Plant uptake of bromide following soil fumigation with methyl bromide

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The highest concentrations in plants grown on soils that have been fumigated with methyl bromide occur during the first year following fumigation.

Methyl bromide is used as a soil fumigant primarily in mixtures with chloropicrin and the C_3 chlorinated hydrocarbons (dichloropropane and dichloropropene) to control nematodes, insects, and weeds. In mixtures with chloropicrin it has been used extensively since 1967 as a preplant soil fumigant to control soil-borne diseases of strawberries, particularly Verticillium wilt. Much of the methyl bromide diffuses throughout the surface 2 to 8 feet of soil, most of it eventually dissipating into the atmosphere. The amount that remains in the soil is either hydrolyzed or decomposed by microorganisms, in either case releasing the bromine as inorganic bromide. In this latter form it is a negatively charged ion and thus tends to move as water moves in the soil in a similar fashion to chloride and nitrate. Plant species absorb bromide from the soil. In some cases there may be phytotoxicity and at certain levels bromide may be hazardous to human health. This is especially true if the plants or edible portions of such plants as spinach, Brussels sprouts, strawberries, and grapes are consumed by humans. In 1970, the Food and Agriculture Organization/World Health Organization suggested a bromide tolerance limit of 20 to 30 ppm (parts per million) for fresh fruits and 30 to 250 ppm for dried fruits.

Materials and methods

In late 1973, small plots (about 4 square yards) of barley were established in Sonoma and Napa counties in several fields that had been recently fumigated with methyl bromide in preparation for planting grapevines the following spring. Small plots of barley were also established in some fields that had been fumigated one or two years earlier where grapevines were already growing. Control plots were set up in an adjacent area which had not been fumigated. All of the fumigation was done by a licensed applicator, commonly 400 pounds per acre (75 percent methyl bromide, 25 percent chloropicrin) injected 26 to 28 inches deep and about 5½ feet between chisel rows. Soils were covered with polyethylene sheeting for several days except where 600 pounds per acre (75 percent methyl bromide, 25 percent chloropicrin) were used, in which case the soil was not covered.

In March 1974, barley plants were sampled in the pre-boot stage. In addition, several native plant species were collected for comparisons, namely, filaree, bur clover, and wild oats, depending upon availability. The fields were too wet at this time for soil sampling. Hence, soil samples corresponding with the plant samples could not be collected until June 1974.

In 1975, soil and plant samples were collected from the same fields and three or four fields which were fumigated in the fall of 1974. Low soil-moisture levels permitted us to obtain soil samples and plant samples at the same time.

Strawberry leaf and fruit samples, and paired soil samples, were collected from control and fumigated fields representing one to six annual fumigations, from six different counties in California.

Grape leaves and fruit samples were collected from several control and fumigated plots.

Sweet potato leaves, petioles, and roots, together with paired soil samples, were collected from four fields in Merced County which were fumigated with methyl bromide and in which ryegrass had been grown between fumigation and planting with sweet potatoes. Four samplings were made during the growing season.

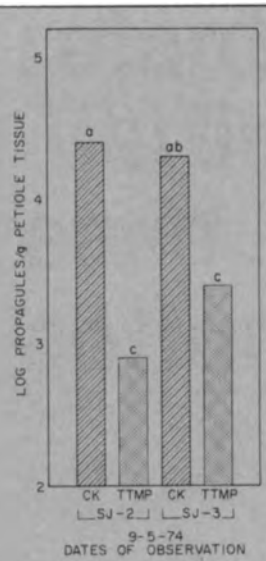
Experimental plots of spinach in Tulare County which had been fumigated with methyl bromide were sampled for subsequent bromide analysis.

Bromide concentration in plant material was determined by X-ray fluorescence; bromide in the soil was extracted with 0.1 M $Ca(NO_3)_2$ solution (two parts solution to one part soil) and determined in the extract with a bromide specific-ion electrode.

Results and discussion

Bromide concentrations and numbers of samples are shown in table 1. All data are taken from plants growing within one year after fumigation, except grapevines which represent samples collected two to four years after fumigation.

