EXECUTIVE SUMMARY

INTERACTION OF O_3 WITH SALINITY ON VEGETATION

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Vegetation growing under field conditions is rarely exposed to a single environmental stress: generally, several stresses occur simultaneously. Plant responses to a single environmental stress such as air pollution are, in fact, modified by soil or climatic factors. Thus, the quantitative effects of air pollutants documented under closely controlled experimental conditions, e.g., photosynthetic changes, mineral content, or dry matter production, may not reflect the effects occurring under field conditions.

Photochemical oxidants (primarily O_3) have been shown to affect the physiological response, growth and yield of many crops. Both the California Air Resources Board (CARB) and U. S. Environmental Protection Agency have funded research to quantify these effects, but only for plants growing under optimum field conditions. This is a necessary primary step to establish baseline response curves for different air pollutant levels. However, research is now necessary to interpret the predicted plant responses based on actual field conditions by considering the most likely environmental stresses which may affect the plants.

Salinity is an existing or potential threat to crop production in most of the irrigated soils of California. It is estimated that crop yields are significantly reduced on at least one-third of the irrigated acreage. Much of this acreage is also subject to detrimental effects of air pollution.

Salinity has been shown to reduce air pollutant injury to crops under laboratory conditions. Hoffman and co-workers at the USDA Salinity Lab in Riverside, CA, showed that a moderate, not injurious, level of salinity reduced O_3 effects on plant injury and yield compared to nonsaline O_3-exposed crops, including alfalfa, pinto beans and red beet. High salinity levels reduced O_3 injury but the salinity itself caused large reductions in yield. Bytnerowicz and Taylor found that salinity decreased O_3 injury in snap beans. High salinity, however, had no effect on O_3-induced reductions in snap bean dry weight. In these salinity-air pollutant studies, the beneficial effects of salinity in reducing air pollutant effects were attributed to salinity-pollutant interactions in causing stomatal closure and, therefore, less pollutant uptake.

There has been little physiological research investigating the metabolic basis for any form of soil environment stress and O_3 interaction. Generally, stomata close to a greater extent with the combination of either salinity or water stress and O_3 than with either single factor. The resulting decrease in gas exchange is believed to reduce the uptake of O_3 into leaves, with subsequent reductions in visible injury symptoms attributable to O_3, or the O_3-induced reduction in yield. In the field an O_3 x salinity effect on stomatal closure over a long period of time could significantly affect the uptake of CO_2, and hence the production of plant dry matter via photosynthesis. However, there are no reports of measurements for photosynthesis in salinity-O_3 interaction studies. Furthermore, there has been little research reported on the effects of O_3 alone on photosynthesis. Coyne and Bingham described an O_3-induced reduction in net photosynthesis for southern California pine stands. If crops are also affected by O_3, the added decrease in CO_2 uptake with saline water could produce a synergistic effect on yield.

Research has only recently been initiated to investigate the effects of salinity by itself on plant photosynthesis. To date, salinity has not been found to affect photosynthetic rates directly, but affects plant productivity primarily through inhibited leaf expansion. This inhibited expansion could be especially important in affecting the pollutant transport into leaves, and, hence, relative sensitivity to air pollutants.

The U.S.D.A. Salinity Laboratory has the controlled salinity treatment plots necessary for a careful investigation of the physiological growth and yield effects of salinity in vegetation. The Statewide Air Pollution Research Center has the facilities for careful control of air pollutant exposures, as well as tools for investigating the responses of plants. Together, research groups from both agencies provided a well designed experiment to quantitatively study the interaction between these two important plant stresses in California: salinity and O_3 air pollution.

Objectives. The primary objective of this study was to determine the effects of O_3 on vegetation in the absence and presence of three levels of salinity stress. Two alfalfa cultivars including a newly developed salinity-resistant cultivar, were tested under field conditions.

Subordinate objectives of the study included:

(1) Obtain physiology data to understand the mechanism for the air pollutant-salinity effects to increase the applicability of the results for other species and conditions.

(2) Establishment of dose-response curves for plant productivity in response to O_3 and salinity alone and in combination.

(3) Determine whether salinity resistant cultivars of plants are also resistant to O_3.

