz
S201	.00	69.1 x	2.52 y	20.7	56.4 yz	84.2 w	11.0 yz
	.05	64.8 xy	2.44 y	19.9	60.8 y	83.0 wx	10.7 z
	.10	64.2 xy	2.45 y	21.1	60.6 y	82.4 wx	11.1 yz
	.15	59.2 yz	2.30 z	25.1	53.6 z	80.5 xy	12.8 wx
	.20	52.4 z	2.26 z	24.7	53.1 z	75.9 z	13.7 w
	.25	58.0 yz	2.48 y	26.9	61.1 y	79.5 y	12.0 xy

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

**Means from arcsin transformation.

***Calculated per pot (4 plants).

Table A2. Effect of ozone on 3 varieties of rice (final harvest)

pots 7-12

Cultivar	Ozone ppm	Total seed weight *** g	100 seed weight g	% of sterile seeds **	Straw weight *** g	Height cm	# of panicles
M7	.00	47.5	2.34	26.1 z	77.7	82.7	12.2 z
	.05	47.9	2.36	30.5 yz	77.2	83.6	11.5 z
	.10	49.5	2.32	30.6 yz	82.2	83.3	11.6 z
	.15	46.0	2.33	33.4 y	77.6	81.7	12.7 yz
	.20	50.4	2.26	27.9 yz	71.1	80.3	14.0 y
	.25	48.0	2.36	30.2 yz	74.2	82.1	11.5 z
M9	.00	38.1 y	2.36	40.8 z	90.7	85.3 x	10.9 z
	.05	32.6 yz	2.33	50.3 y	95.6	83.6 xy	11.1 yz
	.10	30.4 yz	2.32	52.8 y	94.3	84.9 x	11.2 yz
	.15	26.9 z	2.39	52.8 y	94.6	80.5 y	13.0 x
	.20	29.0 z	2.30	50.9 y	81.8	76.2 z	14.9 w
	.25	28.7 z	2.35	52.3 y	95.2	80.4 y	12.4 xy
S201	.00	54.8 y	2.52 y	35.2 yz	74.7 yz	83.2 x	10.6 z
	.05	46.4 z	2.47 yz	35.2 yz	82.0 y	82.3 xy	11.5 yz
	.10	51.5 yz	2.53 y	36.0 yz	81.5 y	83.4 x	11.3 yz
	.15	48.6 yz	2.42 yz	37.0 y	72.1 yz	80.1 xyz	12.7 xy
	.20	54.5 yz	2.36 z	30.3 z	65.8 z	77.4 z	13.5 x
	.25	48.1 yz	2.48 yz	34.9 yz	75.4 yz	79.7 yz	11.1 z

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

**Means from arcsin transformation.

***Calculated per pot (4 plants).

Table A3. Effect of sulfur dioxide on 3 varieties of rice (final harvest)

pots 1-6

Cultivar	SO_2 ppm	Total seed weight *** g	100 seed weight g	% of sterile seeds **	Straw weight *** g	Height cm	# of panicles
M7	.00	60.3	2.40	18.9	58.5	82.8	11.7
	.05	52.3	2.33	23.4	55.1	81.8	11.2
	.10	52.6	2.39	25.4	57.6	84.2	11.4
	.15	51.7	2.35	24.7	59.2	83.1	11.2
	.20	53.4	2.30	21.9	59.3	81.6	11.9
M9	.00	55.4 y	2.48 y	28.0	68.9 yz	87.2 yz	10.3 z
	.05	50.3 y	2.49 y	33.9	69.3 yz	87.5 yz	10.3 yz
	.10	52.5 y	2.48 y	29.9	69.5 yz	88.7 y	10.2 z
	.15	49.1 y	2.41 y	32.6	72.2 y	87.3 yz	10.7 z
	.20	39.6 z	2.22 z	36.8	64.4 z	84.9 z	11.5 y
S201	.00	69.1 y	2.52 x	20.7 yz	56.4 yz	84.2 y	11.0
	.05	63.6 yz	2.45 xy	22.5 yz	56.9 yz	83.5 y	10.4
	.10	62.0 yz	2.45 xy	31.2 y	61.8 y	84.4 y	10.7
	.15	62.8 yz	2.29 yz	18.2 z	53.7 z	82.9 y	10.8
	.20	57.6 z	2.26 z	20.3 z	51.4 z	80.0 z	10.7