There are several points of interest in the data shown in table 1. Plants invariably show an increase in bromide concentration as a result of methyl bromide fumigation; however, there is wide variation in plant uptake from one location to another and from one species to another. Part of the variation may be due to different soil textures, temperature, amount of leaching, nonuniform distribution of the fumigant



*Letters a, b, and c indicate different statistical populations. (P = 0.01.)

Fig. 1. The effect of TTMP, applied at 80 g/ha. in mid-June to cotton foliage of two cultivars, on population of Verticillium dahliae in petiole tissue on September 5, 1974.*

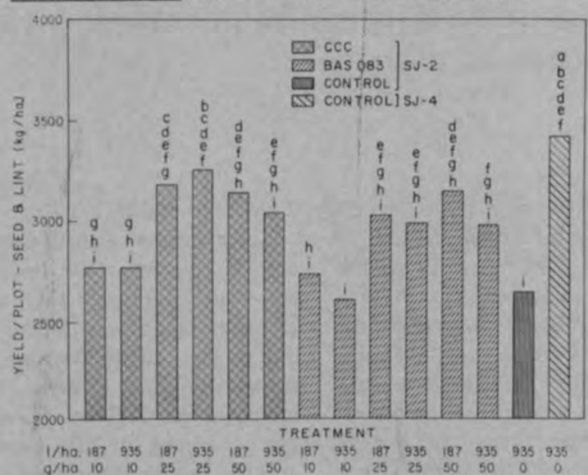


Fig. 2. Effect of CCC and DPC applied at early square formation (mid-June) on yield of cotton seed and lint on land infested with Verticillium dahliae.*

*The volume of solution used to spray the cotton is given in liters/ha. The dosage of each chemical is given in g/ha. The data for the effect of the growth retardants on cv. SJ-4 was omitted because differences in yield due to chemicals were not significant. Bars with the same letter do not differ significantly. (P = 0.05.)

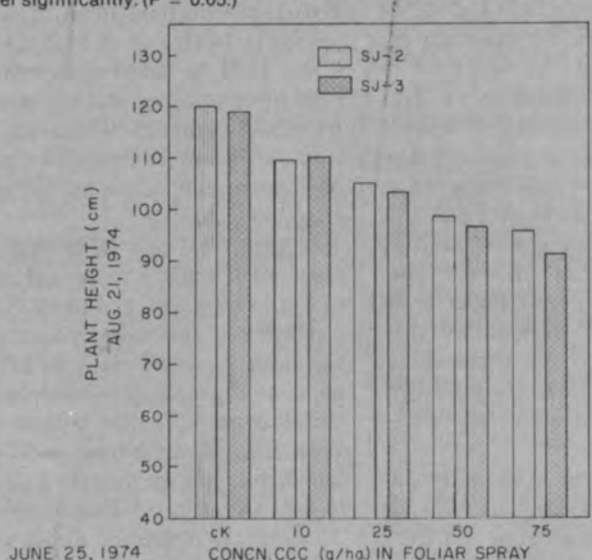


Fig. 3. Height reduction in two cultivars of cotton plants by application of CCC at different dosages.

through the soil, and rooting habits of the particular plant species. It does appear, however, that plants growing in soils that have not been fumigated commonly contain 10 to 30 ppm bromide but may occasionally approach 200 ppm bromide. No symptoms of toxicity to the plants were observed due to the high bromide concentrations, the highest value being almost 8,000 ppm. It is worth noting here that for some weeks after fumigation few, if any, plants grow on the treated soil.

Of equal importance is the distribution of bromide within the plant, as shown in figure 1, comparing strawberry leaf bromide with fruit bromide content (both on a dry weight basis) and a similar comparison for grape. The uptake of bromide by strawberry plants and grapevines as shown by leaf analyses (table 1) indicates much lower concentrations than for barley and bur clover. Furthermore, only a small proportion of the bromide translocates to the fruit in both species. Bromide concentrations in the strawberries and in the grapes were much lower than those found in the leaves of the same plants. Low bromide concentrations in grape leaves were probably due in part to samples being collected two to four years after fumigation. By that time most of the methyl bromide had dissipated into the atmosphere or leached below the rooting depth of the vines.

