

BROMINE RETENTION IN SOILS AND
UPTAKE OF BROMINE BY PLANTS
AFTER SOIL FUMIGATION

THESIS FOR THE DEGREE OF PH. D.
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This is to certify that the
thesis entitled
Bromine Retention in Soils and Uptake
of Bromine by Plants After Soil Fumigation

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of the requirements for

Doctor's degree in Philosophy

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BROMINE RETENTION IN SOILS AND UPTAKE OF BROMINE
BY PLANTS AFTER SOIL FUMIGATION

By

Zenobius Stelmach

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan
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ABSTRACT

The study of bromine retention by some soils and uptake of bromine and its effect upon plants was carried out in the field and in the greenhouse.

Hillsdale, Brady and Houghton soils were used in field study, and Brookston, Oshtemo and Houghton soils were used in the greenhouse.

Plots of Hillsdale soil were treated with the following fumigants in the amount corresponding to the rate per acre: methyl bromide, 435 pounds; sodium bromide, 475 pounds; ethylene dibromide W-85, 9 gallons; and untreated-check.

Whole bean plants, bean pods and soils from Hillsdale soil were sampled at three-weekly intervals and analyzed for total and water extractable bromine, respectively.

Plots of Brady soil were treated with 435 pounds of methyl bromide, 9 gallons of ethylene dibromide W-85, and check. All rates were based on acre basis and all treatments randomized and replicated. Beans and table beets were grown on Brady soil and two samplings of plants and soils were taken for total bromine analysis.

On Houghton soil table beets were planted and soil treatment was the same as for Brady soil.

In the greenhouse surface samples of Brookston, Oshtemo, and Houghton soils were treated with sodium bromide at the rate of 108.8 pounds of sodium bromide per acre. Two samplings of plants and soils were taken for analysis.

2.

All bromine analyses were done by method described by Shrader, et al.

Bean and cabbage plants grown on Hillsdale soil accumulated a considerable amount of bromine during the early stage of growth, but with the progress in growth this amount decreased markedly. The same was true with water extractable bromine of soil which tended to diminish also. An exception was soil treated with sodium bromide in which there was a considerable accumulation of bromine during growing season.

The yield of bean pods rated decreasingly: W-85, check, Mc-2, NaBr; that of cabbage was affected in exactly the same way as above; yield of potatoes: Mc-2, W-85, check, NaBr; and yield of peanuts: W-85, Mc-2, check, and NaBr.

In Brady soil the highest amount of total bromine was in methyl bromide treated plots, and it was the highest also in bean pods and beets from corresponding plots.

Yield of beans and table beets was as follows from highest to lowest: ethylene dibromide, methyl bromide, and check. A quality rating of table beets was as follows: ethylene dibromide, methyl bromide, and check. On Houghton muck, however, the yield of beets from methyl bromide treated plots was the highest, and that from plots treated with ethylene dibromide was the lowest because of reduced stand caused by damping-off fungi.

There were significant increases in yield of bean pods and table beets grown in greenhouse in soils treated with

3.

sodium bromide. No significant differences were found in the amount of bromine present in either plant tissue or soil, or in the yield, due to high or low soil moisture contents.

The highest native content of bromine was in Oshtemo, next in Brookston, and the lowest was in Houghton soil. The highest and most significant retention of bromine was in Houghton, the lowest in Oshtemo, and it was intermediate in Brookston soil.

In the dry year 828 ppm of bromine in bean plants grown on sodium bromide treated plots, on Hillsdale soil, seemed to depress growth of plants, whereas in the year with adequate rainfall 866 ppm found in bean pods near maturity did not cause any harm to plants and resulted in a higher yield of beans than from untreated plots.

In the field experiment 975 ppm of bromine in beets and 176 ppm in Houghton muck, found in samples taken on September 25, 1954, were harmful to beet's development. On the other hand, as much as 1062 ppm of bromine in beets, grown in the greenhouse, did not cause any damage.

In bean plants grown on soil not treated with bromine, the highest content of bromine was in stems, next in roots, and the lowest was in leaves. In bean plants from treated plots the highest amount of bromine was in roots, lower in leaves, and the lowest in stems.

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INTRODUCTION

Since Pasteur's investigations and discovery of certain bacteria as causal agents of different diseases, much progress has been made in methods of sterilization and disease prevention.

With further development of plant pathology and parasitology, sterilization of soil by heat, steam, and chemicals (16, 53, 4, 8) has been carefully and thoroughly investigated.

Soil sterilization is an eradication of all or some of the micro-organisms, plants, insects, and/or animals living in the soil. This treatment can be of different duration, and is designated as: (a) Permanent soil sterilization--duration more than two years; (b) Semi-permanent sterilization--duration from four months to two years; and (c) Temporary or partial soil sterilization--duration of less than four months.

Partial soil sterilization kills nematodes, some fungi and bacteria, but never all of them. It is also called soil fumigation if it is performed by gaseous compounds, and in this study these two terms are used interchangeably.

As reported by many workers (24, 39, 40, 42, 44, 67), the fumigation of soils with bromine carriers was successfully used in the control of golden nematodes of potatoes, Heterodera rostochiensis; sugar beet nematodes, Heterodera schachtii; bulb nematodes, Ditylenchus dipsaci; the genus of

root-knot nematodes, Meloidogyne; citrus root nematodes, Tylenchulus semipenetrans, and to a certain extent also the causal agents of damping off.

The usefulness and properties of chemicals used in partial soil sterilization are determined by:

1. Chemical composition and physical nature of sterilant
2. Chemical changes which reduce toxicity
3. Toxic properties of sterilant
4. Leaching from the soil
5. Fixation of sterilant by the soil
6. Physical and chemical properties of soil

The interaction of the afore mentioned factors affects the effectiveness of sterilants to control the soil-borne diseases and other parasites. The hardiness or immunity of some microorganisms or parasitic insects and animals to certain chemical sterilants is a very important phenomenon and was given careful consideration by many researchers (35, 40, 42, 51). The toxic properties and effective time of duration of sterilant toward cultivated plants has likewise been studied.

This study was primarily concerned with the retention in soil and the uptake of bromine by certain plants.

The compounds which contained bromine were used in field and greenhouse studies on both mineral and organic soils.

3.

The growth, development, and yield of certain crops in respect to the amount of bromine present in the soil, and the bromine present in plant tissue in relation to the compound of bromine incorporated into the soil, were studied.

The amount of bromine in plant tissue at certain intervals of plant growth, and in plant parts, was studied.

Certain varieties or strains of plants within a species may be affected differently by certain fumigants, therefore a further study is needed for investigation of the complicated phenomenon of biological-physical-chemical nature.

LITERATURE REVIEW

Kühn (34) as early as 1881, used carbon disulfide for control of sugar beet nematodes, but without success. In 1911, Bessey (7) successfully used carbon disulfide against root-knot nematodes.

Chloropicrin was used by 1920 while methyl bromide, as soil fumigant, was first used in 1940, and ethylene dibromide was used for control of nematodes in 1945.

The investigation of effectiveness of soil fumigants in the control of nematodes and soil-borne plant diseases progressed rapidly in the last 25 years.

Many new fumigants appeared on the market, and the research on the effect of fumigants on soil as well as on certain species and varieties of plants has increasingly expanded.

Coleman, et al. (13) reported that the soil treatment with carbon disulfide, ethyl alcohol, or toluene, when repeated for three successive days, brought about complete sterilization without marked changes in the chemical constitution of soil. Dry heat induced only slight chemical changes, but the changes due to steam heat sterilization were very great.

Fleming and Baker (18) studied the movement of vapors of carbon disulfide in the soil. The diffusion of vapors was lateral and downward from the point of injection. Similar

results were obtained with several other soil sterilants (25, 26, 55, 58).

Allison (3) pointed out that the solubility of organic matter in the soil increased after sterilization with ethylene oxide due to absorption of ethylene oxide vapors by organic and inorganic colloids. However, the soil permeability or solubility of salts was not affected. The pH of soil increased appreciably. The reduced soil permeability and disintegration of aggregation was not due to physical or chemical changes, but it was because of microbial cell growth and slimes or products of organic matter disintegration which tended to clog pores.

Polyakov (52) reported the degree of penetration and absorption of chlorine in sand. The sorption of chlorine in sand was proportional to the amount of organic matter present.

Chisholm and Koblitzky (11) reported strong adsorption of methyl bromide by dry peat. It was found that clay and sand absorbed less of the material and wet soil absorbed less than dry soil.

Fuhr and Bransford (20) observed little or no absorption of methyl bromide by sandy clay containing 11 percent water. This soil, however, sorbed markedly H_2S , $COCl_2$, HCN , and SO_2 .

Hanson and Nex (25) found that the diffusion of ethylene dibromide was slower both in soils with smaller pores and those at higher moisture contents. Decomposition of

fumigant was 9 percent at pH 5.0 and 50 percent at pH 5.8. Similar results as to distribution and retention of the DD vapors in soils at different moisture contents were obtained by Schmidt (55), and with methyl bromide by Swank and Latta (63).

Beames and Butterfield (5) attributed the wilting of tomatoes and spruces following the methyl bromide fumigation to the reduction of oxygen content of soil.

The biological phenomena after soil fumigation was investigated by many research workers. Fred (19) ascribed the increase in yield of plants which followed partial soil sterilization by ether, carbon disulfide, potassium dichromate, copper sulfate, and Salvarsan, to biological phenomena.

Stoklasa and Ernest (59) pointed out that the measurement of CO_2 evolution from the soil was a reliable and accurate index of organic matter composition and of bacterial activities in the soil.

Waksman and Starkey (68) studied the biological changes in soil after partial soil sterilization with toluene or heat.

Kineaid and Volk (31), Mattheus (40), Tam (64), and Behopolskyj and Bershova (8) reported on different soil sterilants and their effect on soil biology.

The fluctuation of soil microflora after soil sterilization with steam was reported by Katznelson (30). All organisms except *Azotobacter chroococcum* increased in number

after soil re-inoculation and then steadily decreased to a certain level.

Kincaid and Volk (32) reported effects of partial soil sterilization with DD and ethylene dibromide on black-shank, Phytophthora parasitica var. nicotianae; root-knot, Meloidogyne spp., and coarse rot, as well as burning, forms of nitrogen content and yield of tobacco. Correlation of nitrogen with yield seemed to depend on moisture conditions. No effects of soil temperature and soil moisture were noted.

Nettles (47) reported that continuous use of DD and ethylene dibromide as soil sterilants for five crops did not produce any harmful effect in sandy soils. Greater yields were produced during all years when all or part of the nitrogen was in the ammoniacal form.

Thomson and McLeod (66) reported no toxic after-effects in tobacco seedlings fumigated with methyl bromide at one pound per hundred square feet. Control of weeds and stimulation of growth was obtained. Similar results were obtained by other investigators (62).

Many researchers were interested in the chemical changes occurring after soil fumigation. Among them, Russel and Hutchinson (53) described sterilization of soil by 98° C heating, and 4 percent toluene treatment. The largest amount of ammonia was found in heated soil, and the next amount in toluene treated but evaporated soil. Still less was found in soil treated with toluene left in, and the least amount

was in untreated soil.

Chisevski (10) pointed out that the decomposition of organic matter in soil is considerably affected by the nature of base saturation of the organic matter complex.

Sherman (56) ascribed the increase in yield following the soil sterilization in Hawaiian soils by chloropierine and DD* to increase in availability of iron. The yields of plants increased as the ratio of the exchangeable manganese to exchangeable iron decreased.

Milliean (45) pointed out that some fungi compete with higher plants for major and minor elements. The release of P, K, Zn, Mn, and N occurred after partial soil sterilization.

Oteifa (50) recommended increasing the potassium level for the plants infested with root-knot nematodes, Meloidogyne incognita.

Miller (44) found that the nitrogen content of peanut vines was not markedly modified by treatment with ethylene dibromide but that of roots and kernels was increased.

Scheffer (54) described the methods of humus investigation with special emphasis on the biological phase of this problem.

Norman (49) discussed the different theories on lignin, ligno-proteins, interaction of proteins with clay, colloids, and the different kinds of combinations of organic materials with organic colloids.

Bear (6) discussed the relationship between cation and *Dichloropropane-Dichloropropylene mixture

anion uptake by plants and postulated that there exists a constant ratio between the sum of m.e. of cations and the sum of m.e. of anions, irrespective of environment.

Von Brausart (9) expressed the opinion that increased yield of crops due to partial soil sterilization with carbon disulfide or formaldehyde was not solely because of destruction of parasitic soil pests, but was also due to mobilization and increase in solubility of Fe, Cu, B, Co, Mn, and Ni.

Elreden (16) partially sterilized soil by flame heat, steam, and electricity, and received the best crop yields on soils treated with electrical current, next steaming, followed by flame heating, and the least yield on unsterilized soil. He attributed the increase in yields to the killing of such harmful organisms as protozoa, amoebae, and ciliates.

Feldmesser et al. (17) described the quarantine and control of golden nematode, Heterodera rostochiensis, stating that in some sublethal treatments with both hot water and chemicals, there was a tendency for more larvae survival in winter cysts than in those of summer.

McKeen (42) reported on the lethal effect of methyl bromide on microfloral components of a sandy loam compost soil. Fungi were destroyed at lower concentrations than were bacteria and actinomyces. Methyl bromide not only freed vegetable seedlings from disease, but also increased their uniform growth.

Leunsky (37) reported that Azalea plants fumigated in

vacuum with methyl bromide for two hours were not injuriously affected.

Koch and Stover (33) obtained greatly increased growth of tobacco in soil fumigated with Dow N (DD), chlorepicrin, and Dow W-40. These fumigants also seemed to give promise in the control of brown-root-rot of tobacco.

Allen and Raski (2) reported good results in the control of nematodes, Pratylenchus spp., and an increased yield of strawberries was obtained after application of 15 gallons of CBP 55 (Technical chlorebromopropene 55%) per acre, in two applications, five days apart. A single application of DD at the rate of 40 and 80 gallons per acre was also effective.

Parris (51) has controlled root-knot nematodes, Heterodera marioni, with DD, but not the damping off of spinach and pea seeds.

Thorne and Jensen (67) used different rates of DD and ethylene dibromide (W-15). The yield was almost three times higher with 400 pounds per acre of W-15 than with 200 pounds and nearly as much more as compared with check.