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

**Means from arcsin transformation.

***Calculated per pot (4 plants).

Table A4. Effect of sulfur dioxide on 3 varieties of rice (final harvest)

pots 7-12

Cultivar	SO_2 ppm	Total seed weight *** g	100 seed weight g	% of sterile seeds **	Straw weight *** g	Height cm	# of panicles
M7	.00	47.5	2.34	26.1	77.7	82.7 z	12.2 y
	.05	46.7	2.32	31.4	81.3	85.9 y	10.3 z
	.10	45.3	2.33	35.2	77.7	85.1 y	11.2 yz
	.15	48.4	2.34	28.3	72.6	86.4 y	10.8 yz
	.20	49.0	2.31	30.9	76.4	85.0 y	11.2 yz
M9	.00	38.1 y	2.36	40.8 z	90.7	85.3 y	10.9
	.05	26.7 z	2.35	53.3 y	102.7	83.8 yz	10.6
	.10	28.0 z	2.31	52.9 y	86.8	85.0 y	10.7
	.15	24.3 z	2.33	53.5 y	99.5	83.3 yz	10.7
	.20	24.5 z	2.30	56.4 y	92.0	82.0 z	11.2
S201	.00	54.8	2.52 y	35.2	74.7 yz	83.2	10.6
	.05	49.4	2.49 y	32.8	71.3 yz	82.4	10.1
	.10	50.5	2.50 y	36.1	87.3 y	84.4	11.3
	.15	57.8	2.45 yz	31.1	73.3 yz	83.9	10.4
	.20	53.7	2.46 z	29.8	67.1 z	82.3	10.6

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

**Means from arcsin transformation.

***Calculated per pot (4 plants).

Table A5. Number of spikelets per panicle (final harvest) *
Pots 1-12

Cultivar	Ozone ppm	# of Spikelets	SO_2 ppm	# of Spikelets
M7	.00	78.78 x	.00	78.78
	.05	77.66 x	.05	83.38
	.10	77.78 x	.10	83.57
	.15	68.30 yz	.15	81.68
	.20	64.50 z	.20	79.45
	.25	71.38 y		
M9	.00	99.11 x	.00	99.11 z
	.05	100.85 wx	.05	111.93 y
	.10	105.20 w	.10	107.48 yz
	.15	89.19 y	.15	106.60 yz
	.20	78.79 z	.20	105.44 yz
	.25	92.62 y		
S201	.00	82.39 xy	.00	82.39
	.05	84.97 x	.05	79.86
	.10	86.71 x	.10	85.20
	.15	77.52 y	.15	82.57
	.20	69.07 z	.20	83.27
	.25	82.80 xy		

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

Table A6. Number of spikelets per panicle

Cultivar	Ozone ppm	Pots 1-6	Pots 7-12	SO_2	Pots 1-6	Pots 7-12
M7	.00	74.9 xy	82.7 w			
	.05	72.3 xy	83.1 w	.00	74.9	82.7
	.10	76.4 x	79.2 wx	.05	76.8	90.0
	.15	66.6 yz	70.0 yz	.10	79.2	88.0
	.20	62.5 z	66.5 z	.15	76.0	87.3
	.25	69.7 xyz	73.1 xy	.20	76.8	82.1
M9	.00	96.9 x	101.3 x			
	.05	99.5 x	102.3 x	.00	96.9	101.3 z
	.10	98.8 x	111.6 w	.05	107.7	116.2 y
	.15	87.2 y	91.2 y	.10	103.6	111.4 yz
	.20	78.0 z	79.6 z	.15	104.0	109.2 yz
	.25	87.5 y	97.8 x	.20	98.7	112.2 yz
S201	.00	75.5 y	89.3 x			
	.05	85.4 x	84.5 xy	.00	75.5	89.3
	.10	85.1 x	88.3 x	.05	78.6	81.2
	.15	74.1 yz	80.9 y	.10	80.0	90.4
	.20	67.0 z	71.2 z	.15	75.1	90.0
	.25	77.4 xy	88.2 x	.20	82.0	84.6

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

Table A7. Comparison between the pots 1-6 and 7-12*

Ozone

Cultivars	M7		M9		S201	
Parameter	1-6	7-12	1-6	7-12	1-6	7-12
			Control			
% sterile seeds (means)	21.8 xx	30.5	34.2 xx	50.3	20.7 xx	35.2
straw weight (g)	55.8 xx	77.7	70.3 xx	95.6	56.4 xx	74.7
100 seed weight (g)	2.40	2.34	2.48 x	2.36	2.51	2.52
Total seed weight (g)	60.3 xx	47.5	55.4 xx	38.1	69.1 xx	54.8
			.05 ppm			
% sterile seeds (means)	21.8 xx	30.5	34.2 xx	50.3	19.9 xx	35.2
straw weight (g)	60.5 xx	77.2	70.3 xx	95.6	60.8 xx	82.0
100 seed weight (g)	2.38	2.36	2.41	2.33	2.44	2.47
total seed weight (g)	57.1	47.9 xx	54.3 xx	32.6	64.8 xx	46.4
			.10 ppm			
% sterile seeds (means)	22.9 x	30.6	30.3 xx	52.8	21.1 xx	36.0
straw weight (g)	60.4 xx	82.2	70.4 xx	94.3	60.6 xx	81.5
100 seed weight (g)	2.39	2.3	2.46 x	2.32	2.45	2.53
total seed weight (g)	54.0	49.5	59.6 xx	30.4	64.2 xx	51.5