Bromide uptake by plants one, two, three, and four years after fumigation is presented in table 2. The data represent average bromide concentrations for all plant species collected in Napa and Sonoma counties in 1974 and 1975. Bromide concentrations are highest the first year after fumigation and approach concentrations of plants grown in nonfumigated fields in three or four years. It is worth noting here that strawberry leaf concentrations averaged less than 100 ppm bromide and seldom exceeded 400 ppm even when the soil was fumigated annually.

Bromide concentrations in soil and bromide concentrations in barley (whole top at pre-boot stage of growth) in Sonoma County (1974 sampling) are shown in figure 2. There is a reasonably linear relationship between soil bromide and plant uptake (R^2 = 0.74). However, the comparisons for the plots in Napa in 1974 and 1975 and Sonoma in 1975 showed much poorer correlations. Furthermore, soil bromide and bromide in strawberry leaves appeared to be poorly correlated. Additional studies are needed to determine how best to sample fumigated soil before soil analysis for soluble bromide may be used for predicting plant uptake of bromide and possible hazards.

Conclusions

Plants grown on soils that have been fumigated with methyl bromide usually show increased bromide concentrations. The highest concentrations occur during the first year following fumigation. While there is a potential health hazard involved, particularly where animals consume the forage grown, this can be minimized by choice of crop and by monitoring the accumulation of bromide by plants. It appears that fumigation before planting strawberries and grapevines is relatively safe, since the two crops do not absorb as much bromide from the soil as some other plant species and, furthermore, because bromide uptake in the fruit of both is extremely low.

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TABLE 1. Bromide Concentration of Several Plant Species in the Unfumigated and Methyl-Bromide-Fumigated Plots*

Plant species and part	Treatment	Range in bromide conc. (ppm)	Avg. bromide conc. (ppm)	S.E. of means
Barley (whole top)	Check	4 to 575	106 (19)**	38
	Fumigated	120 to 5,235	1,788 (23)	373
Bur clover (whole top)	Check	1 to 407	96 (11)	40
	Fumigated	196 to 2,371	1,334 (14)	155
Filaree (whole top)	Check	4 to 546	135 (14)	47
	Fumigated	718 to 7,380	2,600 (10)	683
Wild oats (whole top)	Check	9 to 876	196 (14)	66
	Fumigated	1,233 to 5,034	3,364 (11)	441
Spinach (leaves)	Fumigated	1,772 to 3,195	2,521 (04)	387
Ryegrass	Fumigated	1,481 to 2,790	2,378 (04)	302
Sweet potato (leaves)				
1st sampling	Fumigated	640 to 923	753 (04)	69
4th sampling	Fumigated	312 to 372	330 (04)	14
Sweet potato (root)	Fumigated	204 to 237	220 (02)	17
Strawberry (leaves)†	Check	14 to 129	63 (09)	16
	Fumigated	3 to 372	88 (36)	13
Grape (leaves)‡	Check	1 to 101	28 (90)	3
	Fumigated	1 to 402	48(278)	4

* These data represent samples collected the first year after fumigation with MeBr at rates of 300 to 600 lb/acre, except for grape leaves.
† Strawberry leaves were collected after one to six annual fumigations with MeBr.
‡ Grape leaves were collected two to four years after fumigation with MeBr.
** Numbers in parentheses refer to the number of samples in the average.

TABLE 2. Bromide Concentrations in Plant Material (ppm on Dry Weight Basis), 1, 2, 3, and 4 Years after Fumigation with Methyl Bromide

	Bromide concentrations (ppm)				
	Untreated	Years after Fumigation			
County	Controls	1	2	3	4
Sonoma	94 (19)*	3018 (16)	360 (15)	516 (8)	12 (3)
Napa	163 (21)	1476 (15)	742 (10)	430 (2)	

* Numbers in parentheses = number of samples included in the average.

Ozone-pesticide interactions

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Pesticides that interact to produce less damage may be of great value in minimizing air pollution losses and should be incorporated into pest management systems where there is significant air pollution.

Air pollutants and pesticides are two of the major environmental contaminants present in agricultural areas. Both categories of contaminants have been the subject of intensive research by scientists interested in pest management, phytotoxicity, and crop production. Most of the main effects of air pollutants and pesticides have, therefore, been documented rather extensively. However, the combined effects (interactions) of air pollutants and pesticides have not received equal attention.

A few fungicides, herbicides, anti-transpirants, and selected chemicals have been