Allen (1) experimenting on light sandy loam with carrots on DD and chlorepicrin fumigated plots found that all treatments gave higher yields and better stands comparing with untreated plots. DD applied at 200 pounds per acre, at 12-inch intervals was the most effective in the reduction of nematode population.

Dalton and Hurwitz (14) reported on soil sterilization with formaldehyde, ethylene oxide, chlonepicrin, chloroform and HCN. Chloroform and HCN decreased the number of microorganisms but did not sterilize soil after 8 and 10 days of exposure, respectively. Possibly toxic concentrations of copper and manganese resulted from the use of chlonepicrin.

Middleton, et al. (43) reported that the application of fumigants to the soil supporting lima beans, reduced the injury index of root-rot.

Stone (61) reported good control of delfinium nematodes, Pratylenchus pratensis, by fumigation of soil with either methyl bromide or DD. One-half percent chlonephenol or 2.5 percent cresylic acid solution was not as effective as the former.

Inghan, et al. (27) indicated promise of pest control by chlordane, BHC, DDT, Toxaphene, and ethylene dibromide without marked disturbances of natural balance of soil fauna.

McClellan (41) reported the results of soil fumigation with Dowfume W-40 (EDB), and DD in control of both meadow and root-knot nematodes in tobacco. Isobrane D (EDB), chlonepicrin and methyl bromide were effective in meadow nematode control. Dowfume 40 did not control nematodes of onions.

Grainger (24) described the effective control of potato-root eelworm, Heterodera rostochiensis, by soil fumigation with DD. Ethylene dibromide and methyl bromide

prevented building up of cysts.

Lear (35) reported that ethylene dibromide, methyl bromide, dichloropropene and chloropicrin were effective nematocides, and controlled or retarded also the following fungi: *Fusarium*, *Pythium* and *Plasmodiophora brassicae* spp. However, Lear, et al. (36) reported that ethylene dibromide was not effective in control of golden nematodes on potatoes. Similar conclusions about the control of nematodes by ethylene dibromide were obtained by other investigators (41).

Cockbill (12) pointed out that soil fumigation with "Shell DD" or ethylene dibromide, at a depth of 9 inches, was very effective in controlling root-knot eelworms on heavily infested soils.

Mai (38) reported that methyl bromide up to 60 pounds per 100 cubic feet, for 16-20 hours of exposure, at 22.2-26.7° C was ineffective in killing either *Corynebacterium sepidarium* or *Fusarium sambucinum*.

Stover and Kech (62) pointed out that under Ontario conditions, methyl bromide at 2 pounds per 100 cubic feet destroyed all soil-borne tobacco pathogens. Elimination of damping off fungi and weeds was obtained at less than one pound of methyl bromide per 100 cubic feet.

Williamson (69) reported on injury of carnations caused by previous soil sterilization with methyl bromide. The plant injuries were roughly proportional to the total colloidal content of the soil, the soil temperature, and the

amount of methyl bromide applied. Methyl bromide can be used to sterilize pure sand if it is free from peat and other organic matter.

Newhall (48) reported the injuries of cuttings of Bonnaflan DeLuxe Chrysanthemums by fumes of Iscobrome (methyl bromide mixture). Other varieties were not affected.

Minz and Palti (46) doubled yield of cucumbers and tomatoes by applications of calcium cyanamide, ethylene dibromide and DD for the control of nematodes.

Graham and Heldeman (23) described the effective control of sting nematode, Belanolaimus gracilis, in cotton and other crops by use of ethylene dibromide or DD at specified rates.

Martin (39) reported destruction of citrus-root nematodes, Tylenchulus semipenetrans, in orchard soil by injections of DD, ethylene dibromide, or chlorthalipyrin in certain dosages into the soil. The yield of citrus replants increased greatly. Soil structure was not changed, but water soluble Ca, Mg, K, and Mn were temporarily increased.

I. EXPERIMENT I --MICHIGAN STATE COLLEGE FARM METHODS AND PROCEDURES

The experiment was set up to study the water extractable total bromine in the soil and the amount of total bromine present in plant tissue at different intervals of plant growth, after the soil was treated with different carriers of bromine.

The soil used for this experiment was Hillsdale sandy loam, located on the Michigan State College Experiment Farm, East Lansing, Michigan.

The pH of the soil was 6.4, and it contained 1.92 percent organic matter.

The soil was plowed in early spring, fertilized with 180 pounds of 20-0-0; 290 pounds of 0-45-0; and 365 pounds of 0-0-20 per acre, on May 27, 1953, and it was finally prepared for planting on May 29, 1953.

The soil plot in the size of 12,000 square feet was divided into 16 equal plots, 50 by 15 feet, and four completely randomized treatments were carried out. Six crops were grown on each plot. All treatments and crops were replicated four times.

The following fumigants were used for the treatments of soil:

1. Dowfume Me-2, 98 percent methyl bromide with 2 percent chloropicrin.

2. Dowfume W-85, EDB, 85 percent ethylene dibromide in an inert solvent.
3. Sodium bromide salt, NaBr.
4. Check, no treatment

All fumigants were applied to the soil on May 5, 1953. Methyl bromide was applied under plastic cover, remaining so for 24 hours; ethylene dibromide by field applicator, and sodium bromide was broadcast and disked into the soil.

The following amounts of fumigants were used on the acre basis:

- (a) Me-2, 435 pounds equivalent to 370 pounds of bromine
- (b) W-85, 9 gallons equivalent to 160.5 pounds of bromine
- (c) NaBr, 475 pounds equivalent to 370 pounds of bromine

At the time of soil treatments the soil temperature was 64° F, air temperature 78° F, and soil moisture was 12 percent.

Potatoes, onions, carrots, and peanuts were planted on May 29, 1953; beans, Black Valentine variety on June 8; and cabbage on June 24, 1953. Because of very poor stands of onions and carrots due to drought, they were excluded from experimental observations.

Observations of growth and yields were recorded. Cabbage and bean plants were sampled and analyzed for total bromine according to the following schedule:

A. Cabbage plants

1. July 23
2. August 13
3. September 4
4. September 24
5. -

B. Soils

- July 1
- July 23
- August 13
- September 4
- September 24

C. Bean plants

1. July 14
2. August 4
3. August 25
4. September 15

D. Bean pods

-
- August 4
- August 25
- September 15

E. Soils

- July 14
- August 4
- August 25
- Sept. 15

The soil was sampled at random to a depth of 10 inches, ten samples from each plot, mixed thoroughly together, and a representative sample was placed in a plastic bag and sealed. Later on it was screened through a 2 mm. screen and analyzed for water soluble bromine.

Plant samples were taken at random, 5 plants from each plot, dried at 160° F for 12-24 hours, ground, stored in bottles, and analyzed for total bromine. The whole cabbage plant with roots was analyzed. The first analyses were on whole bean plants. Thereafter the pods were removed and analyzed separately.

The method used for the determination of bromine in plant tissue and in soils was that described by Shrader, et al. (57). Five gram samples of plant tissue and that of

soils were employed in this investigation. A slight modification of Shrader's method was used for water soluble bromine in soils. The five-gram portion of soil was leached with three 50-ml. portions of distilled water. The leachate was slightly acidified, then neutralized to the color change of methyl red indicator and analyzed for bromine according to Shrader's method.

Method for Determination of Total Bromide

A five or ten-gram portion of plant tissue or soil sample was placed in a 100 ml. nickel crucible and treated with alcoholic potassium hydroxide (2.5 gm. potassium hydroxide per 100 ml. 95 percent ethyl alcohol). After one hour the soil was dried on a steam bath. After that it was dried on a hot plate for a short time and covered with 10 grams of sodium hydroxide pellets. The crucible remained on the hot plate for one to two hours and then was transferred to a muffle furnace at 600° C. Care was taken that the samples were completely dry before they were placed in the furnace. Fusion should be completed without excessive burning or foaming. The sample was kept in the furnace until the volatile gases were removed (4-5 hours for plants and 5-5½ hours for soil samples). Sodium peroxide was added to the sample, a few milligrams at a time to accelerate the oxidation of organic matter. The sample was removed from the furnace and the sodium peroxide added cautiously. If the sample burned

with a glare the bromide was lost.

Complete combustion of organic matter was attained by rotating the melt and returning organic matter to the bottom of the crucible, then adding 0.5 gram more sodium peroxide. The crucible was then returned to the furnace. The combustion was complete when no bubbling or burning occurred. The accuracy of results was not affected by the few carbon particles which remained undigested after the addition of sodium peroxide.

Samples were removed from the furnace, rotated to allow melt to solidify on the crucible sides, cooled, and dissolved in 75 ml. of distilled water. When dissolving was slow, the samples were placed on a hot plate for a few minutes. The solution was transferred from the crucibles to 400 ml. beakers and partially neutralized with about 50 ml. of 6 N bromine free-hydrochloric acid. After that the solution was boiled to destroy peroxides and reduce the volume to 100-125 ml. The solution was then filtered through a No. 2 Whatman filter paper in order to remove nickel and other insoluble hydroxides, and the filtrate and washings were transferred to a 500 ml. Erlenmeyer flask. The filtrate was slightly acidified with 6 N bromine free-hydrochloric acid and neutralized with sodium hydroxide to the color change of methyl red. At this point the volume of solution was about 150 ml.

Two grams of monobasic sodium acid phosphate and 5 ml. of 0.1 N hypochloride solution (NaOCl or KOC) were added,

and the solution was heated to boiling. After one minute boiling 5 ml. of sodium formate solution (50 g. per 100 ml. water) was introduced and boiling continued for 2 minutes. The sample was cooled and treated with a few drops of 1 percent sodium molybdate solution, 500 mlgrms. of potassium iodide, and 25 ml. of sulfuric acid. Immediately the sample was titrated with 0.01 N sodium thiosulfate solution. Starch indicator was added just before the end point (fading of greenish color of solution) was reached. A blank on all reagents was carried through the entire procedure. Appropriate corrections were made.

One milliliter of 0.01 N thiosulfate was equivalent to 0.1332 milligrams of bromide ion.

Experimental Results and Discussion

Cabbage

Unfortunately, 1953 was a dry year, especially during the first part of the summer, thus the cabbage plants did not show expected vigor in growth. The best looking plants were on untreated plots and on those treated with W-85. Plants treated with Mc-2 were not so good and those treated with sodium bromide were poorest.

The plots were not infested by nematodes or other parasites, therefore the increase or decrease in growth and yield of cabbage was attributed to the effect of the particular fumigant under the environmental conditions of this experiment.

The bromine content in the tissue of treated plants was the highest in the samples of July 23, 1953, decreasing rather rapidly so that at the second sampling, on August 13, the bromine content was roughly one-third of the previous amount. The samples taken ^{on} September 4 and 24 decreased steadily, but rather slowly in bromine content.

The content of total bromine in plant tissue and the differences for significance are shown in Table 1.

The highest amount of water extractable bromine in the soil was found in the first samples from the plots treated with sodium bromide, the next amount was in the soil which received methyl bromide, and the least amount in treated soil was in that receiving ethylene dibromide. The lowest

TABLE I.

PPM TOTAL BROMINE IN CABBAGE PLANTS FROM
MINERAL SOIL, MSC FARM, EAST LANSING*

Treatment	Dates of Samplings				
	July 1	July 23	August 13	September 4	September 24
Mc-2	-	1130	338	274	227
W-85	-	830	268	179	166
NaBr	-	993	387	268	177
Check	-	166	165	118	87
L.S.D. 5 percent		272	117	106	153
1 percent		391	169	153	220

*All data averages of four replications of oven dry material

TABLE II

PPM WATER EXTRACTABLE BROMINE IN SOIL FROM
CABBAGE PLOTS, MSC FARM, EAST LANSING

Treatment	Dates of Samplings				
	July 1	July 23	August 13	September 4	September 24
Mc-2	38	12	22	12	7
W-85	24	8	18	10	5
NaBr	64	43	40	17	14
Check	8	4	7	5	3
L.S.D. 5%	27	13	12	5.5	2
1%	39	18	17	8	3

amount was in the untreated soil. With time the water extractable soil bromine decreased gradually and the differences among the individual treatments changed from time to time, as shown in Table II.

Yield of cabbage was the highest on W-85 treated plots. Yields decreased in order on untreated plots, those treated with Mc-2, and were least on NaBr treated plots. (See Table VI.)

It seems that the presence of a considerable amount of water extractable bromine in the soil during the period of plant growth tended to depress the uptake of anions. This reduced absorption depressed the physiological plant processes, especially at the early growth stage, because of the toxic properties of the bromine (6). However, the depression may be also partially due to lack of oxygen, because the introduced sodium in sodium bromide treatment resulted in the formation of a compact layer on top of the soil (5).

Beans

The growth of bean plants was very slow at the beginning of the experiment, but improved slightly after a few rain showers. Neither Mc-2 nor NaBr treated plots supported bean plants properly. A few light rains in early August induced vigorous growth on all plots, especially those treated with Mc-2 and NaBr; however, they were not able to catch up with the comparably better appearing and

growing beans on W-85 and the check plots.

The examination of roots showed that the best developed roots were from plants grown on W-85 treated plots, next and almost equal sized roots were from plants on check and Me-2 plots while very poorly developed roots were found on plants on NaBr treated plots.

The highest content of total bromine was obtained in bean plants from NaBr treated plots. The plants from the check plots contained the least bromine while those from the other two treatments were intermediate and in order of Me-2 and W-85, respectively. As is seen in Table III, the amount of bromine in plants sampled on July 14 and August 4 decreased rather little, but samples of August 25 and September 15 showed rapid decrease in the amount of bromine in plant tissue from all treated plots. The bromine contents of untreated plants did not follow the same pattern.

The content of total bromine in bean pods was lower than in bean plants. The amount of bromine as related to different bromine carriers is shown in Table V. Between August 4 and August 25 the bromine content of bean pods increased slightly in plants treated with NaBr and Me-2 and then decreased rapidly. On the other hand, the bromine contents of bean pods from the W-85 and check plots decreased consistently as the season progressed.

