

Effects of fumigating crops with hydrogen sulfide or sulfur dioxide

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Adding CO₂ to emissions from geothermal energy sources can prevent plant injury and even increase plant growth rate.

Emissions generated by geothermal energy sources may be injurious or beneficial to crops, forests, or ornamental plantings, depending upon concentrations and composition of the gases. Noncondensable gases from these wells are usually made up of about four-fifths carbon dioxide (CO₂) with lesser amounts of hydrogen sulfide (H₂S), ammonia (NH₃), hydrogen (H₂), nitrogen (N₂), and methane (CH₄). The additional CO₂ may increase the rate of plant growth, and H₂S, although injurious at high levels, could increase yield at low levels. Recent studies by Shin *et al.* showed that adding CO₂ up to 15 parts per million (ppm) above ambient levels plus 1 ppm H₂S for 3 hours caused a stimulation in apparent photosynthesis and stomatal relaxation with lettuce.

The present studies were conducted to aid in predicting what effects emission of H₂S and CO₂ from geothermal energy development would cause on four important crops: lettuce, sugarbeets, cotton and alfalfa. A limited comparison was made between the effects of H₂S and sulfur dioxide (SO₂) on lettuce and beets because H₂S is oxidized in the atmosphere to SO₂.

Experiments

The plants were grown in fiberglass-covered greenhouses with an average light transmittency of 80 percent. Airflow at one exchange per minute was supplied by evaporative coolers after purification by filtration through activated charcoal. Temperature range within the greenhouse approximated that of the outside. All plants were grown from seed in containers in a soil mixture of peat, redwood shavings, and silt 1-1-1. Essential nutrients were added to the soil as salts and in solution when the plants were watered.

The fumigating gases were dispensed from cylinders, and flow rates were controlled by means of pressure reducers and thermostated capillary flow controllers. The gases were injected continuously through capillary flow controllers into the incoming airstream immediately after the ventilating fans. H₂S and SO₂ concentrations, monitored intermittently with a Phillips Model PW 9700 H₂S analyzer, remained uniform and reproducible over extended periods of several weeks. Six treatments consisted of carbon-filtered air (control); 30 parts per billion (ppb) H₂S; 100 ppb H₂S; 300 ppb H₂S; 300 ppb H₂S + 50 parts per million CO₂; and 300 ppb SO₂. Carbon dioxide was monitored with a Model 215B Beckman Infrared Analyzer.

Lettuce

The first of three crops of *Lactuca sativa* 'Dark Green Boston' head lettuce was grown from March 13 until May 10, 1976. Only the control and H₂S treatments were used. Fumigation with 30 ppb H₂S caused a large increase in fresh weight of the total plant (160 percent of control) but 100 ppb treatment results were equal to the control, and 300 ppb caused severely reduced growth; head weight was 33 percent of control. A second crop, grown August 12 to November 8, 1976, involved all treatments except the SO₂ (see table 1). Plants exposed to 0, 30, and 100 ppb H₂S did not exhibit visible injury. The fresh and dry weights following 0 and 100 ppb treatments were not significantly different at harvest time; with 30 ppb H₂S, however, the plants formed larger and firmer heads as demonstrated by increased head weight. Exposure to 300 ppb H₂S caused early chlorotic symptoms and gave the plants a mottled appearance. The leaves remained narrow, no

heads were formed and the weight of plants was reduced. At 300 ppb H₂S + 50 ppm CO₂, the plants did not develop chlorotic symptoms until four weeks before harvest and initially grew faster than plants treated with 300 ppb H₂S alone. Reduction in weight of plants was therefore less severe but no heads developed.

The third crop, grown from October 20, 1976 until January 4, 1977, included a treatment with SO₂ at 300 ppb. The fresh and dry weights at 30 ppb H₂S, 100 ppb H₂S and 300 ppb SO₂ were significantly increased but were reduced at 300 ppb H₂S. The addition of 50 ppm CO₂ to 300 ppb H₂S showed again to be beneficial as demonstrated by an increase in fresh and dry weights. Difference between the results of second and third crops may be a seasonal effect, since temperatures were considerably lower during the latter experiment.