The interaction between ambient O_3 and salinity on vegetation was evaluated in the field. Alfalfa, an important crop grown in the Sacramento and San Joaquin Valleys and Southern California, was the test plant. Two cultivars, one salinity resistant "U.C. Salton," but of unknown O_3 sensitivity, and a second salinity sensitive and moderately sensitive to O_3 "Moapa," were grown at three salinity levels in soil plots at the U.S.D.A. Salinity Laboratory, Riverside, California. Salinity treatments were imposed by irrigating with waters having electrical conductivities (EC) of 0.7, 3 and 6 dS m^{-1} which resulted in saturated-soil extract conductivities (EC_e) over all treatments and harvests of approximately 1.8, 6.4 and 9.6 dS m^{-1}, respectively. The 1.8 dS m^{-1} conductivity level represented soils with no salinity problem. The 6.4 and 9.6 dS m^{-1} conductivity levels represented soils with salinity problems as found in approximately 29% of the irrigated agricultural areas of California. To evaluate the effects of excess salinity in the absence or presence of O_3, plants were exposed in open-top chambers to filtered or unfiltered air at ambient O_3 concentrations continuously over approximately four and one-half months from July through mid-November 1985. Important physiological measurements including net photosynthesis, stomatal conductance, water potential, and tissue elemental content, were made to determine the metabolic basis for the salinity-O_3 interaction. The dry matter production and distribution within the plants were evaluated at four harvests by measuring fresh weight, dry weight, number of nodes per stem, number of empty nodes per stem, and height.

There was no overall significant interaction between ambient O_3 and salinity. There was little effect of O_3 itself on growth, yield, or physiology. Ozone primarily caused leaf injury, as measured as percent empty nodes for three of the four harvests. For two of these harvests, leaf injury occurred to the same extent in ambient and filtered chambers regardless of the salinity level; for the other harvest injury was reduced with increasing salinity. There were also O_3 effects on total fresh weight, total dry weight, and height - but only for one harvest each. Salinity was much more detrimental than O_3 in affecting plants, causing occasional reductions in fresh weight, dry weight, increased stem percent dry weight, decreased percent empty nodes, decreased height, decreased photosynthetic rates, more negative stem water pressure potentials, and altered elemental content. There were large differences in growth and yield between the two cultivars. A large difference in alfalfa growth and physiology appeared to develop between chambers and outside plots as the growing season progressed. However, it could not be analyzed statistically because of differences in soil salinity levels between these two treatments. Outside plants tended to have higher fresh and dry weights, a higher percent dry weight, were shorter, had fewer empty nodes, and altered elemental content compared to ambient chamber plants.

Conclusions

This study was complex because of changes in plant response with salinity, O_3, cultivar, chambers, and season. However, the following generalizations are indicated by the study.

1. Increased soil salinity did not interact with ambient O_3 to decrease growth or yield below that caused by the individual stresses.

2. The only interaction, between soil salinity and O_3 was decreased O_3-induced leaf senescence with high levels of soil salinity at one harvest.

3. Open-top field chambers themselves had effects on plant growth, especially with cooler, overcast weather conditions. These chamber effects can overshadow any single treatment effects or interactions.

4. Crop cultivars differed in their response to stresses, thus, results with only one cultivar produce an incomplete picture of possible pollutant and environmental factor interactions.

5. Alfalfa did not respond well in chamber studies in cooler months such as the fall. The stems tended to elongate in chambers compared to outside, resulting in lodging of plants, and associated apparent decreases in yield.

6. Repeated physiological measurements are required for accurate assessment of the metabolic basis for any interaction responses.

Recommendations

This study indicated the complexity of studies investigating interactions between air pollutants and other stress factors in the field. Future studies should minimize the influence of other factors on plant response to maximize the potential to detect statistically significant stress interactions. Recommendations to accomplish this include:

1. Investigate stress interaction using an exposure system that minimizes environmental modification due to chamber walls, air movement, etc. Open air release (ZAP) systems or air exclusion systems are recommended over field chambers.

2. Conduct the study only during a single season of the year, i.e., summer rather than spring or fall, to minimize influence of seasonal environment on the stress interaction.

3. Increase levels of each factor beyond two.

4. Intensively investigate important physiological responses to the stresses on a frequent basis.