The water extractable bromine content of the soil is presented in Table IV. There was a small fluctuation of

TABLE III

PPM TOTAL BROMINE IN BEAN PLANTS FROM MINERAL
SOIL, MSC FARM, EAST LANSING

Treatment	Dates of Samplings			
	July 14	August 4	August 25	September 15
Mc-2	828	832	586	228
W-85	585	523	469	184
NaBr	929	873	461	170
Check	165	243	394	182
LSD 5 percent	193	211	266	65
1 percent	277	303	382	93

TABLE IV

PPM WATER EXTRACTABLE BROMINE IN SOIL FROM
BEAN PLOTS, MSC FARM, EAST LANSING

Treatment	Dates of Samplings			
	July 14	August 4	August 25	September 15
Mc-2	30	23	25	12
W-85	17	11	16	5
NaBr	50	63	83	25
Check	15	10	9	6
LSD 5 percent	23	10	21	7
1 percent	33	14	30	10

TABLE V

PPM TOTAL BROMINE IN BEAN PODS FROM MINERAL
SOIL, MSC FARM, EAST LANSING

Treatment	Dates of Sampling		
	August 4	August 25	September 15
Mc-2	524	570	116
W-85	602	474	33
NaBr	666	699	128
Check	389	242	55
LSD 5 percent	207	115	70
1 percent	298	165	100

TABLE VI

MEAN YIELDS OF CROPS OF FOUR REPLICATIONS FROM
MINERAL SOIL, MSC FARM, EAST LANSING

Treatment	Cabbage		Beans	
	Size of Plot Sq. ft.	Heads in pounds per Plot	Size of Plot Sq. ft.	Seeds Grams per Plot
Mc-2	75	34	50	82
W-85	75	44	50	237
NaBr	75	27	50	81
Check	75	36	50	225
LSD 5 percent		10.0		54.0
1 percent		16.7		77.5

1

water extractable bromine at different times of sampling which was almost linear in the Mc-2, and W-85 treated soils. Sodium bromide treated soils showed a considerable accumulation of water extractable bromine in the samples of July 14 to August 25 with a rapid linear decrease later on. This phenomenon is a rather interesting one, but cannot be explained without further investigations.

Yield of bean seeds was the highest on W-85 treated plots, next on check plots, and low and almost equal on Mc-2 and NaBr treated plots. (Table VI.)

From the data of this experiment it appears that an amount of bromine closely approaching or exceeding 1,000 p.p.m. in the dry tissue of Black Valentine bean plants at the early stage of growth depressed development of the plants.

Potatoes and Peanuts

Potatoes were not detrimentally influenced by bromine treatments of soil. These plants showed good general appearance and growth irrespective of treatment. However, the plants from NaBr treated plots showed slight browning of leaf tips, especially when dry and hot weather prevailed.

The highest yield of potato tubers was on Mc-2 treated plots, next highest on W-85, next on the check, and slightly lower on NaBr treated plots. The data in Table VI show the yield of potatoes as affected by different soil

treatments and the significance for difference at the 5 and 1 percent levels.

Peanuts showed rather progressive growth as a result of treatment with W-85 or where the soil was untreated, a little slower growth on Mc-2 treated plots, and a stunted growth on the NaBr treated plots. These differences in growth and development continued throughout the season. The peanut plants from the NaBr treated plots exhibited a yellowish appearance, and the leaves turned brown by the first small frost, whereas plants from plots receiving other treatments were not frosted. This indicates that the physiological system of plants from NaBr treated plots was upset.

Peanut yields were highest on W-85 treated plots and least on those plots which received NaBr. They were intermediate and about equal on untreated and Mc-2 treated plots. The very significant increase in yield due to W-85 treatment, and the significant depression in yield due to NaBr treatment are shown in Table VII.



TABLE VII

MEAN YIELDS OF CROPS OF FOUR REPLICATIONS FROM
MINERAL SOIL, MSC FARM, EAST LANSING

Treatment	Peanuts		Potatoes	
	Size of Plot Sq. ft.	Peanuts Pounds per Plot	Size of Plot Sq. ft.	Tubers Pounds per Plot
Mc-2	90	10	135	47
W-85	90	13	135	45
NaBr	90	8	135	30
Check	90	10	135	33
LSD 5 percent		1.06		6.77
1 percent		1.53		9.52

EXPERIMENT II.--MICHIGAN STATE COLLEGE MUCK FARM METHODS AND PROCEDURES

In the spring of 1954 an experiment was set up on Houghton muck and Brady loam on the Michigan State College Muck Experimental Farm, Clinton County, to study the growth and yield of table beets and beans as affected by two different carriers of bromine. The retention of bromine by these soils was also considered.

The pH of Houghton muck soil was 6.3 and this soil contained 82.6 percent of organic matter and 17.4 percent of ash. The pH of Brady soil was 6.7 and it contained 4.6 percent of organic matter.

Both soils were plowed, cultivated and harrowed in spring to prepare the seedbed. The Houghton muck was fertilized with 1,000 pounds of 0-10-30 per acre and the Brady with 1,000 pounds of 12-12-12.

Three treatments of soils were used: 1) Methyl bromide (Mc-2); 2) Ethylene dibromide 85% (W-85); and 3) Check. All treatments were replicated four times.

Methyl bromide was used in the amount of 435 pounds per acre, corresponding to 370 pounds of bromine, and ethylene dibromide, 9 gallons per acre corresponding to 160.5 pounds of bromine.

On the muck soil 12 plots were prepared and also 12 on mineral soil. Each plot was 48 by 12 feet, covering an

area of 576 square feet. On the mineral soil each plot was subdivided for two crops, beans and table beets.

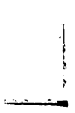
Eight out of 12 plots on muck soil, and 16 out of 24 plots on mineral soil were to be treated by either methyl bromide or ethylene dibromide. Ethylene dibromide was applied by field applicator on May 26, 1954, and on the same day only two plots were treated with methyl bromide. The remaining plots were treated, two at a time, on May 28, June 1, and June 4, 1954.

The soil moisture at the first treatment on May 26 was 11 percent and 62 percent, and soil temperature was 24° C and 21° C for Brady and Houghton soils, respectively.

The methyl bromide fumigated plots remained under cover for 48 hours. After all treatments were accomplished and the plastic covers removed from the last plots, all treated plots were aerated by means of cultivator and beans and table beets were planted on mineral soil and table beets on the muck soil on June 15, 1954.

The beet plant seedlings on Houghton muck soil suffered damping off, and therefore a half of each plot, irrespective of treatment and damage, was replanted on July 7, 1954.

During the growing period two samplings of soils and plants were made. The first sampling took place on August 19 and second on September 25, 1954. Six plants were sampled from each plot, dried for 12-24 hours at 160-170° F



(beets were sliced and dried slightly longer) stored in tightly covered bottles and analyzed for total bromine. Only beet roots and bean pods were analyzed.

Sampling of plants was performed in completely randomized order while that of soil was from ten places directly in the plant rows. Soil samples were cores to a depth of ten inches.

The soil samples from a certain plot were thoroughly mixed, air dried, screened through a 2 mm. screen and again mixed. A representative sample was then preserved in a closed container.

The plant tissues as well as the soils were analyzed by the method described by Shrader, et al. (57). The samples used were 5 grams in weight.

Because the fresh soil samples were not analyzed immediately, but were air dried, the water extractable bromine gave low values, and was decided as not reliable. The determinations should be run on fresh soil samples.

The yields of table beet roots and bean seeds were recorded.

For the sake of a comparison of quality the beets were graded as follows: (a) Large, larger than $2\frac{3}{4}$ inches in diameter; (b) Medium, $2-2\frac{3}{4}$ inches; and (c) Small, smaller than 2 inches in diameter.

EXPERIMENTAL RESULTS AND DISCUSSION

Beet seedlings grown on W-85 treated Houghton muck were badly affected by damping off. No damping off occurred on the soil treated with Mc-2 but some did occur on the untreated muck.

No visible differences in growth and general appearance of beans and beets were observed on the mineral soil plots on July 27, 1954. On the muck soil, however, there was a vigorous growth of beets on the Mc-2 treated plots, a less vigorous growth on the check plots and a weak growth on the W-85 treated plots. On the other hand, observations on the muck soil on August 19 showed the most vigorous growth and darkest green color of beets to be on W-85 treated plots with the next best beets on the check plots. The beets from Mc-2 treated plots were starting to show symptoms of nitrogen deficiency at that time. The nitrogen starvation may be explained by partial exhaustion of readily available nitrogen by the rapidly growing plants in a very good stand, and also partially by a tie-up of nitrogen by speeded multiplication of soil microorganisms (30).

On some of the Mc-2 treated plots in the spots where the Mc-2 gas was distributed, there were visible signs of stunted growth and curling of leaves, presumably due to high bromine content in the soils in these areas. The soils and plants from these spots were analyzed separately and the

data are presented in Table XI. Such spots were present only on the muck soil.

The total bromine contents of beet root tissue from the mineral soil samplings of August 19 were the highest in plants from Mc-2 treated plots, followed by that of plants treated with W-85, and were the lowest in plants from check plots. In the second sampling the plants from the W-85 treated plots were the highest in the content of bromine, next were plants from Mc-2 plots, and the lowest content of bromine was in plants from check plots.

The amount of bromine in treated plant tissue, from the first to the second sampling, diminished roughly by one third. Table VIII shows the amount of bromine present at different samplings and the differences for significance.

The total bromine content of mineral soil from beet plots on August 19, 1954, was the highest from Mc-2 treated plots, next from those treated with W-85, and lowest where bromine was not applied. A similar gradient was obtained with the soils from second sampling. The second sampling showed slightly lower bromine values than the first one. No significant treatment difference in the amount of total bromine was found in the first soil samplings, and only the bromine in the check soils was significantly lower in the second sampling, as is shown in Table VIII.

TABLE VIII.

PPM TOTAL BROMINE* IN SOILS AND BEET ROOTS
 FROM BRADY LOAM SOIL, MSC EXPERIMENTAL
 MUCK FARM, CLINTON COUNTY, MICHIGAN

Treatment	Dates of Sampling			
	Soils		Beet roots	
	August 19	September 25	August 19	September 25
Me-2	107	94	951	630
W-85	79	75	837	655
Check	49	43	120	102
LSD 5 percent	32	26	115	181
1 percent	48	40	174	273

*Means of four replications

1

The yield of table beets on mineral soil was not significantly affected by treatment. The highest yield was on W-85 treated plots while the lowest yield occurred where Mc-2 was applied. However, there were differences in the quality of the beets. The medium sized table beets have been considered the best seller. The highest percentage of medium sized beets was on W-85 treated plots (69.25%), the next highest on Mc-2 treated plots (67.75%), and the lowest on the checks (58.75%). The higher percentage of medium sized beets on plots treated with bromides can be attributed to the immediate availability of plant nutrients in the root spheres at the early growth stage and thereafter, thus all plants had the same chance for growth and competition (9, 39).

The amount of total bromine in the table beet tissue of plants grown on Houghton muck soil was highest in plants from Mc-2 treated plots, next highest where treatment was W-85, and the lowest where bromine was not applied. A similar picture with total bromine was found in the soil. All treatment differences significant at the 1 percent level are shown in Table IX.

The yield of table beets on Houghton muck soil was the highest on Mc-2 treated plots, next highest on check plots, and lowest on W-85 treated plots. The low yield on W-85 treated plots was due to the reduction of stand by the damping off fungi. The quality of beets was, in decreasing order: (1) Mc-2 treated plots - 75, and 20.75 percent;

TABLE IX

PPM TOTAL BROMINE* IN SOILS AND BEET ROOTS
FROM HOUGHTON MUCK SOIL, MSC EXPERIMENTAL
MUCK FARM, CLINTON COUNTY, MICHIGAN

Treatment	Dates of Sampling			
	Soils		Bean Pods	
	August 19	September 25	August 19	September 25
Mc-2	148	148	936	803
W-85	88	83	646	604
Check	33	33	139	105
LSD 5 percent	31	30	83	113
1 percent	47	45	126	170

* Means of four replications

TABLE X

YIELD OF CROPS ON MSC EXPERIMENTAL MUCK FARM
(MEANS OF FOUR REPLICATIONS IN POUNDS)

Treatment	Houghton Muck	Brady Loam	
	Table Beets Per Plot 576 Square Feet	Table Beets Per Plot 288 Square Feet	Bean Seeds Per Plot 288 Square Feet
Mc-2	543	293	103
W-85	388	305	108
Check	503	301	103
LSD 5 percent	131	73	9.42
1 percent	198	110	14.27

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(2) Checks - 57.50 and 37.50 percent; and (3) W-85 treated plots - 24.75, and 73.50 percent of medium size and large size, respectively. The high amount of large size beets from plots treated with W-85 was due to greatly reduced stand by early damping off. Table X shows the yield of table beets.

In Table XI is shown the bromine content of table beet tissue from the spot where the depressed growth occurred, four feet apart, and from the plot as a whole. It is seen that 975 ppm in the plant tissue and 186 ppm in soil found on September 29, 1954, caused depressed development of beet roots, and the leaves were curled, deformed, and more intensively brownish-red colored.

The total bromine content of bean pods from mineral soil sampled on August 19 was the highest in plants taken from Mc-2 treated plots, next in those treated with W-85, and lowest in plants from check plots. This can be seen in Table XII.

The second sampling on September 25, 1954, showed the diminution of total bromine in bean pods to be roughly about one-half in those taken from the bromine treated plots with only slight decreases in those from check plots. All differences in the total amount of bromine were significant at the 1 percent level as shown in Table XII.

The highest amount of bromine in the mineral soil from bean plots was in that treated with Mc-2, next in that

TABLE XI

PPM TOTAL BROMINE CONTENT OF SOIL AND BEET ROOT TISSUE FROM AREA OF DETRIMENTAL
BEET GROWTH AND CLOSE VICINITY ON HOUGHTON MUCK, MSC EXPERIMENTAL
MUCK FARM, CLINTON COUNTY, MICHIGAN

Treatment	Muck Soil*		Beet Tissue	
	On Spot	Four Feet Away From the Spot	On Spot	Four Feet Away from the Spot
Mc-2	186	152	975	715
		148		649

* For total bromine determination all samples of soils and plants were duplicated

TABLE XII
PPM TOTAL BROMINE* IN SOILS AND BEAN PODS FROM BRADY LOAM SOIL,
MSC EXPERIMENTAL MUCK FARM, CLINTON COUNTY, MICHIGAN

Treatment	Soils		Dates of Sampling		Bean Pods	
	August 19	September 25	August 19	September 25	August 19	September 25
Mc-2	95	76	866		454	
W-85	77	74	696		291	
Check	52	42	108		77	
LSD 5 percent	26	17	209		93	
1 percent	40	26	317		140	

* Means of four replications

which received W-85, and least in soils from check plots. The amount of total soil bromine was slightly lower at the time of the second sampling.

