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Effects of Soil Fumigations with Telone and Nemagon on Physio-Chemical and Ultrastructural Changes in Carrot Roots and Sweet Corn Seeds

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EFFECTS OF SOIL FUMIGATIONS WITH TELONE AND NEMAGON ON PHYSIO-CHEMICAL AND ULTRASTRUCTURAL CHANGES IN CARROT ROOTS AND SWEET CORN SEEDS

by

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Maureen Mei-chu Chen

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ABSTRACT

Effects of Soil Fumigations with Telone and Nemagon

on Physio-chemical and Ultrastructural Changes

in Carrot Roots and Sweet Corn Seeds

by

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Department: Plant Nutrition and Biochemistry

Carrots (Daucus carota L. cv. Royal Chantenay) and sweet corn (Zea mays L. cv. Iochief) were grown on the Utah State University's Greenville farm in 1969 and 1970. The soil was fumigated with Telone (a mixture of 1,3-dichloropropene and other chlorinated hydrocarbons) at the rates of 10, 20, and 30 gal/acre and Nemagon (1,2-dibromo-3-chloropropane) at the rates of 1, 2, and 3 gal/acre one week before planting. Samples of uniformly mature carrot roots were taken for the studies of total carotenes, β-carotene, total and reducing sugars, respiration, and ultrastructural changes; and those of sweet corn seeds for the studies of total carotenoids, starch, total sugar, and total nitrogen changes.

Compared to the controls, carrots grown on fumigated soil had a significantly higher content of total carotenes, β-carotene, and total sugars, and a lower rate of respiration. The electron microscopic study indicated that the carrots from Telone (30 gal/acre) and Nemagon (3 gal/acre) fumigated soil had larger chromoplasts that contained more globuli and crystals than those of the controls. The soil fumigations with Telone and Nemagon also brought about the increase in total carotenoid content in sweet corn seeds.

(43 pages)

INTRODUCTION

Pesticides continue to play a major role for the control of the large number and variety of pests that attack the crops. Practical control of plant-parasitic nematodes with chemicals is a relatively recent development. The use of nematocides has developed rapidly from a few hundred pounds in 1943 to an annual total exceeding 60 million pounds in 1963, and an even more rapid increase in their use has occurred recently.

The effective nematocides in use today are volatile halogenated hydrocarbons. It is considered that they have high vapor pressure to spread through the soil particles. In addition, because of the volatile character, they may cause negligible residue problems. Since the halogenated hydrocarbons are phytotoxic, they are usually applied to the soil as preplant treatments.

Some possible mechanisms of the action of the organic halide nematocides have been proposed but still uncertain. The toxicity of the organic halides seems to be related with their activity in bimolecular nucleophilic displacement reactions; and is in the order as $I > Br > Cl$.

Telone and Nemagon are two of the most effective nematocides used for the control of root knot nematodes as carrot root nematodes, lesion or medow nematodes, cyst formers as sugar beet and golden nematodes and many other species. A wide variety of crops can be treated with Telone and Nemagon, and it is especially useful for citrus replanting areas, cotton, floral or nursery crops, pineapples, tobacco, and vegetables of all kinds in sandy or muck soils.

Telone (a mixture of 1,3-dichloropropene and other chlorinated hydrocarbons) and Nemagon (1,2-dibromo-3-chloropropane) are halogenated hydrocarbons, and nearly a hundred species of bacteria, yeasts, and molds representing thirty genera have been described to attack one or more kinds of hydrocarbons. Therefore, the nature of the microbial population of the soil may be altered, and chemical and physical changes may occur in the soil following fumigation.

The commercial soil fumigants have been recognized to control nematodes but their effects on the crops grown on these soils have not been fully understood. Telone was recently found to increase β-carotene content of carrot roots and sweet corn seeds (Emerson et al., 1969).