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

Table A8. Comparison between the pots 1-6 and 7-12*

Ozone

Cultivars	M7		M9		S201	
Parameter	1-6	7-12	1-6	7-12	1-6	7-12
			.15 ppm			
% sterile seeds (means)	21.9 xx	33.4	36.9 xx	52.8	25.0	37.0
straw weight (g)	57.9 xx	77.6	66.8 xx	94.6	53.6 x	72.1
100 seed weight (g)	2.38	2.33	2.38	2.39	2.30 x	2.42
total seed weight (g)	54.1 x	46.0	45.2 xx	26.9	59.2 xx	48.6
			.20 ppm			
% sterile seeds (means)	22.5	27.9	8.0 xx	50.9	24.7	30.3
straw weight (g)	57.2 xx	71.1	61.8 xx	81.8	53.1 xx	65.8
100 seed weight (g)	2.31	2.26	2.32	2.30	2.26	2.36
total seed weight (g)	52.6	50.4	38.7 xx	29.0	52.4	54.5
			.25 ppm			
% sterile seeds (means)	21.5 xx	30.2	36.7 xx	52.3	26.9 xx	34.9
straw weight (g)	64.8 x	74.2	72.0 xx	95.2	61. xx	75.4
100 seed weight (g)	2.28	2.36	2.45	2.35	2.48	2.47
total seed weight (g)	54.2	48.0	42.0 xx	28.7	58.0 xx	48.5

*Treatments for each column (for every variety) not followed by any letter are not significantly different at .05 probability level using Duncan's Multiple Range Test to determine differences between means.

Table A9. Statistical Comparisons between pots 1-6 and 7-12

SO_2

Cultivars	M7		M9		S201	
Parameter	1-6	7-12	1-6	7-12	1-6	7-12
		Control				
% sterile seeds (means)	18.9	26.1	28.0	40.8	20.7	35.2
straw weight (g)	58.5 xx	77.7	68.9 xx	90.7	56.4 xx	74.7
100 seed weight (g)	2.40	2.34	2.48	2.36	2.52	2.52
total seed weight (g)	60.3 xx	47.5	55.4 xx	38.1	69.1 xx	54.8
		.05 ppm				
% sterile seeds (means)	23.4	31.4	33.9	53.3	22.5	32.8
straw weight (g)	55.1 xx	81.3	69.3 xx	102.7	56.9 x	71.3
100 seed weight (g)	2.33	2.32	2.49 x	2.35	2.45	2.49
total seed weight (g)	52.3	46.7	50.3 xx	26.7	63.6 xx	49.4
		.10 ppm				
% sterile seeds (means)	25.4 x	35.2	29.9 xx	52.9	31.2	36.1
straw weight (g)	57.6 xx	77.7	69.5 xx	86.8	61.8 xx	87.3
100 seed weight (g)	2.39	2.33	2.48 xx	2.31	2.45	2.50
total seed weight (g)	52.6	45.3	52.5 xx	28.0	62.0 xx	50.5

x - statistically significant difference at 5% level.

xx - statistically significant difference at 1% level.

Table A10. Statistical comparisons between pots 1-6 and 7-12

SO_2

Cultivars	M7		M9		S201	
Parameters	1-6	7-12	1-6	7-12	1-6	7-12
		.15 ppm				
% sterile seeds (means)	24.7	28.3	32.6 xx	53.5	18.2 xx	31.1
straw weight (g)	59.2 x	72.6	72.2 xx	99.5	53.7 xx	73.3
100 seed weight (g)	2.35	2.34	2.41	2.33	2.29 x	2.45
total seed weight (g)	51.7	48.4	49.1 xx	24.3	62.8	57.8
		.20 ppm				
% sterile seeds (means)	21.9 x	30.9	36.8 xx	56.4	20.3 x	29.8
straw weight (g)	59.3 xx	76.4	64.4 xx	92.0	51.4 xx	67.1
100 seed weight (g)	2.30	2.31	2.21	2.30	2.26	2.36
total seed weight (g)	53.6	49.0	39.6 xx	24.5	57.6	53.7

x - statistically significant difference at 5% level.

xx - statistically significant difference at 1% level.