Sugarbeets

Three crops of *Beta vulgaris* 'Holly' hybrid sugarbeets were grown, each receiving all six treatments. In the first crop five pots per treatment were planted with three beets per pot. In the second crop, replication was increased to ten pots per treatment with three beets per pot. Because the beet is such a competitive species, one beet in each pot was stunted. Average weight per beet at harvest was recorded (see table 2). In the third crop two beets were grown per pot in an attempt to overcome the stunting but some weight variation in the two beets still occurred. Average weights were used for statistical evaluation of all results in the beet study (see table 2).

H₂S at 30 and 100 ppb significantly increased fresh and dry weight of leaves and fresh weight of roots above controls in the first crop. Similar significant increases or numerical trends were shown in the second and third crops. At 300 ppb H₂S, the three parameters were reduced in all three crops when compared with the values obtained with 30 ppb. Addition of 50 ppm CO₂ plus 300 ppb H₂S caused an increased dry weight of leaves in the first crop and fresh root weight in the second crop when compared with the 300 ppb H₂S alone.

Fumigation with 300 ppb SO₂ caused an increase in fresh leaf weight in the first crop when compared with the control. No significant difference between these two treatments was shown in the other two crops. Comparisons of the effects of 300 ppb H₂S and 300 ppb SO₂ showed them to be statistically equal except in the second crop where H₂S reduced leaf dry weight more than SO₂. On a few days when relative humidity increased in the greenhouses to 70 to

80 percent, severe foliar injury occurred on the beets being fumigated with SO₂. None was seen with H₂S.

Cotton

Gossypium hirsutum 'Acala SJ3' cotton was grown as single plants in 18-liter pots. Ten plants per treatment and three treatments were used: carbon filtered air, carbon filtered air + 300 ppb H₂S, and carbon filtered air + 300 ppb H₂S + 50 ppm CO₂.

Fresh and dry weight of leaves and dry weight of combined leaves and stems were unaffected by 300 ppb H₂S, but the addition of CO₂ caused a significant increase over H₂S alone (see table 3). The sulfide seemed to accelerate maturity because flower and boll weights were tripled. The sulfate accumulation was less than in other plants such as alfalfa. The reduced level of sulfate with CO₂ as compared with H₂S alone could be a diluting effect caused by increased carbon fixation.

Alfalfa

Medicago sativa 'Hayden' alfalfa was grown, three plants per 18-liter pot, with the same three atmospheres as cotton. Ten pots per treatment were used. Six successive cuttings were taken, dried, and weighed (see figure). The results showed that 300 ppb H₂S caused no effect on the first two cuttings but reduced dry weight significantly during the succeeding four cuttings. Addition of 50 ppb CO₂ stimulated growth significantly in five of the six cuttings above growth with H₂S. With four of the six cuttings growth was greater in the H₂S + CO₂ treatment than in the control. The total for all six cuttings showed an average increase in yield of 24 percent.

Conclusions

Yield of lettuce in two of three experiments and the fresh and dry weight of sugarbeet leaves and roots was increased by 30 ppb H₂S. Toxicity of H₂S was equal to or slightly greater than SO₂ in a sustained "chronic" type of exposure with both lettuce and sugarbeets, but SO₂ caused foliar injury to beets when humidity was high. Adding 50 ppm CO₂ to 300 ppb H₂S overcame growth depression caused by H₂S alone or increased growth above controls in cotton and alfalfa.

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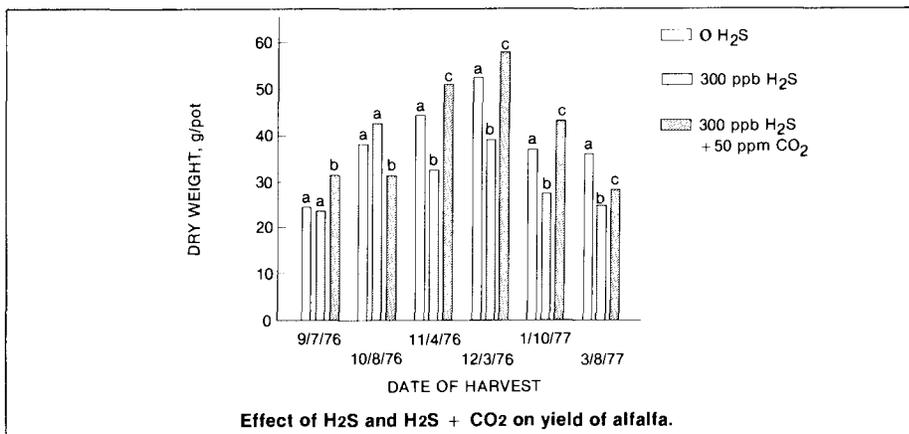