Treatments did not cause significant differences at the time of the first soil sampling, and only the soil from the check plots was significantly different at the second sampling.



EXPERIMENT III -- GREENHOUSE METHODS AND PROCEDURES

In the spring of 1954, an experiment was set up in the greenhouse to study the retention of bromine by clay, sandy, and organic soils, and to investigate the uptake of bromine by plants at two bromine and two water levels.

Oshtemo loamy sand, Brookston clay loam, and Houghton soils were used in the greenhouse. Two treatments: sodium bromide (NaBr), and check (no bromine added) were considered at two water levels.

Table beets, Detroit Dark Red variety, and string beans were used for experimental crops.

Each treatment was replicated three times in the completely randomized order, and two harvesting dates for crops and soil samplings were set up for chemical analysis of the total bromine present.

The whole experiment comprised 72 two-gallon glazed pots.

The brief information pertaining to the soils used in this experiment are shown in Table XIII.

The fertilizers for each soil were used on the acre basis in the following amounts:

Brookston	-	2,000 pounds of 6-18-24
Oshtemo	-	2,000 pounds of 5-10-20
Houghton muck	-	3,000 pounds of 10-10-20

TABLE XIII.

SOILS USED IN GREENHOUSE EXPERIMENT

Soils	Pounds* per Pot	pH	Percent Organic Matter	Percent Ash
Brookston clay loam	14.5	6.3	6.12	
Oshtemo loamy sand	19.0	6.1	0.51	
Houghton muck	7.0	6.3	82.60	17.4

*Air dried soil

Because ready mixed fertilizers were not available, the grades needed were mixed from the individual carriers. The amounts necessary to obtain the desired applications were mixed with the soil on May 2.

Copper sulfate in the amount corresponding to 50 pounds per acre was added to the muck soil in solution form. This was done on May 7, 1954.

The soil sterilant used in the greenhouse was C.P. sodium bromide at the rate of 108.8 pounds per acre, which corresponds to 85 pounds of bromine. Sodium bromide was dissolved in distilled water and as a solution was added to the soil. The amount of sodium bromide needed for 12 pots of each soil was dissolved and made up to 600 ml. of solution. This was for (1) Brookston - 4.28 gm., (2) Oshtemo - 5.57 gm., and (3) Houghton muck - 8.23 gm.

Fifty ml. of prepared sodium bromide solution was added to each pot. After the addition of soil sterilant the soils were watered and brought up to the moisture equivalent.

Soils in the greenhouse were sterilized on May 14. The air temperature was 85° F and that of soils was: 96°, 94° and 91° F for Brookston, Oshtemo, and Houghton soils, respectively.

During the period of time after the soils were sterilized and before the plants were planted, the soil moisture was kept at the moisture equivalent.

Both table beets and beans were planted on July 26.

Moisture equivalent was determined for soils used in the greenhouse experiment, and two watering levels, low and high, were arbitrarily established and maintained in each soil until the time of first sampling of plants and soils.

TABLE XIV
WATERING SCHEME FOR TABLE BEETS AND BEANS

Soil	Pounds Soil Weight	Percent Mois- ture Equiva- lent	Light Watering		Heavy Watering	
			Percent Moisture	Liters Water	Percent Moisture	Liters Water
Brookston	14.5	23	18.89	1.245	24.96	1.645
Oshtemo	19.0	8	11.57	1.000	18.52	1.600
Houghton muck	7.0	45	40.23	1.281	59.13	1.881

The pots were weighed each day and the water was adjusted to the correct level.

The plants were thinned to six plants of both table beets and beans per pot, after one week from the emergence.

The bean pods from three plants were sampled out of each pot in every treatment. They were oven dried as mentioned in experiments I and II, ground, stored in closed glass containers, and analyzed for total bromine.

Both plant tissues and soils were analyzed by methods described by Shrader, et al. (57).

The second sampling of bean pods and soils took place on November 14.

The roots of table beets and corresponding soils were sampled for the first time on November 14 and the second time on December 29.

The roots of table beets were washed, sliced, dried in an oven at 160-170° F for 24-36 hours, ground, stored in glass containers and analyzed for bromine content. The soils were prepared in the manner previously mentioned.

After the first sampling of bean pods, beets and corresponding soils, the high water level was discontinued because of cool and cloudy weather which did not stimulate as much water evaporation as during the hot summer spell, and, therefore, the high water level would have been harmful to plants.

The yield of bean pods and table beets were recorded.

EXPERIMENTAL RESULTS AND DISCUSSION

There was no visible difference in the growth of table beets and beans due to bromine treatment or water levels. However, there were some visible differences due to soils.

At the beginning of the second half of September, 1954, some symptoms of manganese deficiency appeared on bean plants growing on checks, both at low and high water levels, on Houghton muck and Oshtemo sand. The deficiency was corrected by addition to the soils of manganese sulfate, dissolved in distilled water, in the amount equivalent to 10 pounds per acre. Such symptoms did not occur on beans from sodium bromide treated pots, which is in agreement with ideas of von Brausart (9) about mobilization of minor elements, and also those of Martin (39) and Millikan (45).

Bean pods

The total bromine analyses of bean pods sampled on October 3, 1954, showed very significant differences due to bromine treatment. The percentage of bromine in bean pods from sodium bromide treated muck soil was the lowest, was higher in plants from Oshtemo sand, and was the highest from Brookston clay loam. These data are shown in Table XV, XVa. Water levels did not significantly affect the amount of bromine in bean pods.

TABLE XV

PPM TOTAL BROMINE CONTENT IN BEAN PODS GROWN IN
GREENHOUSE, AND SAMPLED ON OCTOBER 3, 1954

Soils	Repli- cation	High-Water-Low				Total	Soils Mean	Replica- tions Means
		Check	NaBr	Check	NaBr			
Brookston	1	11	509	-	550	1,070	308	254
	2	-	236	26	319	581		220
	3	-	443	6	400	849		238
Oshtemo	1	-	639	-	644	1,283	305	
	2	26	507	-	679	1,212		
	3	46	550	20	547	1,163		
Houghton	1	29	312	46	310	697	199**	
	2	20	338	174	316	848		
	3	26	444	20	348	838		
Total		158	3,978	292	4,113	8,541		
Water Means			230		245			
Bromine Treatment Means				25	450**			

TABLE XVa

ANALYSIS OF VARIANCE OF TOTAL BROMINE CONTENT (PPM)
IN BEAN PODS GROWN IN GREENHOUSE AND SAMPLED
ON OCTOBER 3, 1954

Source	D.F.	S.S.	M.S.	F
Total	35	1,956,309		
Replications	2	6,971	3,485	0.73
Soils	2	82,786	41,393	8.63**
Bromine Treatment	1	1,621,803	1,621,803	338.09**
Soils x Bromine	2	125,620	62,810	13.09**
Water	1	2,010	2,010	0.42
Soil x Water	2	266	133	0.03
SoilxWaterxBromine	2	11,325	5,662	1.18
Bromine x Water	1	-	-	-
Error	22	105,528	4,797	

** Significant at 1 percent level

LSD 5% 50 for bromine, and water, and 61 for soils, and replicates
1% 65 for bromine, and water, and 79 for soils, and replicates

At the time of the second sampling (November 14), there was a decrease in the total bromine content of bean pods. This decrease was varied with soil. In the pods from Brookston clay loam it decreased almost one-half, as compared with previous sampling, from Oshtemo sand roughly one-third, and from Houghton muck slightly less than one-fourth.

The content of bromine found in pods from the second sampling was very significantly different due to bromide treatment. (See Tables XVI, XVIa.)

Total bromine content in the soils sampled on October 3, was very significantly different due to bromine treatment and was significantly high in Brookston soil. No significant difference was found due to water levels. In plants grown on check pots the lowest bromine content was in Houghton, next in Oshtemo, and the highest amount in Brookston. In the soils treated with sodium bromide, the lowest amount of bromine was in plants grown on Oshtemo sand, higher in those on Brookston clay loam, and the highest in those on Houghton muck. The latter results are in agreement with findings of many researchers (3, 11, 20). (See Tables XVII, XVIIa.)

In the soil samples of November 14 there were significant differences due to bromine treatments, and no significance due to soils except for Houghton muck soil. The checks of all soils showed decrease in the amount of total bromine roughly in one-half. The sodium bromide treated soils showed decrease in more than half of the bromine

TABLE XVI

PPM TOTAL BROMINE IN BEAN PODS SAMPLED
ON NOVEMBER 14, 1954, FROM GREENHOUSE

Soils	Treatment			Total	Soils Means	Replications Means	
	Check	NaBr					
Brookston	1	14	286	300	157	1	164
	2	3	315	318		2	181
	3	9	316	325		3	174
Oshtemo	1	-	430	430	216**		
	2	-	444	444			
	3	44	379	423			
Houghton	1	4	250	254	146		
	2	9	316	325			
	3	13	282	295			
Total	96	3018		3114			
Treatments Means	11**	335**					

TABLE XVIa

ANALYSIS OF VARIANCE OF BROMINE PPM IN BEAN
PODS SAMPLED ON NOVEMBER 14, 1954

Source	D.F.	S.S.	M.S.	F
Total	17	512,200		
Replications	2	890	445	0.79
Soils	2	17,167	8,584	15.33**
Treatments	1	474,338	474,338	847.03**
Soils x Treatments	2	14,203	7,102	12.68**
Error	10	5,602	560	

**Significant at 1% level

LSD 5% 24, for bromine treatment, and 30, for soils or replications
1% 35, for bromine treatment, and 42, for soils or replications

TABLE XVII

PPM TOTAL BROMINE CONTENT IN SOILS FROM GREENHOUSE
WHICH WERE SAMPLED ON OCTOBER 3, 1954 (BEAN POTS)

Soils	Repli- cation	High water		Low water		Total	Soils Mean	Replica- tions Means
		Check	NaBr	Check	NaBr			
Brookston	1	58	90	66	89	303	75**	70
	2	68	84	74	86	312		68
	3	64	82	58	86	290		66
Oshtemo	1	54	74	66	72	266	68	
	2	52	80	66	74	272		
	3	56	92	54	76	278		
Houghton	1	34	104	35	92	265	60	
	2	31	84	32	82	229		
	3	32	92	31	72	227		
Total		449	782	482	729	2,442		
Water Means			68		67			
Bromine Treatment Means				52	84**			

TABLE XVIIa

ANALYSIS OF VARIANCE OF TOTAL BROMINE CONTENT (PPM)
IN SOILS FROM GREENHOUSE (BEAN POTS) - SAMPLINGS
OF OCTOBER 3, 1954

Source	D.F.	S.S.	M.S.	F
Total	35	14,443		
Replications	2	64	32	0.83
Soils	2	1,411	706	18.25**
Bromine Treatment	1	9,344	9,344	241.57**
Soils x Bromine	2	2,373	1,187	30.69**
Water	1	11	11	0.28
Soils x Water	2	94	47	1.22
Bromine x Water	1	206	206	5.33*
Soils x Bromine x Water	2	89	44.5	1.15
Error	22	851	39	

* Significant at 5 percent level

** Significant at 1 percent level

LSD 5%, 4 for bromine and water, and 5 for soils and replicates
1%, 6 for bromine and water, and 7 for soils and replicates

found on October 3, 1954. (See Tables XVIII, XVIIIa.)

The yield of bean pods sampled on October 3 was the highest and very significantly different on both check and sodium bromide treated Houghton soil. It was lower on Brookston and the lowest was on Oshtemo check. There were significant increases in the yield due to sodium bromide treatment. Slightly higher yields due to higher watering level occurred on all soils, but in no soil were these increases in yields significant. (See Tables XIX, XIXa.)

The second sampling on November 14 showed significant increases in yield of bean pods due to sodium bromide treatment. The yield data are shown in Table XX.

Table beets

The analyses of the roots of table beets showed very significant differences in the content of total bromine due to soil treatment, in the samples of November 14. No significant difference was found due to soil type, except Brookston check or water level. (See Tables XXI, XXIa.)

Total bromine in soils sampled on November 14 was high in soils treated with sodium bromide and the amount of bromine in both check and sodium bromide treated soils was significantly different at one percent level. (Tables XXII, XXIIa.) The same significance was found in samples of December 29, 1954. (Table XXIII.)