The aim of this study was to investigate the total carotene, β-carotene, total and reducing sugar, respiration, and ultrastructural changes in carrot roots, and total carotenoid, starch, total sugar, and total nitrogen changes in sweet corn seeds through soil fumigation with Telone (10, 20, and 30 gal/acre) and Nemagon (1, 2, and 3 gal/acre).

REVIEW OF LITERATURE

The hydrocarbons such as methyl bromide, ethylene dibromide, chloropicrin, 1, 3-dichloropropane, 1, 2-dibromo-3-chloropropane, and some mixtures such as D-D, and Telone have been widely used as soil fumigants (National Academy of Science, 1968).

Some of the organic pesticides and hydrocarbons have been found to serve as carbon and energy sources of certain soil microbes. Hydrocarbons are degraded by microorganisms growing under aerobic and anaerobic conditions. Cell substances, carbon dioxide, organic acids, alcohols, unsaturated compounds are the products. Hydrocarbon-oxidizing microorganisms are widely distributed in soil including 14 species of Actinomyces, 13 Pseudomonas, 10 Proactinomyces, 10 Mycobacterium, 9 Bacillus, 7 Bacterium, 7 Micrococcus, 6 Aspergillus etc. (Zobell, 1946). A Pseudomonas sp. isolated from soil can metabolize 3-bromopropanol via the sequence: 3-bromopropanol to 3-bromopropionic acid to 3-hydroxypropionic acid to CO_2 (Castro and Bartnicki, 1965). Pseudomonas was also reported having two halidohydrolases which catalyzed a variety of dehalogenation that conformed to the general equation: $L\text{-}RCHXCOO^- + OH^- \longrightarrow D\text{-}CHOHCOO^- + X^-$, where X=Cl or I, R=H, CH_3, or CH_4CH_2 (Goldman, Milue and Keister, 1968). Certain microbial genera such as Pseudomonas, Agrobacterium, Bacillus, Alcaligenes, Arthrobacter and Nocardia were responsible for the decomposition of 2, 2-dichloropropionate and effective in liberating chloride ion (Kearney, Kaufman and Beall, 1964). Some chlorinated hydrocarbons such as D-D, 1,2-dichloropropane, 1,3-dichloropropane could be utilized by B. subtilis and A. globiformis at concentrations up to and including 1000 ppm (Altman and Lawlor, 1966).

It was reported that the population of the nitrifiers was reduced more than that of the ammonifiers by soil fumigants. The inhibition in nitrification had resulted in an accumulation of ammonium nitrogen in the fumigated soil, and the effect was in an order as methyl bromide >D-D> ethylene dibromide (Wensley, 1953). It was also indicated that the nitrate production was decreased by heptachlor, lindane, and BHC; increased by toxaphene, TDE and DDT; and unchanged by dieldrin, aldrin, chlordane, and methoxychlor (Eno and Everett, 1958). The form of nitrogen in the soil would influence the absorption of other ions by plants. In relation to nitrate, the ammonium ion resulted in a lower content of K, Ca, and Mg and a higher content of Cl and S in plants (Evans and Weeks, 1947; Harward et al., 1956). Tobacco in soil fumigated with D-D and methyl bromide, tomato in soil fumigated with chloropicrin, and celery in soil fumigated with Telone have been reported having poor growth. The reason for the poor growth of those plants was attributed to the inhibition of nitrifying bacteria resulting in the high ammonium levels in the fumigated soil (McCants, Skogley and Woltz, 1959; Thiegs, 1955; Wolcott et al., 1960). Tams (1945) demonstrated that the treatment of soil with either chloropicrin or D-D stimulated the development of pineapple roots, causing statistically significant increases in total length, and total dry weight of pineapple plants. He illustrated that the application of those two fumigants suppressed nitrification for 24 weeks, so that the nitrogen taken up from the soil by the pineapple plants was mainly in the form of ammonium. The results of his experiment have shown that the pineapple plants absorbed and assimilated ammonium more rapidly than nitrate. Altman and Tsue (1965) described that D-D stimulated seed germination and increased growth of sugar beets, which might be related to the more available nitrogen in the fumigated soil. Whitehead, Tite and Fraser (1970) found that D-D or Telone increased the yields and total sugars contents in sugar beets and barley. Martin and Pratt (1958) stated that chloride or bromide sensitive plants might be injured when planted in soil fumigated with halogenated hydrocarbons. The leaf burn of avocadoes has been caused following chloropicrin fumigation. Onions, sweet potatoes, and potatoes often grew poorly following soil fumigation with Nemagon.

