Acid fog injures California crops

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The effect of acid rain on agricultural crops has been studied extensively in the past decade by plant scientists in the United States. Research has shown that agricultural crops can be injured as acidity in rain approaches pH 3. Since this level of acidity is rarely reached in normal rainfall in California, acid rain had been thought to be of little or no consequence to agriculture in this state. Recent measurements of fog, however, have indicated that fog acidities in the range of pH 2 to 3 routinely occur in southern California, and fog with an acidity greater than pH 2 has been reported. Similar levels have also been reported in the southern San Joaquin Valley. The findings of fog more acidic than vinegar (pH 3.0) or lemon juice (pH 2.0) prompted the research reported here, to determine the possible effects of acidic fog on crops.

Experimental procedures

Solutions for producing simulated acidic fog were prepared from the background ions occurring in natural fog in southern California. These solutions were acidified to specific pH levels with a 2.5:1 ratio of nitric to sulfuric acid, the ratio reported to occur in some southern California fogs. Fog was generated from the acidic solutions using commercial fog nozzles.

Plants were exposed to the fog at acidity levels from pH 1.6 to 5.6 or 1.6 to 3.2. Potted plants in a greenhouse and field-growing plants in 1.5-meter plot rows received one- or two-hour fog treatments on one day or two consecutive days each week for several weeks. Exposures were made at night or predawn to simulate the period when most natural fog occurs. Plots were enclosed in polyethylene shelters during fogging to prevent drift between plots.

Plants were evaluated several days after treatment for leaf injury from acidic fog. At normal harvest maturity, crops were harvested, and growth and yield were measured.

Acidity is measured by "pH" (hydrogen ion concentration) units on a scale of 0 to 14. The midpoint, 7, indicates a neutral solution. Values above pH 7.0 are considered "basic," or alkaline; those values below 7.0 are "acidic." As the pH scale decreases, the acidity increases; for example, pH 2.0 is more acidic than pH 4.0.

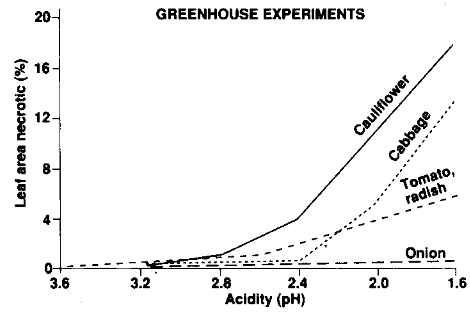

Fig. 1. Leaf injury to four vegetable crops, after eight total hours of exposure to acid fog, became more severe with greater acidity.

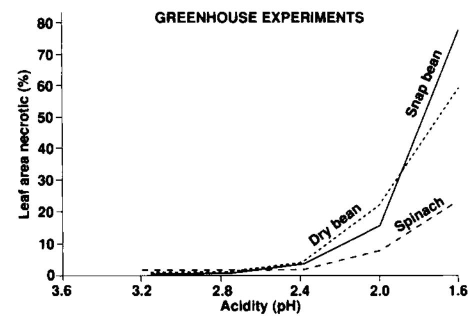

Fig. 2. The same length of exposure to acid fog caused greater injury to dry bean, snap bean, and spinach plants.

Acid fog injury appears as distinct, irregularly shaped, light-colored spots on the plant canopy. This spinach leaf was exposed to acidic fog at pH 2.0. Levels of 2.5 to 2.6 reduced marketability of crops such as spinach, cauliflower, and lettuce.

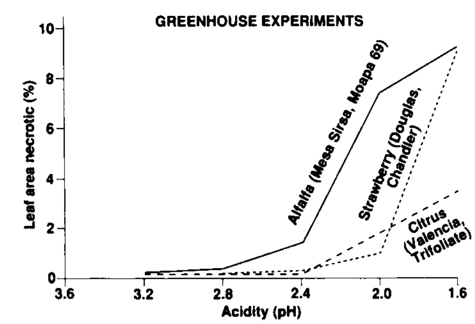

Fig. 3. Field and fruit crops after the same exposure showed considerably less injury.

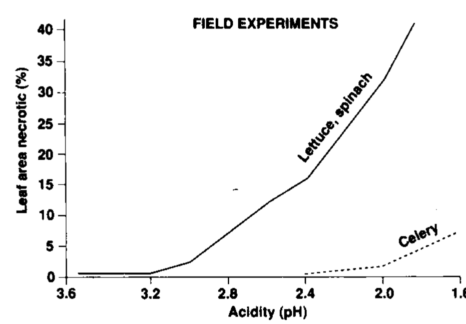

Fig. 4. Vegetable crops in the field were also injured by exposure to eight total hours of fog at the greater acidity levels.

Acid fog injury

These experiments indicated that most crops are quite tolerant to acid fog, but would be injured at acidity levels near pH 3. Most injury occurred on the most exposed portion of the plant canopy. Injury became more severe as acidity increased toward pH 2. A single two-hour exposure to acidic fog at pH 2.8 or greater caused low injury to most plants. Marketability of several crops (cauliflower, spinach, lettuce) was reduced at acidity levels of pH 2.4 to 2.6. Acidities greater than pH 2 were required to reduce crop yield, and then only after repeated exposure. Celery and onions were injured but had no loss in yield after several exposures to fog as great as pH 1.6. Injury to foliage after eight total hours of intermittent exposure to fog over several weeks is illustrated in figures 1 to 4.