1

TABLE XVIII

PPM TOTAL BROMINE CONTENT IN SOILS
FROM GREENHOUSE WHICH WERE SAMPLED
ON NOVEMBER 14, 1954, (BEAN POTS)

Soils	Repli- cations	Treatment Check	NaBr	Total	Soils Means	Replica- tions Means
Brookston	1	58	72	130	63	1 56
	2	64	66	130		2 62
	3	50	68	118		3 59
Oshtemo	1	52	68	120	62	
	2	63	64	127		
	3	43	82	125		
Houghton	1	30	58	88	52*	
	2	31	84	115		
	3	29	80	109		
Total		420	642	1062		
Treatments Mean		47	71*			

TABLE XVIIIa

ANALYSIS OF VARIANCE OF BROMINE PPM
IN SOILS FROM GREENHOUSE (BEAN POTS)
(SAMPLED ON NOVEMBER 14, 1954)

Source	D.F.	S.S.	M.S.	F
Total	17	4,954		
Replications	2	97	48.5	0.61
Soils	2	444	222.0	2.80
Treatments	1	2,738	2,738.0	34.48**
Soils x Treatments	2	881	440.5	5.55*
Error	10	794	79.4	

* Significant at 5 percent level

** Significant at 1 percent level

LSD 5%, 9 for bromine treatment, and 11 for soils or replicates
1%, 13 for bromine treatment, and 16 for soils or replicates

1

1

TABLE XIX
YIELD OF BEAN PODS (GRAMS) SAMPLED ON OCTOBER 3, 1954
FROM GREENHOUSE

Soils	Repli- cation	High Water		Low Water		Total	Soils Mean	Replica- tions Means
		Check	NaBr	Check	NaBr			
Brookston	1	11.00	11.65	8.95	11.97	43.57	10.63	12.68
	2	12.10	9.48	7.70	9.63	38.91		12.27
	3	10.57	9.82	12.40	12.27	45.06		13.82
Oshtemo	1	7.55	12.00	4.73	10.37	34.65	9.83	
	2	11.15	10.80	9.08	10.72	41.75		
	3	9.70	11.95	9.17	10.75	41.57		
Houghton	1	20.15	19.78	14.76	19.25	73.94	18.31**	
	2	14.25	18.27	15.80	18.25	66.57		
	3	19.98	19.73	19.93	19.60	79.24		
Total		116.45	123.48	102.52	122.81	465.26		
Water means			13.34		12.52			
Bromine treatment means				12.17*	13.68*			

TABLE XIXa
ANALYSIS OF VARIANCE OF YIELD OF BEAN PODS (GRAMS)
SAMPLED ON OCTOBER 3, 1954 (FROM GREENHOUSE)

Source	D.F.	S.S.	M.S.	F
Total	35	649		
Replications	2	16	8	2.71
Soils	2	526	263	89.15**
Bromine Treatment	1	21	21	7.12*
Soils x Bromine	2	8	4	1.36
Water	1	6	6	2.03
Soils x Water	2	2	1	0.34
Bromine x Water	1	5	5	1.69
Soils x Bromine x Water	2	0	0	0.00
Error	22	65	2.95	

* Significant at 5 percent level

** Significant at 1 percent level

LSD 5% 1.23 for bromine and water, and 1.51 for soils and replicates
1% 1.61 for bromine and water, and 1.97 for soils and replicates

TABLE XX

YIELD OF BEAN PODS IN GRAMS FROM SOILS
WHICH WERE USED FOR GREENHOUSE STUDY
(SAMPLED ON NOVEMBER 14, 1954)

Soils	Replica- tions	Treatment Check	NaBr	Total	Soils Means	Replica- tions Means
Brookston	1	17.90	18.40	36.30	17.33	18.74
	2	14.60	18.35	32.95		17.95
	3	14.25	20.45	34.70		18.05
Oshtemo	1	14.80	16.85	31.65	15.43	
	2	9.92	19.65	29.57		
	3	14.60	16.75	31.35		
Houghton	1	19.25	25.25	44.50	21.99**	
	2	20.82	24.35	45.17		
	3	18.90	23.38	42.28		
Total		145.04	183.43	328.47		
Treatments Mean		16.12**	20.38**			

TABLE XXa

ANALYSIS OF VARIANCE OF BEAN PODS' YIELD
FROM SOILS USED IN GREENHOUSE
(SAMPLED ON NOVEMBER 14, 1954)

Source	D.F.	S.S.	M.S.	F
Total	17	256		
Replications	2	2	1.0	0.29
Soils	2	137	68.5	20.15**
Treatments	1	82	82.0	24.12**
Soils x Treatments	2	1	0.5	0.15
Error	10	34	3.4	

** Significant at 1 percent level

LSD 5% 1.90, for bromine treatment, and 2.34, for soils
1% 2.70, for bromine treatment, and 3.30, for soils

1

TABLE XXI

PPM TOTAL BROMINE CONTENT IN BEETS FROM GREENHOUSE
WHICH WERE SAMPLED ON NOVEMBER 14, 1954

Soils	Replica- tions	High water		Low Water		Total	Soils Mean	Replica- tions Means
		Check	NaBr	Check	NaBr			
Brookston	1	28	860	66	956	1,910	504	515
	2	34	1094	44	920	2,092		542
	3	46	984	28	984	2,042		554
Oshtemo	1	115	1030	124	946	2,215	567	
	2	152	1044	114	996	2,306		
	3	138	1032	132	984	2,286		
Houghton	1	132	908	118	900	2,058	540	
	2	98	904	78	1022	2,102		
	3	120	1062	124	1012	2,318		
Total		863	8918	828	8720	19,329		
Water means			543		530			
Bromine Treatment Means				94**	980**			

TABLE XXIa

ANALYSIS OF VARIANCE OF TOTAL BROMINE CONTENT (PPM) IN BEETS
FROM GREENHOUSE WHICH WERE SAMPLED ON NOVEMBER 14, 1954

Source	D.F.	S.S.	M.S.	F
Total	35	7,163,535		
Replications	2	9,338	4,669	2.029
Soils	2	24,410	12,205	5.304*
Bromine Treatment	1	7,064,078	7,064,078	3,070.000**
Soils x Bromine	2	7,572	3,786	1.645
Water	1	1,508	1,508	0.655
Soils x Water	2	2,612	1,306	0.567
Bromine x Water	1	738	738	0.320
Soils x Bromine x Water	2	2,660	1,330	0.578
Error	22	50,619	2,301	

* Significant at 5 percent level

** Significant at 1 percent level

LSD 5% 34.40 for bromine and water, and 42.14 for soils and replicates
1% 44.94 for bromine and water, and 55.06 for soils and replicates

1

TABLE XXII

TOTAL BROMINE CONTENT (PPM) IN SOILS FROM GREENHOUSE
(BEET POTS) SAMPLED ON NOVEMBER 14, 1954

Soils	Replication	High Water		Low Water		Total	Soils Mean	Replications Means
		Check	NaBr	Check	NaBr			
Brookston	1	54	83	54	63	254	64	65
	2	54	73	58	70	255		62
	3	46	86	50	74	256		62
Oshtemo	1	54	73	58	79	264	64	
	2	54	63	58	74	249		
	3	54	73	58	74	259		
Houghton	1	35	98	34	94	261	61	
	2	32	92	32	80	236		
	3	32	89	32	79	232		
Total		4.5	730	434	687	2266		
Water Means			64		62			
Bromine Treatment Means				47**	79**			

TABLE XXIIa

ANALYSIS OF VARIANCE OF TOTAL BROMINE CONTENT (PPM) IN SOILS
FROM GREENHOUSE (BEET POTS) SAMPLED ON NOVEMBER 14, 1954

Source	D.F.	S.S.	M.S.	F.
Total	35	12,658		
Replications	2	72	36	1.83
Soils	2	89	44.5	2.27
Bromine Treatment	1	8,962	8,962	456.31**
Soils x Bromine	2	2,697	1,349	68.69**
Water	1	16	16	0.82
Soils x Water	2	180	90	4.58*
Bromine x water	1	107	107	5.45*
Soils x Bromine x Water	2	103	51.5	2.62
Error	22	432	19.64	

* Significant at 5 percent level

** Significant at 1 percent level

LSD 5% 3 for bromine and water, and 4 for soils and replicates
1% 4 for bromine and water, and 5 for soils and replicates

TABLE XXIII

TOTAL BROMINE CONTENT (PPM) IN SOILS
FROM GREENHOUSE SAMPLING-DECEMBER
29, 1954

Soils	Repli- cations	Treatment Check	NaBr	Total	Soils Means	Replica- tions Means
Brookston	1	33	59	92	51	53
	2	43	61	104		55
	3	45	63	108		54
Oshtemo	1	52	58	110	57	
	2	55	64	119		
	3	52	58	110		
Houghton	1	31	85	116	54	
	2	27	77	104		
	3	29	75	104		
Total		367	600	967		
Treatments Mean		41**	67**			

TABLE XXIIIa

ANALYSIS OF VARIANCE OF TOTAL BROMINE CONTENT
(PPM) IN SOILS FROM GREENHOUSE SAMPLING OF
DECEMBER 29, 1954

Source	D.F.	S.S.	M.S.	F.
Total	17	4,752	280.0	
Replications	2	7	3.5	
Soils	2	103	51.5	2.85
Treatments	1	3,016	3,016.0	167.56**
Soils x Treatments	2	1,448	724.0	40.22**
Error	10	180	18.0	

** Significant at 1 percent level

LSD 5%, 4 for bromine treatment, and 5 for soils and replicates
1%, 6 for bromine treatment, and 8 for soils and replicates

Total bromine content in beet roots sampled on December 29, 1954, was very significantly low in both check and sodium bromide treated Houghton muck, as compared with corresponding samples from both Brookston and Oshtemo soils. (Table XXIV.)

This may suggest a possibility of stronger tie-up of bromine with some organic compounds and, therefore, the availability of bromine to the beets was lower than from Oshtemo or Brookston soils. Further investigation of this phenomenon would be needed in order to have a more complete picture.

The amount of total bromine in beet roots decreased appreciably in both checks and sodium bromide treated pots if compared with the first samples of November 14.

Yields of table beets sampled on November 14 were the highest and differences significant at the five percent level were obtained. They were highest on Brookston, next on Houghton muck, and the lowest on Oshtemo soil. Also, the yield of table beets sampled on December 29 was the highest on Brookston, next on Oshtemo, and the lowest on Houghton muck. There was a significant increase in yield due to sodium bromide treatment. The yields and differences for significance are shown in Tables XXV, XXVa, XXVI, XXVIa.

To show the accumulation of bromine in different parts of growing bean plants, the plants were dismembered into

TABLE XXIV

TOTAL BROMINE CONTENT (PPM) IN BEET TISSUE FROM
GREENHOUSE SAMPLING OF DECEMBER 29, 1954

Soils	Repli- cations	Treatment Check	NaBr	Total	Soils Means	Replica- tions Means
Brookston	1	-	600	600	326	330
	2	-	654	654		337
	3	28	676	704		344
Oshtemo	1	45	639	684	342	
	2	60	625	685		
	3	49	634	683		
Houghton	1	69	629	698	343	
	2	65	618	683		
	3	53	621	674		
Total Treatments Mean		369	5,696	6,065		
		41**	633**			

TABLE XXIVa

ANALYSIS OF VARIANCE OF TOTAL BROMINE CONTENT (PPM)
IN BEET TISSUE SAMPLINGS OF DECEMBER 29, 1954

Source	D.F.	S.S.	M.S.	F.
Total	17	1,585,837		
Replications	2	520	260	0.74
Soils	2	1,014	570	1.63
Treatments	1	1,576,496	1,576,496	4,517.00**
Soils x Treatments	2	4,321	2,161	6.19*
Error	10	3,486	349	

* Significant at 5 percent level

** Significant at 1 percent level

LSD 5% 19 for bromine treatment, and 24 for soils and replicates
1% 27 for bromine treatment, and 33 for soils and replicates

TABLE XXV

YIELD OF TABLE BEETS (GRAMS) FROM GREENHOUSE
SAMPLED ON NOVEMBER 14, 1954

Soils	Repli- cation	High Water		Low Water		Total	Soils Mean	Replica- tions Mean
		Check	NaBr	Check	NaBr			
Brookston	1	23.00	26.30	12.20	18.80	80.30	20.37**	15.21
	2	16.80	18.40	14.60	22.50	72.30		14.09
	3	17.00	26.00	24.00	24.80	91.80		16.39
Oshtemo	1	8.40	15.80	12.90	12.00	49.10	11.66	
	2	9.20	14.80	8.60	10.40	43.00		
	3	10.36	13.80	12.90	10.80	47.86		
Houghton	1	8.80	18.80	13.30	12.20	53.10	13.66	
	2	7.50	18.00	5.90	22.40	53.80		
	3	7.40	20.30	14.10	15.20	57.00		
Total		108.46	172.20	118.50	149.10	548.26		
Water Means			15.59		14.87			
Bromine Treatment Means				12.61**	17.85**			

TABLE XXVa

ANALYSIS OF VARIANCE OF YIELD OF TABLE BEETS (GRAMS) FROM
GREENHOUSE WHICH WERE SAMPLED ON NOVEMBER 14, 1954

Source	D.F.	S.S.	M.S.	F.
Total	35	1,137		
Replications	2	31	15.50	1.38
Soils	2	499	249.50	22.14**
Bromine Treatment	1	247	247.00	21.92**
Soils x Bromine	2	51	25.50	2.26
Water	1	4	4.00	0.35
Soils x Water	2	7	3.50	0.31
Bromine x Water	1	31	31.00	2.75
Soils x Bromine x Water	2	19	9.50	0.84
Error	22	248	11.27	

* Significant at 5 percent level

** Significant at 1 percent level

LSD 5% 2.41 for bromine and water, and 2.95 for soils and replicates
1% 3.15 for bromine and water, and 3.85 for soils and replicates



TABLE XXVI

YIELD OF TABLE BEETS (GRAMS) GROWN IN GREENHOUSE
SAMPLED ON DECEMBER 29, 1954

Soils	Repli- cations	Treatment Check NaBr		Total	Soils Means	Replica- tions Means
Brookston	1	24.00	29.50	53.50	23.72**	20.48
	2	21.00	21.50	42.50		19.69
	3	22.50	23.84	46.34		19.26
Oshtemo	1	15.70	18.10	33.80	18.05	
	2	19.70	19.30	39.00		
	3	16.40	19.10	35.50		
Houghton	1	15.70	19.90	35.60	17.66	
	2	16.66	19.98	36.64		
	3	15.10	18.60	33.70		
Total		166.76	189.82	356.58		
Treatments Mean		18.53*	21.09*			

TABLE XXVIA

ANALYSIS OF VARIANCE OF TABLE BEETS' YIELD (GRAMS)
GREENHOUSE SAMPLINGS OF DECEMBER 29, 1954

Source	D.F.	S.S.	M.S.	F.
Total	17	222		
Replications	2	5	2.50	
Soils	2	138	69.00	15.00**
Treatments	1	29	29.00	6.30*
Soils x Treatments	2	4	2.00	0.43
Error	10	46	4.60	

* Significant at 5 percent level

** Significant at 1 percent level

LSD 5% 2.22 for bromine treatment and 2.79 for soils and replicates
1% 3.14 for bromine treatment and 3.84 for soils and replicates

leaves, including petioles and blades, stems and roots, and were analyzed for total bromine. The results of analyses are shown in Table XXVII for plants grown on untreated and sodium bromide treated soil.

TABLE XXVII

TOTAL BROMINE CONTENT IN PPM IN THE PARTS OF
BEAN PLANTS WHICH WERE GROWN IN GREENHOUSE
AND WERE SAMPLED AT THE STAGE OF
MATURITY

Part of Plant	Treatment	
	Check	NaBr
Leaves	54	444
Stems	100	376
Roots	80	490

The stems of beans grown in soils which were untreated with sodium bromide were the highest in bromine content, next were roots and leaves were the lowest. However, the content of bromine in bean tissue grown in soil treated with sodium bromide was in decreasing order: roots, leaves, and stems.