Some chlorinated hydrocarbon insecticides including aldrin and heptachlor were found to be absorbed and translocated into crops such as radishes, beets, potatoes, carrots, cucumbers and lettuce (Lichtenstein, 1960). Lichtenstein, Myrdal and Schulz (1965) also indicated that carrots tolerated and absorbed pesticide residues from soil. The concentrations of aldrin and heptachlor residues in the carrots ranged from 22 to 80% of the concentrations in the soil. They also mentioned that the amount of insecticides absorbed and translocated into plant tissues was dependent on the insecticide employed, the varieties of crops, and the soil types.

In carrots, carotenoids are present in chromoplasts. However, the ultrastructure of the chromoplasts has not been studied thoroughly. From the structural point of view, there are three types of chromoplasts. The chromoplasts in carrot roots as well as in tomato fruits contain the microscopic crystals of carotenoids. Steffen and Reck (1964) studied the development of chromoplasts in carrots with light microscope and reported that carotenes appeared first in globuli and then formed crystalloid structure. Frey-Wyssling and Schwegler (1965) worked on the same problem with the electron microscope and gave no detail information on the developmental process. The ultrastructural development of the chromoplasts in tomato fruit has been investigated in more detail by Harris and Spurr (1969). They demonstrated that there were two important sub-ultra units in the mature crystalline chromoplasts: osmiophilic globuli and crystals. The carotenes were expected to be concentrated in globuli and crystals.

EXPERIMENTAL

Sample selection

Seeds of carrots (*Daucus carota* L. cv. Royal Chantenay) and sweet corn (*Zea mays* L. cv. Iochief) (Joseph Harris Co., Rochester, N.Y.) were sown on May, 1969, and 1970, on the Utah State University's Greenville farm at North Logan, Utah. Telone, at the rates of 10, 20, and 30 gal/acre and Nemagon at the rates of 1, 2, and 3 gal/acre were applied by means of an experimental fumigant injector one week before planting. The sandy loam soil was irrigated whenever it was necessary. All experiments were arranged in a completely randomized block design. Seven replications were used with each treatment randomized within a replication.

After 3 1/2-4 months, carrots were harvested. Uniform roots were selected on the basis of size and separated into three groups of specific gravity: 1.01, 1.02, and 1.03 (Clark, Lombard and Whiteman, 1940). Sweet corn was harvested when it had attained a moisture level of 60%. The per cent moisture of seeds was used as a basis for determining the maturity (Henry *et al.*, 1956).

Methods of chemical analyses

1. Total carotenoids and carotenes were analyzed by the methods of AOAC (1960); β-carotene was determined by the method described by Devine, Hunter and Williams (1945).

2. Shaffer-Somogyi method (AOAC, 1960) was used for total and reducing sugar determination, and starch was extracted and measured by the method of McCready *et al*. (1950).

