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Natural Gas as a Source of CO2 for Greenhouse Plants

by Roderick McKeag [1]

Products of combustion of natural gas (methane) are CO_2 and water. Through the efficient burning of pure natural gas, high purity CO_2 can be obtained in a 1:1 ratio based on volume. The purity of CO_2 obtained is directly proportional to the purity of the fuel burned. Since sulfur is a contaminant of natural gas and its combustion product, SO_2, is injurious to some plants in very small concentration, it is essential to detect SO_2 in the greenhouse before it reaches dangerous concentrations.

Gas suppliers have established maximum tolerances for sulfur in natural gas, varying with sources of the gas. The tolerance limits for greenhouse crop plants and symptoms of injury are needed. The purpose of this investigation was to find one or more plant indicators for SO_2 injury that were more sensitive to SO_2 than carnation. It was also hoped to establish the degree of safety a grower would have with natural gas containing several levels of sulfur contamination.

Fumigation chamber conditions

Natural gas used in combustion passed from an 8 psi line through a meter and a pressure regulator reducing it to 6 psi. It then passed over liquid mercaptan to receive its sulfur contamination before being combusted by a small "bunsen-type" burner. To cool the gas, a 2-inch pipe system of about 4 feet in length was used. A chamber to hold the plants was constructed of wood with the dimensions of 3 x 3 x 6 feet. This structure was covered with polyethylene and set on a table. Four-inch fans were used on each end to dilute the combustion products. The fan connected between the chamber and the cooling pipe pulled the combustion products and air into the chamber. Temperatures of approximately 85F and CO_2 levels of 800-840 ppm could be maintained by this equipment. This system was placed in a shaded area and received only north radiation. This was measured at 200-400 ft-c by a Weston sunlight meter.

Experimental plants

Plants were grown under greenhouse conditions and moved into the chamber to be tested. All plants were watered at the beginning of each experiment.

Plants were analyzed by a visible injury index. CO_2 measurements were made with a MSA Lira infrared gas analyzer. Temperature was measured by a laboratory thermometer. Sulfur contaminants in the gas and air mixtures were measured by the Public Service Company of Colorado with a Model 300 iodine-bromine titrator. Total gas analysis on a set of samples was done by Tectrol, St. Joseph, Michigan;

[1] This work is a part of that done by the author in completing the requirements for the M.Sc. Degree at Colorado State University.

and SO_2 was checked by Mr. John B. Pate of the National Center for Atmospheric Research, Boulder, Colorado.

Results

Plants were fumigated with combustion products from natural gas high in sulfur content to determine sensitivity and detrimental effects on various plants including carnation and chrysanthemum. Stages of development and varietal symptomology were also studied.

Early in the study, three plants were selected for their symptomology and growth characteristics to be used as indicator plants: petunia, tomato, and snapdragon. A graphic representation of relative sensitivity appears in figure 1.

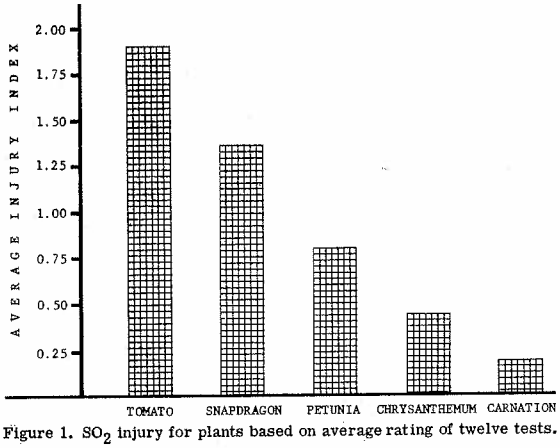

Figure 1. SO_2 injury for plants based on average rating of twelve tests.

Plates 1-5 show typical symptoms of SO_2 damage on the carnation, chrysanthemum, and indicator plants. These symptoms were consistent throughout the study and agree with other researchers.