SUMMARY AND CONCLUSION

Part I

In the study of bromine uptake by cabbage and bean plants, and the yield of some plants grown on Hillsdale sandy loam which was treated with Mc-2, W-85 and NaBr, the following results were obtained:

1. Four samplings of cabbage plants and five soils were taken during the growing season at three-weekly intervals.
2. The method described by Shrader, et al. was used for determination of total bromine in plants and soils.
3. The differences in total bromine content of plant tissue due to soil treatment diminished steadily.
4. There were some fluctuations in the water extractable bromine of soil during the period of study.
5. The amount of water extractable bromine in soils from treated plots was in decreasing order: (1) NaBr, (2) Mc-2, (3) W-85, and (4) Check.
6. The yield of cabbage was the highest on W-85 treated plots, next on check, followed by Mc-2, and the least was on NaBr treated plots.
7. Growth of bean plants was depressed on NaBr and Mc-2 treated plots.

8. Four samplings of bean plants and soils and three of those of bean pods were taken.
9. The amount of total bromine in bean plants was in decreasing order from following plots: (a) NaBr treated, (b) Mc-2, (c) W-85, and (d) Check.
10. The relative amount of bromine in bean plants decreased with the progress in plant growth.
11. The bromine content of bean pods was lower than that of the whole bean plants.
12. The bromine content of bean pods increased at the time of the second sampling on NaBr and Mc-2 treated plots, and decreased later on. Progressive decrease of bromine in pods during whole period of study was on W-85, and check plots.
13. There was a steady decrease in water extractable bromine in soils from all treatments except those treated with NaBr which showed considerable accumulation of bromine from July 14 to August 25 with the rapid decrease later on.
14. The highest yield of bean seeds was on W-85 treated plots, next on checks, followed by Mc-2, and the lowest was on NaBr treated plots.
15. The growth and yield of potatoes was not greatly affected by soil treatment. The yield of potato tubers was in diminishing order as follows: (a)

Mc-2 treated plots, (b) W-85, (c) Check, and (d) NaBr.

16. Peanuts grew vigorously on W-85 and check plots and depressed growth occurred on NaBr and Mc-2 treated plots. The highest yield of peanuts was on W-85 treated plots, next on both Mc-2 and checks and the lowest was on NaBr treated plots.

Part II

In the 1954 field study of the growth, yield and bromine content of table beets and string beans as affected by soil fumigation with Mc-2, and W-85, versus unfumigated checks, on mineral and organic soils, the following results were obtained:

1. The beet roots, bean pods, and soils from corresponding plots were sampled and analyzed for total bromine content on August 19 and September 25, 1954.
2. At the first sampling the total bromine content in beet tissue was not significantly different, and that from check was significantly different at the second sampling. The amount of total bromine in beet tissue diminished from the first to the second sampling.
3. The total bromine content in mineral soil from

both first and second samplings was in diminishing order: (a) Mc-2, (b) W-85, (c) Check.

4. The highest yield and the best quality of beets was on W-85, next on Mc-2, and finally on check plots.
5. The amount of total bromine in beet tissue from Houghton muck was the highest on Mc-2, next W-85, and the least on checks. The same relationship was in the bromine from soils. All differences due to bromine treatment were significant at the 1 percent level.
6. The yield of table beets, in quantity and quality, was the highest on Mc-2 treated plots, next on checks, and the least on W-85 treated plots.
7. The 975 ppm of bromine in beet tissue and 175 ppm in the soil present on September 24, 1954, suppressed development of beets. The leaves were curled and brownish-red colored.
8. The content of total bromine in bean pods on mineral soil was the highest in plants from Mc-2 treated plots, next from W-85 plots, and the lowest was from check plots. The same relationship was shown at the second sampling. All differences were significant at the 1 percent level.
9. The bromine content of mineral soil, from bean

plots, followed the same pattern as that from beet plots. The bromine content from check soils was very significantly different at the time of the second sampling.

Part III.

In the greenhouse study with beans and table beets on Brookston clay loam, Oshtemo, and Houghton soils, and with check and NaBr treatment at two water levels, the following results were obtained:

1. No visible differences were noted during the plant growth due to NaBr treatment or water levels, but there were some differences due to soils.
2. In late September manganese deficiency symptoms occurred on beans on Oshtemo and Houghton checks. It was corrected by addition of dissolved MnSO_4 , equivalent to 10 pounds per acre. No deficiency symptoms occurred on NaBr treated soils.
3. The first sampling of bean pods showed significant difference in bromine content due to NaBr treatment and no significant differences due to water levels.
4. The bromine content of bean pods was in decreasing order: (a) Brookston clay loam, (b) Oshtemo sand, (c) Houghton muck.



5. At the second sampling on November 14, there were decreases in the amount of bromine in plant tissues.
6. The bromine content of bean pods was significantly different due to bromine treatment, but not different due to water levels. The pods from Oshtemo sand were very high in the amount of bromine present.
7. The check soils sampled on October 3, showed the lowest amount of bromine in muck, higher in Oshtemo sand, and the highest in Brookston clay loam.
8. The amount of total bromine in NaBr treated soils was in diminishing order: Houghton muck, Brookston clay loam, Oshtemo sand.
9. The yield of bean pods on October 3 was significantly higher on both check and NaBr treated Houghton muck.
10. There were insignificant yield increases due to NaBr treatments and a high water level.
11. The yield of bean pods on November 14 was significantly high due to NaBr treatment.
12. In beets sampled on November 14, a very significant increase in bromine content due to bromine treatment was found. No such increase was found due to soils or moisture levels.

13. Beet samples and soils which were sampled on December 29 showed a significantly high amount of bromine content due to NaBr treatment.
14. The highest yield of table beets occurred on Brookston clay loam soil at the November 14 and December 29 samplings. Also significant increases in yields of afore-mentioned samplings was found to be due to NaBr treatments in all three soils.

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APPENDIX

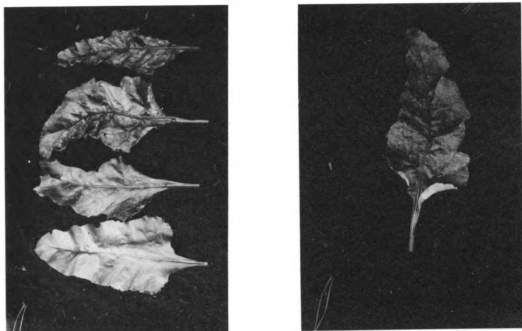


Figure 1. Left: On bottom - normal, healthy leaf of table beet plant; next three leaves - from spot of high bromine content in Houghton soil.
 Right: Leaf affected by high bromine content in soil.



Figure 2. Table beet plants in early stage of growth on Houghton muck. From right to left four rows each are: 1) Protective planting; 2) First planting, Mc-2 treated plot; 3) Replanted, Mc-2; 4) First planting, W-85 treated plot; 5) Replanted, W-85 plot.

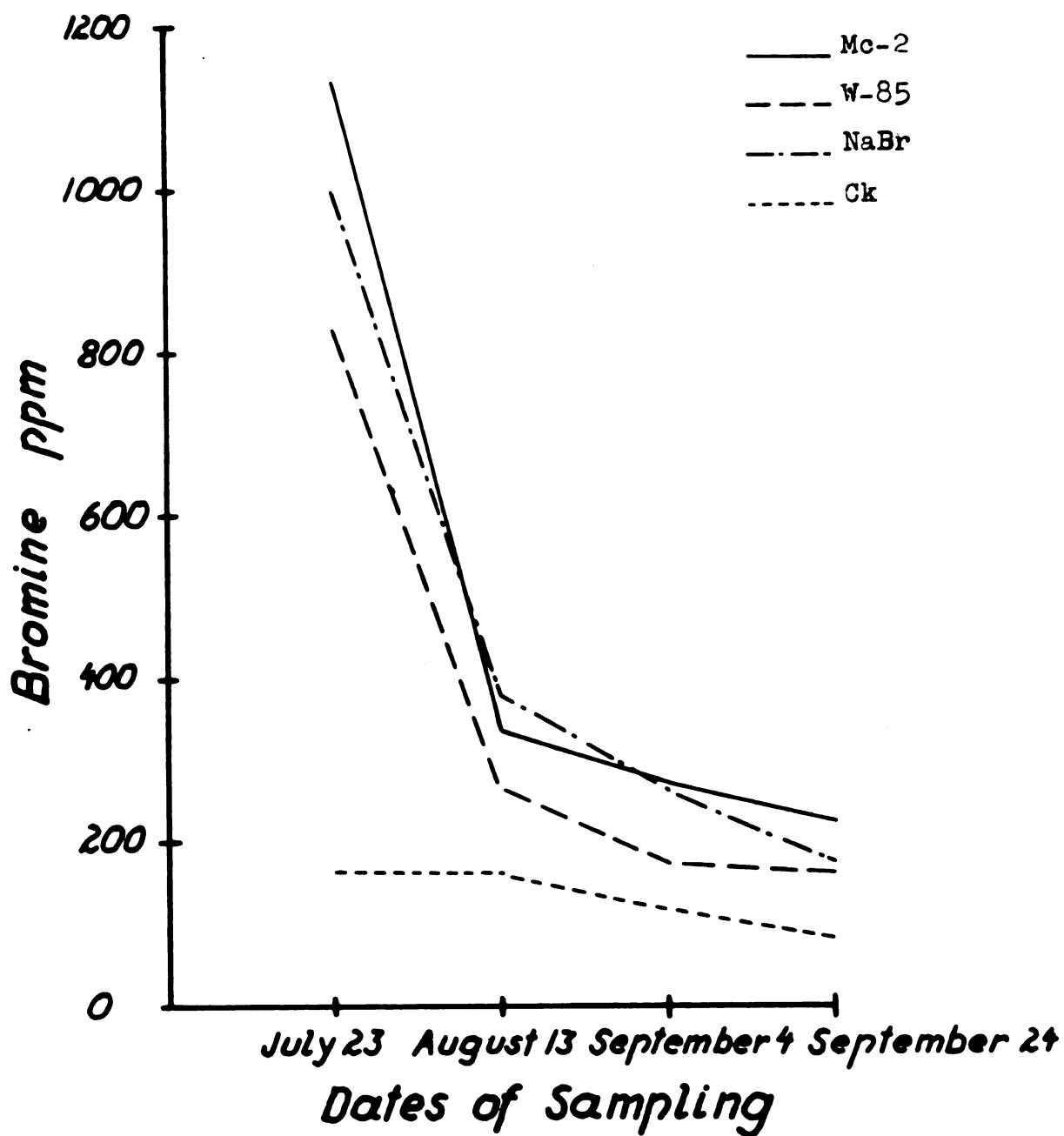


Figure 3. Ppm in cabbage plants grown on Hillsdale sandy loam (means of four replicates).

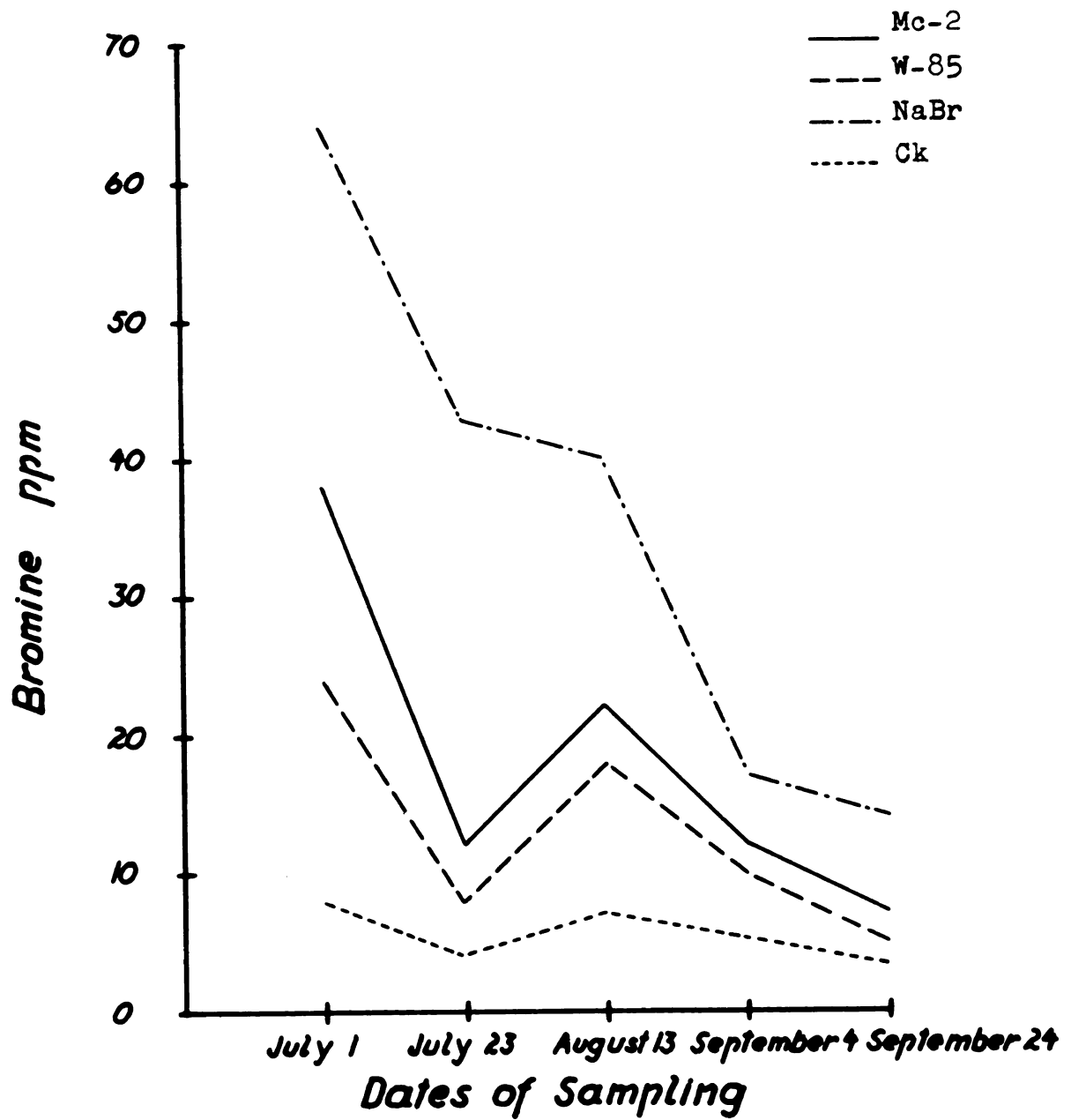


Figure 4. Ppm water extractable bromine in Hillsdale soil (cabbage plots) - means of four replicates.