3. Micro-Kjeldahl method (AOAC, 1960) was used for the determination of total nitrogen.

4. Respiratory rates of discs of carrot roots were measured with Gilson Respirometer at 25 C.

Methods of the ultrastructural studies

Transectional slices of phloem from the middle part of carrot root approximately 1 mm^3 were fixed by the following fixatives: (1) 3% $KMnO_4$ (Frey-Wyssling, 1965); (2) Karnovsky's fixative and 3% OsO_4 (Karnovsky, 1965); (3) 5% glutaraldehyde and 5% OsO_4 vuffered in 0.1 M potassium phosphate buffer solution, pH 7.3 (Sabatini, Miller and Barbett, 1964; Wood and Luft, 1965). After fixation, tissues were washed with distilled water or buffer solution, then dehydrated in a graded ethanol and embedded in Epon 812 (Luft, 1961). Block sections around 80 µm were mounted on the 200 mesh copper grids and stained with uranyl acetate and Reynold's lead, and finally examined with a Zeiss EM-9A electron microscope.

Statistical analysis

Analysis of variance was made and the means were compared according to Tukey's ω-procedures (Steel and Torrie, 1960).

RESULTS AND DISCUSSION

Effects of soil fumigations with Telone and Nemagon on physio-chemical changes of carrot roots and chemical changes in sweet corn seeds

Soil fumigation with Telone and Nemagon brought about considerable increases in the contents of total carotenes (15-54% in 1969 and 16-45% in 1970), β-carotene (16-56% in 1969 and 15-48% in 1970), and total sugars (5-55% in 1969 and 6-30% in 1970) in carrot roots (Tables 1 and 3, and Figures 1, 2, 4, and 5). The influence on sweet corn seeds showed the same tendency, the increase in total carotenoids was up to 33% in 1969 and 26% in 1970, and total sugars was up to 58% in 1969 and 44% in 1970 (Tables 2 and 4, and Figures 3 and 6). Soil fumigation with Telone and Nemagon did not change the starch, reducing sugars, and total nitrogen contents in both crops (Tables 1, 2, 3, and 4). The respiratory rates of carrot grown on fumigated soil were decreased. The reduction by Telone-fumigation ranged from 23-35% in 1969 and 13-27% in 1970, and by Nemagon-fumigation from 23-45% in 1969 and 23-31% in 1970 (Tables 1 and 3, and Figures 1, 2, 4, and 5).

The mechanisms whereby these two fumigants caused the changes in the chemical composition and the physiological processes of the crops are unknown. However, this experiment demonstrated some specific changes that took place when these two compounds were applied as preplant fumigants to the soil. Carrots grown on the fumigated soil respired less rapidly. This may imply a lower rate of destruction of carotenoids by lipoxidases, which in turn result in the increase of carotene content in the carrot roots. The residues of Telone and Nemagon or their degradation products in the soil may be absorbed by carrots or sweet corns, and subsequently may influence the biosynthesis of carotenoids directly or indirectly.

It has been demonstrated that soil fumigation with methyl bromide, ethylene dibromide, D-D, chloropicrin, and Telone reduced the population of the nitrifiers that resulted in an accumulation of ammonium nitrogen in the soil (Wensley, 1953; McCants et al., 1959; Martin and Pratt, 1958; Thiegs, 1955; Wolcott et al., 1960; Tams, 1945; Altman and Tsue, 1965). The nitrogen content of soil was confirmed to be the most important factor relating to the formation of carotenoids in rye and oats (Wynd and Noggle, 1946). Nagel (1940) found that when additional nitrogen in the form of nitrite was fed to the tobacco plants, there was an increase in the total carotenoids production and at the same time, there was a decrease in the xanthophyll-carotene ratio, indicating the preferential synthesis of carotenes. Therefore, one possibility is that the increase in the carotene content of carrots and the carotenoid content of sweet corn seeds might result from the more available ammonium nitrogen in the soil fumigated with Telone and Nemagon.