Plates 6 and 7 show 5 stages of development of the indicator plant and the corresponding damage at each stage. Sensitivity of tomato plants to SO_2 is reduced when the plant matures to the open flower stage, although it is quite sensitive throughout the active growing period. Petunia fails to respond to SO_2 when the plant is very young, but it is very sensitive throughout the growing and reproductive stages. Snapdragon was insensitive to SO at both ends of its growth cycle indicating a correlation between sensitivity and the theoretical growth-rate curve. Response to SO_2 in the snapdragon is in proportion to growth rate.

The threshold concentration of sulfur-contaminated atmosphere causing damage to the most sensitive plant tested, tomato Marglobe, was 0.5 grains sulfur per 100 cubic feet.

Whether this concentration or higher concentrations would ever occur in Colorado greenhouses is doubtful. This statement is based on data supplied by Public Service Company of Colorado. Their tests of total sulfur content of the main gas line showed 0.3 to 0.4 grains sulfur per 100 cubic feet.

Formulas that can be used to determine theoretical SO_2 potential for natural gas are:

1) $Kg = P$
   K = constant, g = grains of total sulfur,
   P = ppm SO_2 potential

2) $\frac{b}{a} = \frac{1}{D}$
   b = ppm CO_2 at burner, a = ppm CO_2 above atmospheric, D = dilution factor

3) $\frac{1}{DP} = C$
   D = dilution factor, P = ppm SO_2 potential,
   C = SO_2 contamination

In our tests:

1) $16 \times 0.4 = 6.4$ ppm SO_2
2) $119{,}000/500 = 238$ times
3) $\frac{1}{238} \times 6.4 = 0.027$

Since 0.5 grains sulfur per 100 cubic feet is required to damage tomato and 1.4 grains per 100 cubic feet is required to damage carnation, natural gas is a relatively safe source of CO_2 as long as the sulfur content does not exceed the above levels.

Varietal differences to SO_2 injury were found in chrysanthemum varieties, Jupiter (sensitive), and Princess Ann (resistant). Since varietal differences were noticed in chrysanthemum, tests were run to determine if varietal differences would be evident in other species such as tomato. A range of growth stages for the 3 varieties, Marglobe, Manapal, and Fireball, were tested and replicated but no differences were evident. Since the tomato is a more sensitive species than chrysanthemum, perhaps the varietal differences, if any, were in amplitude below detection.

Editor's Note:

Editor's Note: All of the goals of this investigation were not achieved. Plant indicators more sensitive to SO_2 injury were found. Tomato (any variety) can be grown along with carnation, rose, or chrysanthemum and will show SO_2 injury before the flower crops. Sulfur contamination of 0.5 to 1.0 grains/100 ft in the fuel supply could cause injury on the tomato plants without injuring carnation or chrysanthemum. It is suggested that growers of flower crops use actively growing tomato plants as indicators. Re-

planting tomatoes at 4 to 6 month intervals and pruning the plants occasionally to keep active growth on the plants should insure the presence of sensitive growth at all times.

We were not able to establish the level of SO_2 in parts per million in the greenhouse atmosphere required to injure the various plants. Differences in measurement of total sulfur in fuel by gas companies and measurement of contaminants by atmospheric scientists have contributed to this problem. Too, there is no simple way to measure SO_2 in a greenhouse except with indicator plants.

We do feel, however, that natural gas with total sulfur content no higher than 0.5 to 1.0 grain per 100 cubic feet is safe for the majority of flower crops. While no work was done with rose, its tolerance for SO_2 is near chrysanthemum or carnation, possibly even higher. Additional work is being done this year to resolve the problem outlined here.