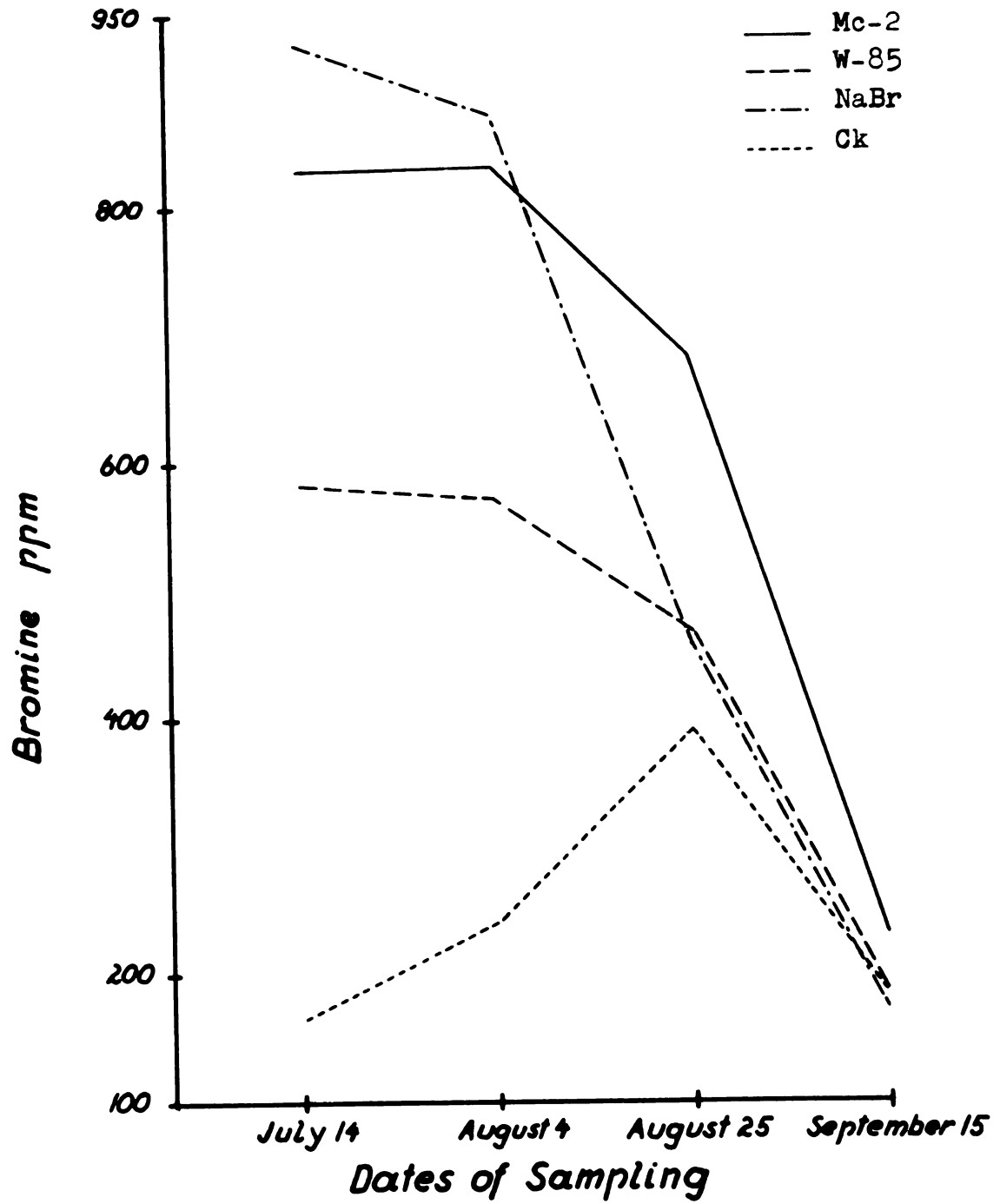


Figure 5. Ppm bromine in bean plants grown on Hillsdale sandy loam (means of four replicates).

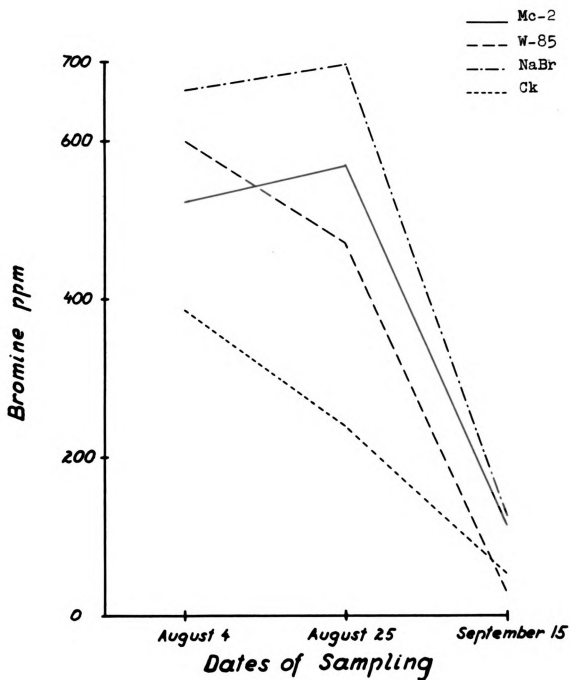


Figure 6. Ppm bromine in bean pods grown on Hillsdale sandy loam (means of four replicates).

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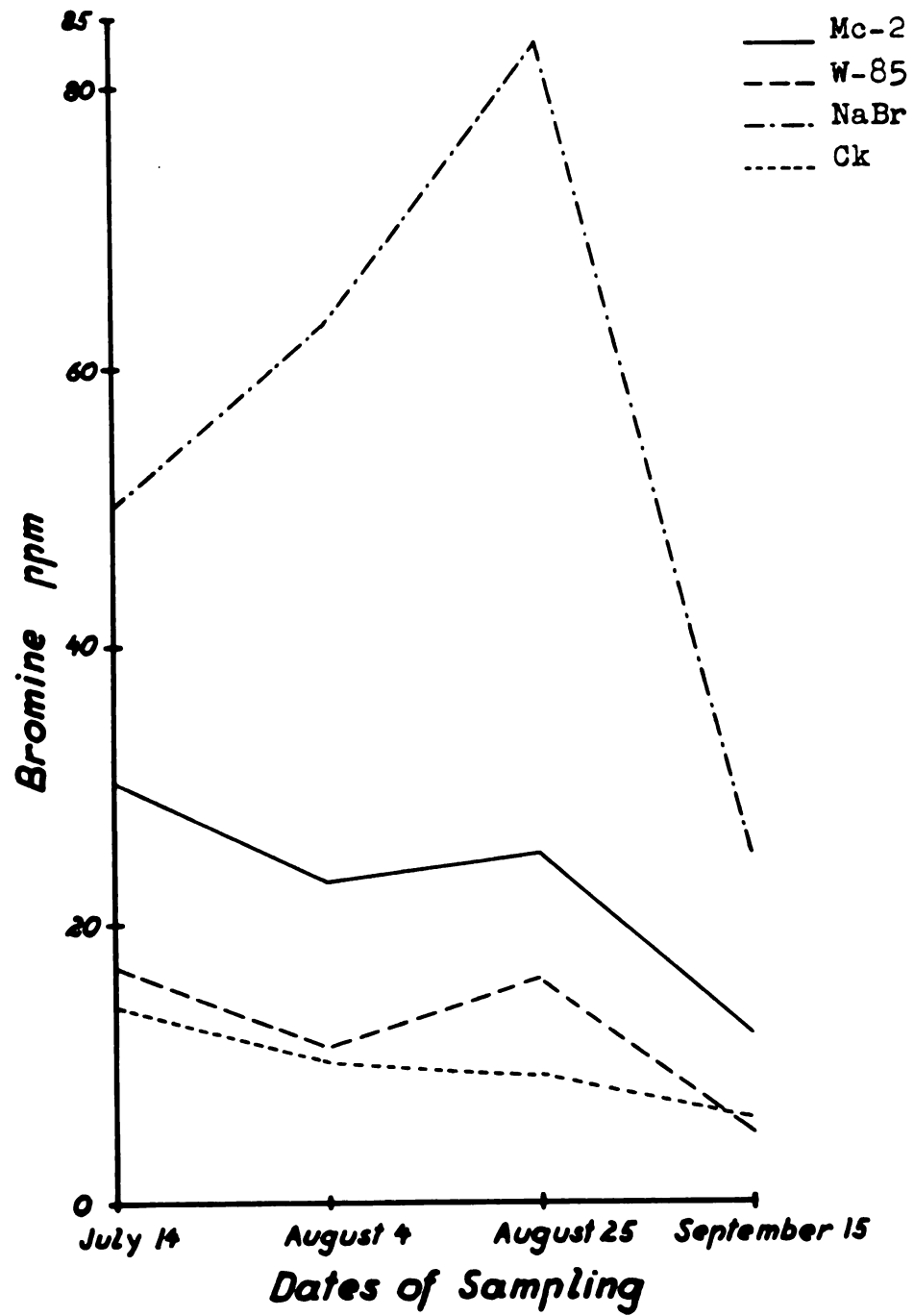


Figure 7. Ppm water extractable bromine in Hillsdale soil from bean plots (means of four replicates).

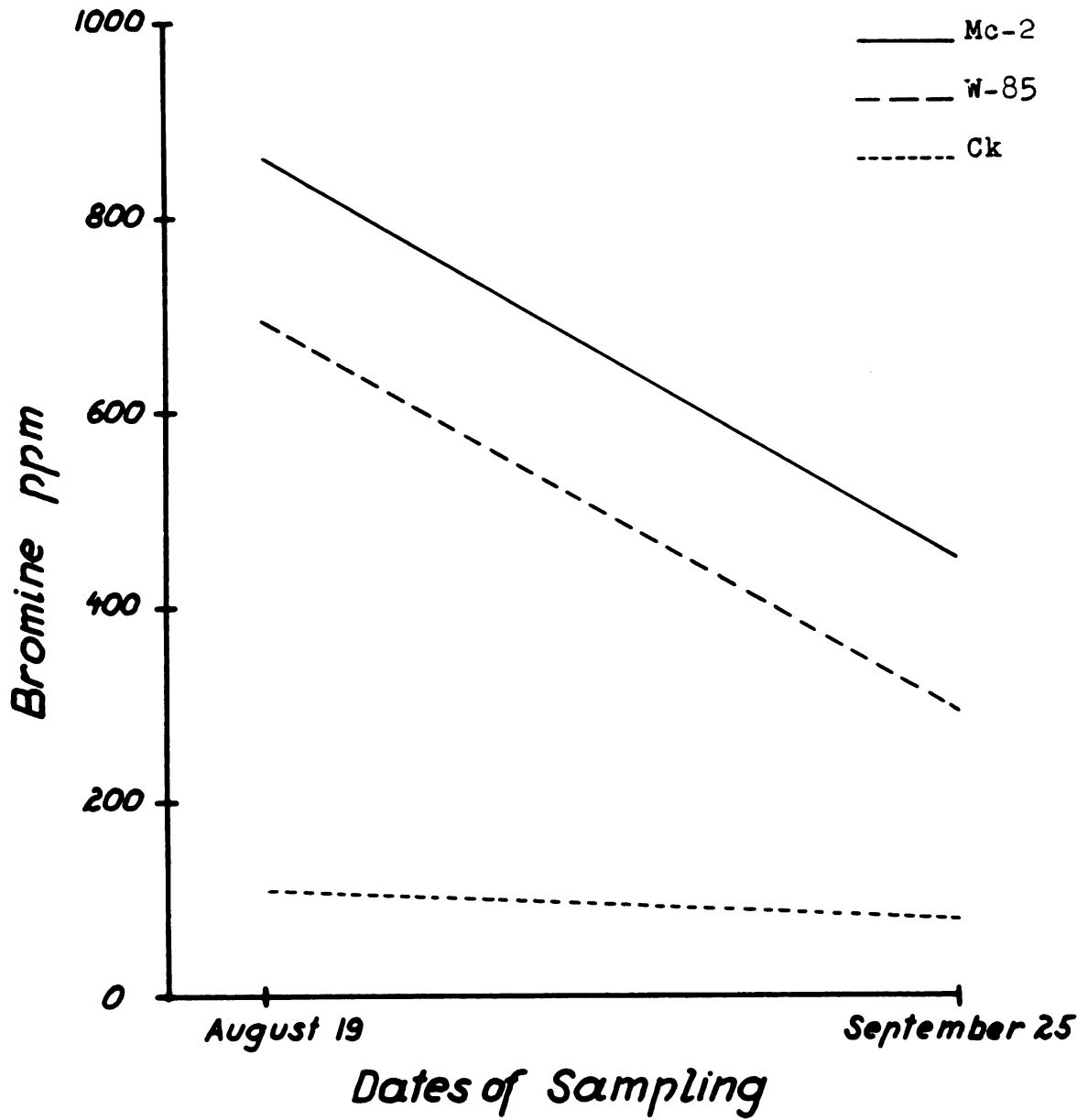


Figure 8. Ppm bromine content of bean pods grown on Brady soil (means of four replicates).