The poor growth and chlorosis of certain plants have been found after soil fumigated with organic halides; and the reason of these symptoms was due to the increase of soluble halide ions in soil through fumigation (Martin and Pratt, 1958). Alkyl halides such as Telone and Nemagon rapidly oxidized the

Fe^{+2} porphyrins into Fe^{+3} halide complexes as hemino (Castro, 1964). The exact role of chloride or bromide in certain plants is still unknown, but Fe ion chelated the porphyrin is the prosthetic group of cytochrome b and c. From the present study, it is supposed that the increased amount of soluble chlorides or bromides through soil fumigation with Telone and Nemagon or the absorbed residue of Telone or Nemagon had not reached the toxic level for carrots, but might be enough to inhibit cytochromes in electron transfer chain. This may substantiate the finding that carrots grown on the fumigated soil respired less rapidly.

Specific gravity of carrot roots related to the content of total carotenes

It has been reported that there was no relationship between shape ratio and carotene concentration in carrot roots (Pepkowitz et al., 1944). Results from the present work showed that carrots with different specific gravities (1.01, 1.02, and 1.03) contained the same amount of carotenes and β-carotene. Soil fumigation with Telone and Nemagon did not affect specific gravity and the size of the carrot roots.

Contents of total carotenes and total sugars, and the respiratory rates of stored carrot roots grown on Telone or Nemagon fumigated soil

The carrots were stored at 3 C in polyethylene bags. During the four months of storage, the total carotene content remained fairly constant while the total sugar content decreased (Table 5). Compared with the carrots grown on unfumigated soil, the carrots grown on fumigated soil had higher contents of total carotenes and total sugars, and a lower respiration rate during the storage period (Table 5).

The ultrastructural changes of chromoplasts in carrot roots by soil fumigation with Telone and Nemagon

In the present study, three kinds of fixative have been used. Among them, the glutaraldehyde-osmium tetraoxide fixative gave the best results. Through the electron microscopic study, it appeared that the chromoplasts of carrot grown on the fumigated soil (Telone at 30 gal/acre, and Nemagon at 3 gal/acre) were larger and contained more globuli and crystals than those of the controls (Figures 7, 8, and 9).

The carotenes in chromoplasts of crystalline type were located in globuli and crystals (Steffen and Reck, 1964; Harris and Spurr, 1969). It is possible that increases in the amount and size of globuli and crystals in the chromoplasts might result in an increase in carotene content of the carrot roots.

Table 1. Effects of Telone and Nemagon on the contents of total and reducing sugars, total carotenes and β-carotene and the rates of respiration of carrot roots, 1969 experiment

Treatment		Total carotenes	β-carotene	Total sugars	Reducing sugars	Respiration
Compound	Dosage gal/acre	μg/100 g	μg/100 g	g/100 g	g/100 g	μl O_2/g/hr
Control	--	5250	4933	4.51	1.80	117.9
Telone	10	6989**	6586**	5.13**	1.31 ns	91.5*
	20	6943**	6668**	7.11**	1.74 ns	84.9*
	30	8084**	7689**	6.22**	1.50 ns	81.0**
Nemagon	1	6062**	5728*	4.76*	1.82 ns	87.9*
	2	6461**	5995**	6.73**	1.95 ns	81.3**
	3	6989**	6729**	6.50**	2.01 ns	66.6**

*Significant at 0.05 level.
**Significant at 0.01 level.
ns = Not significant at 0.05 level.

Table 2. Effects of Telone and Nemagon on dry weight, total carotenoids, starch, total sugars, and total nitrogen of sweet corn seeds, 1969 experiment

Treatment						
Compound	Dosage gal/acre	Dry Weight %	Total carotenoid µg/100 g	Starch g/100 g	Total sugars g/100 g	Total nitrogen g/100 g
Control	--	40.0	1459	21.4	3.81	0.51
Telone	10	40.0^{ns}	1780*	21.3^{ns}	3.50^{ns}	0.51^{ns}
	20	40.3^{ns}	1882*	21.2^{ns}	4.34*	0.52^{ns}
	30	40.5^{ns}	1947**	21.4^{ns}	6.01**	0.52^{ns}
Nemagon	1	40.2^{ns}	1588*	21.6^{ns}	4.13^{ns}	0.51^{ns}
	2	39.9^{ns}	1690*	21.5^{ns}	4.22^{ns}	0.51^{ns}
	3	40.2^{ns}	1775*	21.3^{ns}	4.96**	0.51^{ns}

*Significant at 0.05 level.
**Significant at 0.01 level.
ns = Not significant at 0.05 level.