TABLE 1. Effects of Increasing Levels of H₂S, H₂S + CO₂, and SO₂ on Head Lettuce

Treatment	2nd crop*			3rd crop†		
	Total plant wt. (g)	Head wt. fresh	Head wt. fresh (g)	Total plant wt. (g)	Head wt. fresh	Head wt. fresh (g)
0 (control)	384.7 a‡	20.9 a	180.6 a	208 b	11.1 a	121.8 b
30 ppb H ₂ S	398.1 a	20.2 a	266.6 b	248 a	13.1 d	138.6 a b
100 ppb H ₂ S	351.1 a	18.2 a	213.4 a	256 a	13.1 d	160.6 a
300 ppb H ₂ S	119.6 b	8.4 b	no head	156 c	8.0 c	80.3 c
300 ppb H ₂ S + 50 ppm CO ₂	199.9 b	11.7 b c	no head	201 b	9.9 b	113.3 b
300 ppb SO ₂			no head	244 a	12.9 d	152.1 a

*Exposed Aug. 24 - Nov. 8, 1979
 †Exposed Nov. 10, 1976 - Jan. 4, 1977
 ‡Values having different letters different at 5% level

TABLE 2. Effects of Increasing Levels of H₂S, H₂S + CO₂, and SO₂ on Sugarbeets

Crop and replication	Treatment	Leaves		Roots	Dates of planting and harvest
		Fresh wt. (g)	Dry wt. (g)	Fresh wt.	
1st 3 beets/pot, 5 pots	0 (control)	414 c*	42 b	215 c	7/23/76 - 11/30/76
	30 ppb H ₂ S	679 a	65 a	323 ab	
	100 ppb H ₂ S	625 ab	59 a	345 a	
	300 ppb H ₂ S	547 b	46 b	167 c	
	300 ppb H ₂ S + 50 ppm CO ₂	528 b	60 a	259 abc	
	300 ppb SO ₂	549 b	48 b	222 bc	
2nd 3 beets/pot, 10 pots	0 (control)	335 a	93 bc	300 b	11/18/76 - 5/23/77
	30 ppb H ₂ S	363 a	97 ab	382 a	
	100 ppb H ₂ S	397 a	108 a	408 a	
	300 ppb H ₂ S	312 a	81 c	225 c	
	300 ppb H ₂ S + 50 ppm CO ₂	369 a	91 bc	305 b	
	300 ppb SO ₂	367 a	103 ab	256 bc	
3rd 2 beets/pot, 10 pots	0 (control)	380 c	43 b	300 bc	5/4/77 - 7/25/77
	30 ppb H ₂ S	543 a	61 a	508 a	
	100 ppb H ₂ S	505 ab	52 ab	354 b	
	300 ppb H ₂ S	419 bc	47 b	239 c	
	300 ppb H ₂ S + 50 ppm CO ₂	433 bc	53 ab	286 bc	
	300 ppb SO ₂	398 c	47 b	268 bc	

*Values having different letters different at 5% level.

TABLE 3. Effect of H₂S and H₂S + CO₂ on Cotton

Treatment	Leaves		Leaves & stems	Flowers & bolls	Percent total sulfate
	Fresh wt. (g)	Dry wt. (g)	dry wt. (g)	dry wt. (g)	
0 (control)	236.8 yz*	45.1 yz	85.6 z	7.5 z	1.40
300 ppb H ₂ S	203.6 z	40.5 z	78.3 z	20.8 y	1.60
300 ppb H ₂ S + 50 ppm CO ₂	252.8 y	48.7 y	101.7 y	21.8 y	1.34

*Values having different letters different at 1% level.