Examination of acidity at leaf surfaces of plants exposed to acid fog revealed that leaf tissue was able to neutralize acidic input. Neutralization capacity varied with plant species. As expected, leaves neutralized less acidic fogs more readily than those with high amounts of acidity. The mechanism of this neutralization was not determined in these studies, but neutralization apparently takes place at the leaf surface where buffering chemicals are transferred from inside the leaf. Species varied in susceptibility to injury from acidic fog even though they demonstrated similar capacities to neutralize acidity.

Conclusions

Although injury to vegetable crops can occur from exposure to acidic fog, ozone still accounts for most yield loss from air pollutants in California.

A more subtle effect of acid fog may be host/pest or host/disease interactions. In our field studies, severity of insect and disease injury to crops appeared to be influenced by exposure to acidic fog. Incidence of bacterial soft rot on lettuce, Rhizoctonia basal stalk rot on celery, and cabbage looper feeding on spinach were all increased at low pH fog treatment levels. The mechanisms for these interactions were not determined in these studies. Our results suggest, however, that exposure of crops to acid fog may affect pest management strategies by increasing the need for pesticides for insect or disease control.

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Persimmons for California

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Oriental persimmons were probably introduced into Europe from Japan by early silk and tea traders. Europeans, especially the Italians, refer to the persimmon, *Diospyros kaki* L. (Ebenaceae family), by the Japanese name kaki. This is because the name persimmon is strictly American, of Algonquian origin. In 1856, Commodore Matthew C. Perry obtained persimmon seeds when the American naval fleet visited Japan. He had them planted on the grounds of the Naval Observatory, near Washington, D.C., but none of the seedlings survived.

Later, the U.S. Department of Agriculture (USDA) imported from the Orient a large number of cultivars as well as the species *D. lotus*, which is commonly used as a rootstock for *D. kaki* cultivars. These and other cultivars brought over by Japanese and Chinese immigrants before 1919 were propagated at the USDA Plant Introduction Garden then in Chico, California. The USDA station at Beltsville, Maryland, also assembled many cultivars, which were distributed primarily to the southern states.

In 1919, a quarantine was imposed on the importation of persimmons to prevent introduction of diseases and insect pests. Many cultivars from the Chico Plant Introduction Garden were repropagated on the University of California campus at Los Angeles and at the UC Wolfskill Experimental Orchards in Winters. Part of the UCLA collection was moved to the UC South Coast Field Station in Santa Ana in 1960.

The distribution of cultivars from these sites, nurseries, and individual growers provided the nucleus of the persimmon industry in California. Some cultivars assembled at the Chico Plant Introduction Garden were subsequently discovered to have been mislabeled, misspelled, or carried under the provincial names of their points of origin in China, Korea, or Japan when they were introduced. Researchers in California, Italy, and Israel noticed that a cultivar presumed to be Fuyu that was distributed from Chico occasionally bore male flowers, whereas other Fuyu trees did not. Male flowers have never been reported on the original Fuyu trees in Japan. In Italy and Israel, the cultivar that bears male flowers is referred to as the California Fuyu, because the cultivar was initially sent to these countries from California.

Although the fruits of Fuyu and California Fuyu or Cal-Fuyu are indistinguishable in shape, size, and color, the two clones should be marketed as separate cultivars. During our attempt to clear up the confusion in names and identification of other persimmon cultivars, we found these two clones to be genetically different. Leaves sampled from trees growing in the two campus collections were analyzed for isozyme patterns using starch gel electrophoresis (as described by Tao and Sugiura, *HortScience* 22:932-35, 1987). Cal-Fuyu and Fuyu differ from one another in their GPI (glucose-phosphate isomerase) patterns but are nearly alike in their PGM (phosphoglucomutase) patterns (fig. 1). GPI patterns of Fuyu and Jiro are indistinguishable, but the

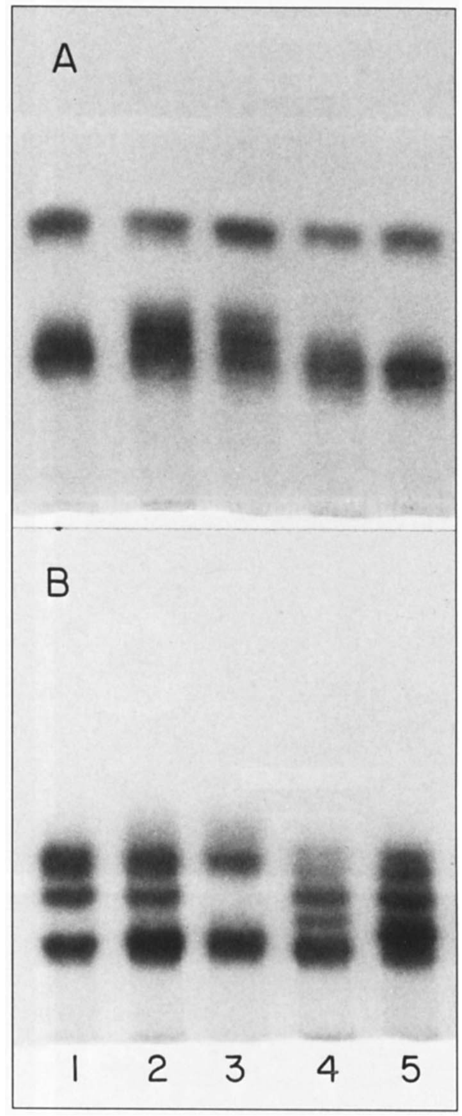

Fig. 1. Genetic differences and similarities in persimmon cultivars are apparent in leaf isozyme patterns of glucose-phosphate isomerase (A) and phosphoglucoisomerase (B) for California Fuyu (1), Fuyu (2), Jiro (3), Hana Fuyu (4), and Gosho (5).