Table 3. Effects of Telone and Nemagon on the contents of total and reducing sugars, total carotenes and β-carotene, and the rates of respiration of carrots, 1970 experiment

Treatment: Compound	Treatment: Dosage gal/acre	Total carotenes μg/100 g	β-carotene μg/100 g	Total sugars g/100 g	Reducing sugars g/100 g	Total nitrogen g/100 g	Respiration μl/hr/g
Control	--	5359	4927	4.70	2.27	0.14	108.8
Telone	10	6361**	5881**	5.95**	1.89 ns	0.13 ns	94.9*
	20	6746**	6270**	5.42**	2.04 ns	0.14 ns	88.5*
	30	7790**	7315**	5.72**	2.18 ns	0.16 ns	79.1**
Nemagon	1	6216**	5668**	5.00*	2.28 ns	0.15 ns	83.7*
	2	6734**	6182**	6.10**	1.98 ns	0.14 ns	82.8*
	3	7724**	6650**	5.95**	2.10 ns	0.15 ns	75.3**

*Significant at 0.05 level.
**Significant at 0.01 level.
ns = Not significant at 0.05 level.

Table 4. Effects of Telone and Nemagon on dry weight, total carotenoids, starch, total sugars, and total nitrogen of sweet corn seeds, 1970 experiment

Treatment		Dry weight	Total carotenoid	Starch	Total sugars	Total nitrogen
Compound	Dosage gal/acre	%	µg/100 g	g/100 g	g/100 g	g/100 g
Control	--	41.0	1526	21.5	3.89	0.58
Telone	10	41.2^{ns}	1720*	21.8^{ns}	3.73^{ns}	0.57^{ns}
	20	41.9^{ns}	1810*	21.2^{ns}	4.43*	0.53^{ns}
	30	41.3^{ns}	1918**	21.8^{ns}	5.59**	0.60^{ns}
Nemagon	1	41.0^{ns}	1652*	21.0^{ns}	4.24*	0.58^{ns}
	2	40.4^{ns}	1703*	21.5^{ns}	4.44*	0.57^{ns}
	3	41.2^{ns}	1821*	21.1^{ns}	4.73**	0.55^{ns}

*Significant at 0.05 level.
**Significant at 0.01 level.
ns = Not significant at 0.05 level.

Table 5. Effects of storage on the total carotenes, total sugars, and respiratory rates of carrot roots grown on Telone or Nemagon-fumigated soil

Treatment		Total carotenes µg/100 g		Total sugars g/100 g		Respiratory rate µl O_2/g/hr	
Compound	Dosage gal/acre	2 months	4 months	2 months	4 months	2 months	4 months
Control	--	5206	5344	4.0	3.7	82.1	74.0
Telone	10	6894**	6833**	4.7**	4.5**	66.3*	60.8*
	20	7047**	6909**	6.7**	6.4**	68.0*	60.4**
	30	7830**	7915**	5.8**	5.5**	58.4**	55.3*
Nemagon	1	5952**	6004*	4.4*	4.1*	69.0*	62.4*
	2	6390**	6375**	6.3**	6.0**	63.7*	59.6*
	3	6706**	6855**	6.2**	5.9**	57.8**	54.9**

*Significant at 0.05 level.
**Significant at 0.01 level.