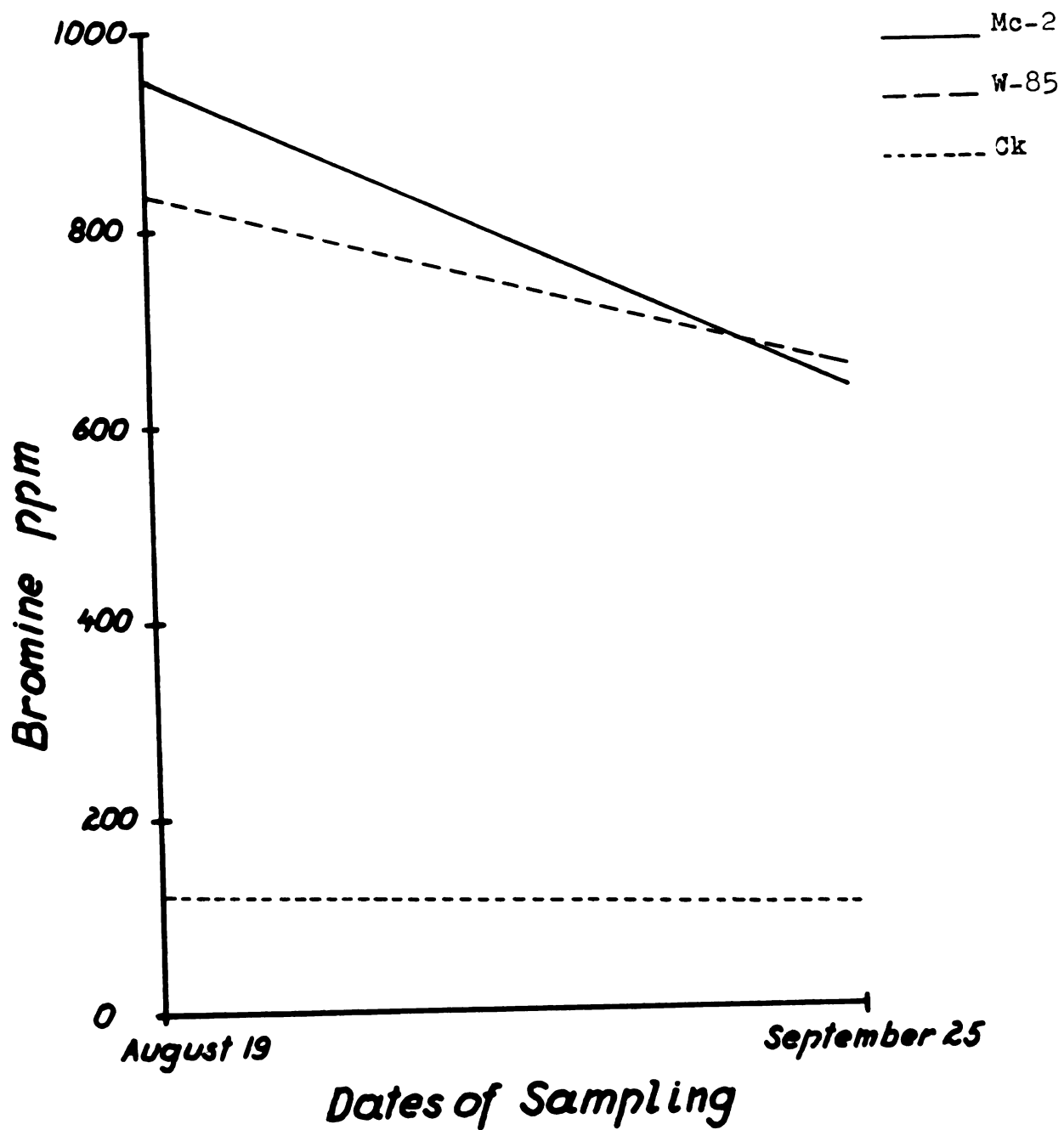


Figure 9. Ppm bromine content of table beets grown on Brady soil (means of four replicates).

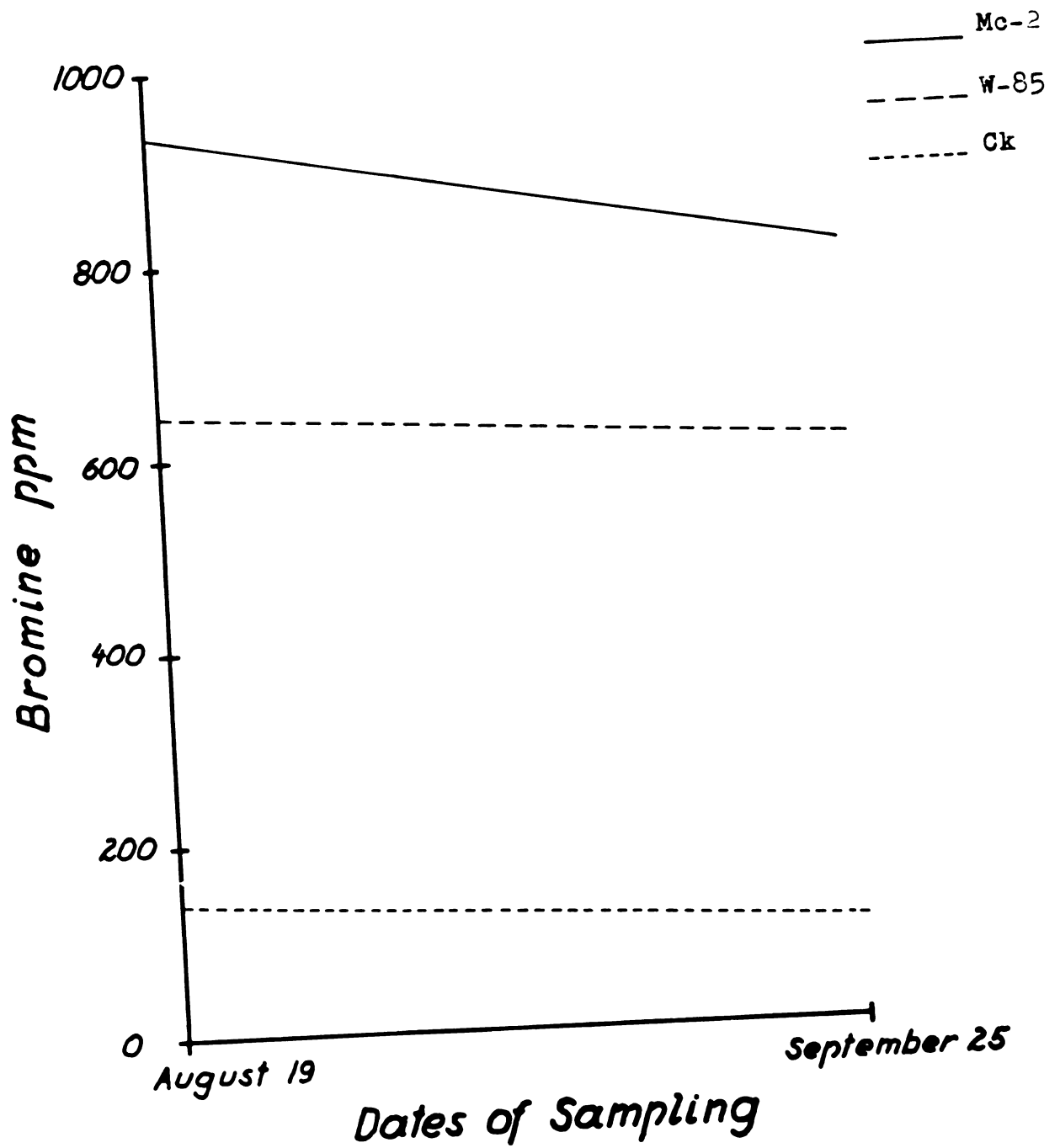


Figure 10. Ppm bromine content of table beets grown on Houghton Muck (means of four replicates).

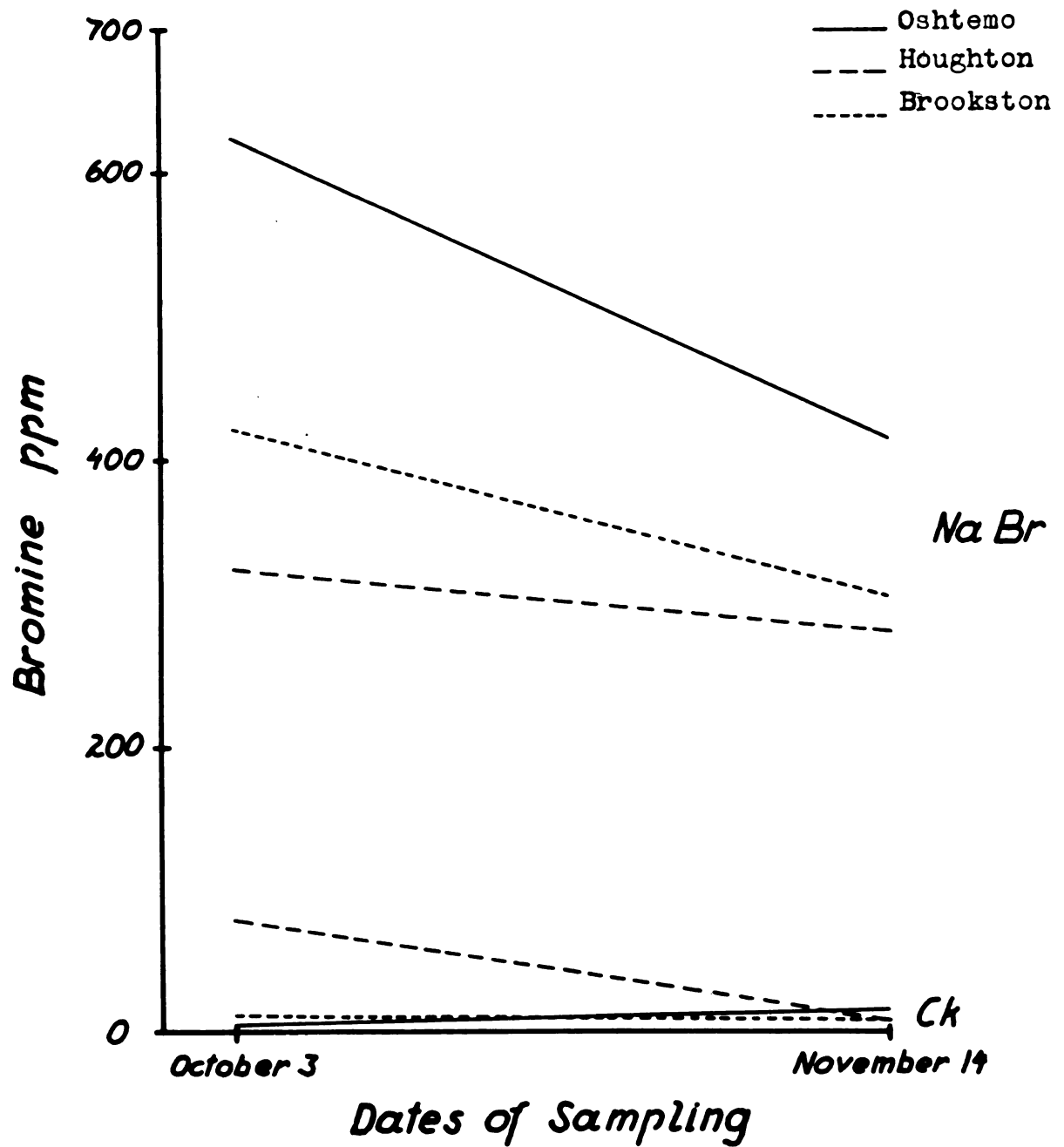


Figure 11. Ppm bromine content in bean pods grown in greenhouse on three soils (low moisture level).

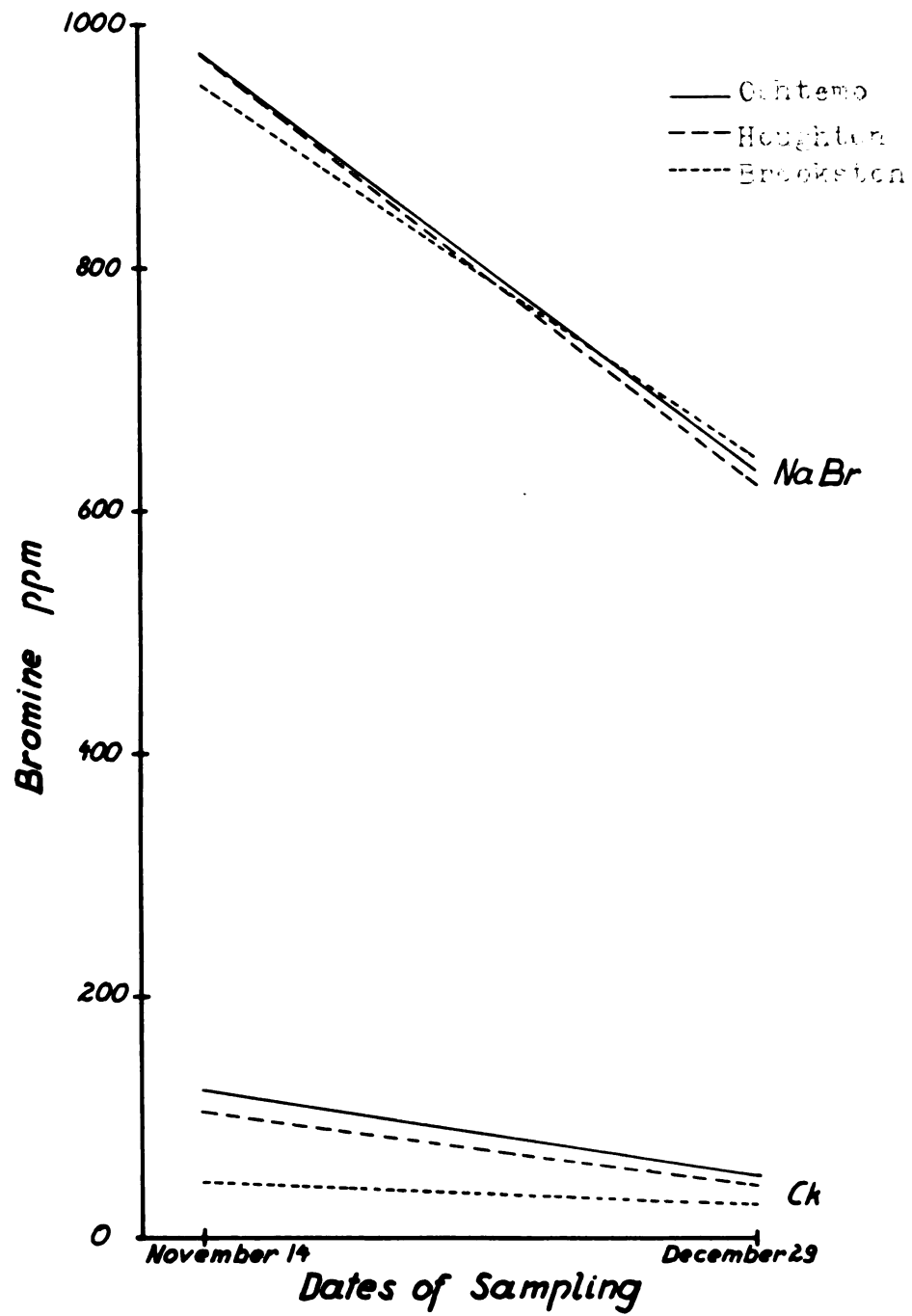


Figure 18. Ppm bromine content of 3-yr old roots grown in greenhouse on three soils (low moisture level).

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