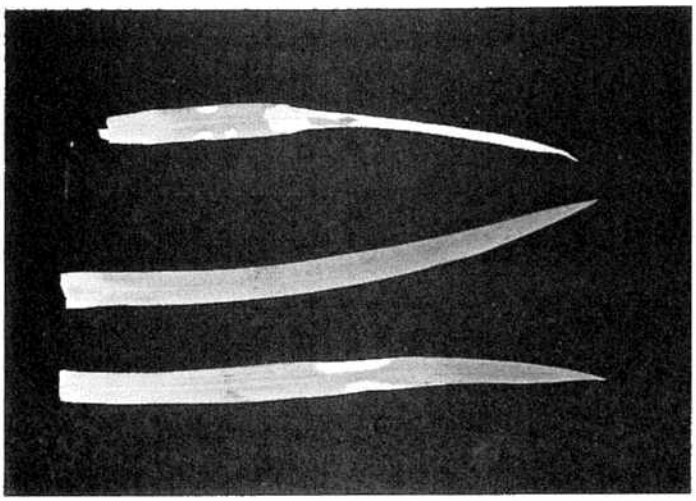

Plate 1

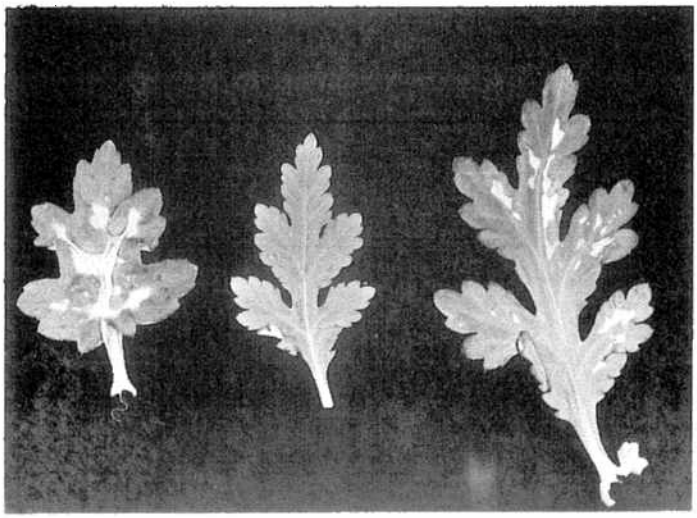

Plate 2

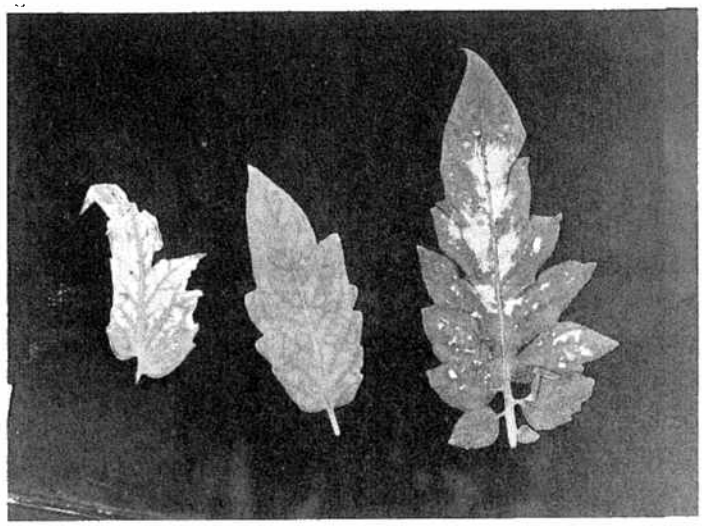

Plate 3

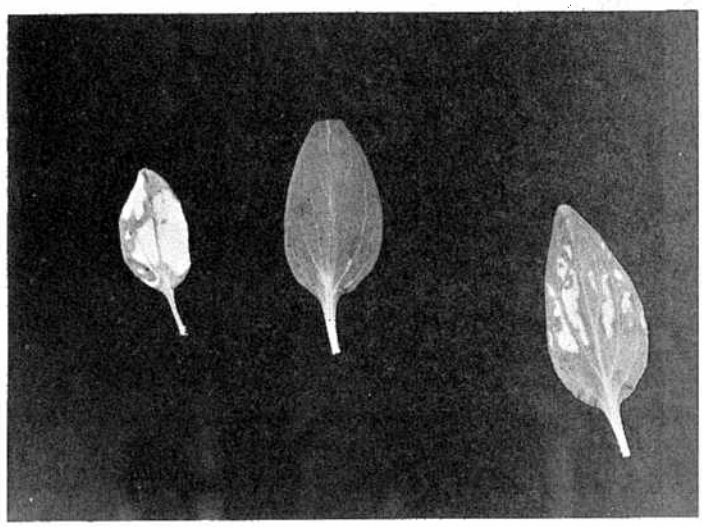

Plate 4

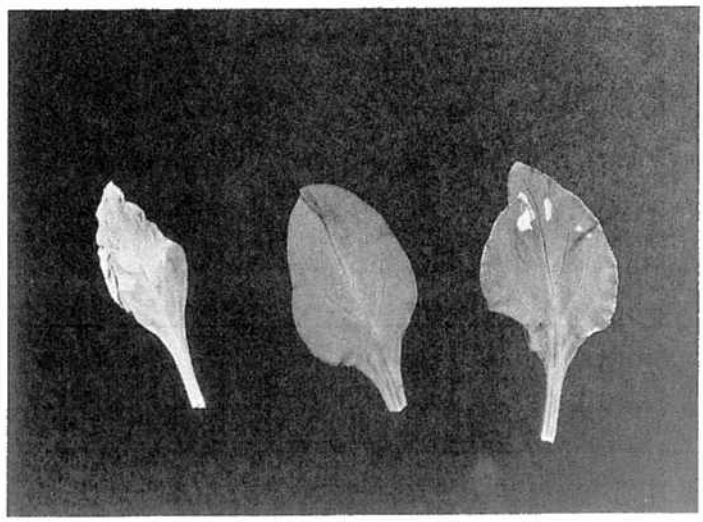

Plate 5

Plates 1-5 show severe SO_2 injury on left and moderate injury on right compared to uninjured leaves (center). The plates show leaves of carnation (1), chrysanthemum (2), tomato (3), snapdragon (4), and petunia (5). For relative sensitivity to SO_2, see figure 1.

Plate 6

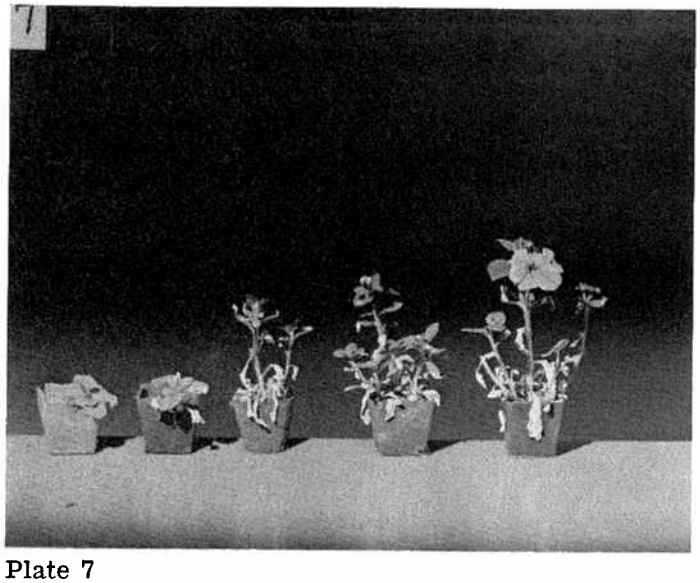

Plate 7

Plates 6 and 7 show stages of development most sensitive to SO_2 injury. Tomato is most easily injured in actively growing middle stages. Young plants of petunia are relatively resistant to SO_2 injury.

Your editor,

W D Holley

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