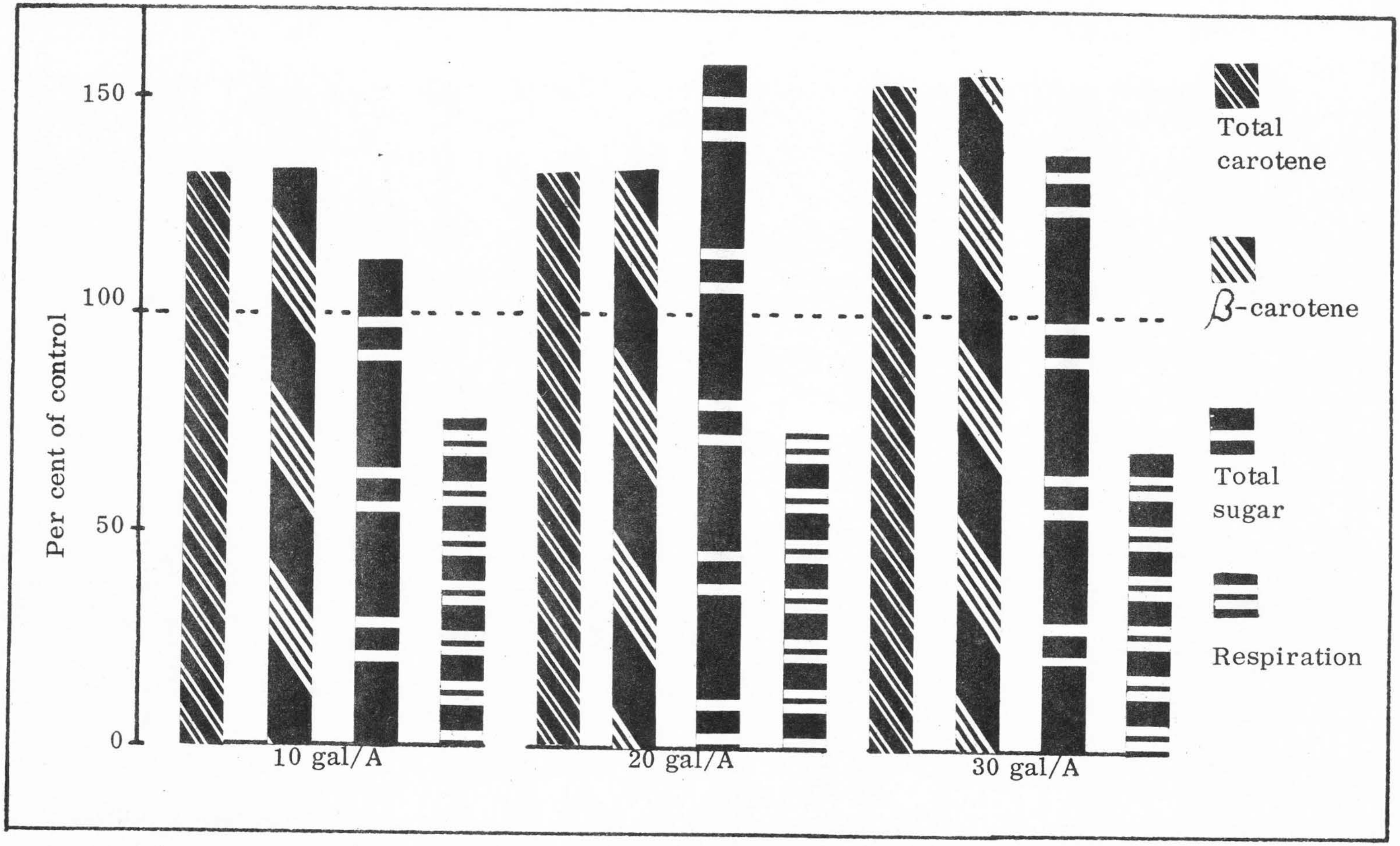

Figure 1. Effects of Telone on total carotenes, β-carotene, total sugars, and respiration of the roots of carrots, 1969 experiment.

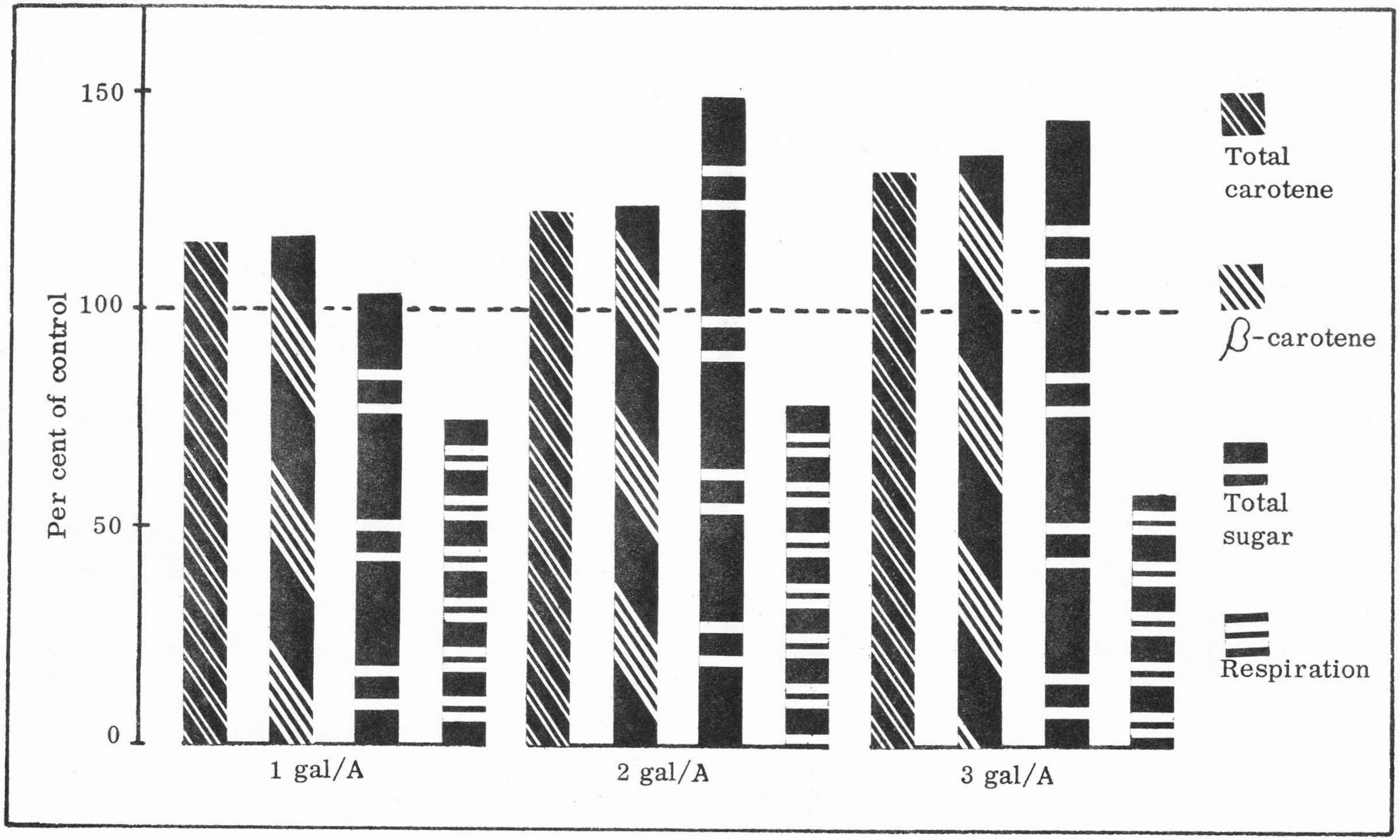

Figure 2. Effects of Nemagon on total carotenes, β-carotene, total sugars, and respiration of the roots of carrots, 1969 experiment.

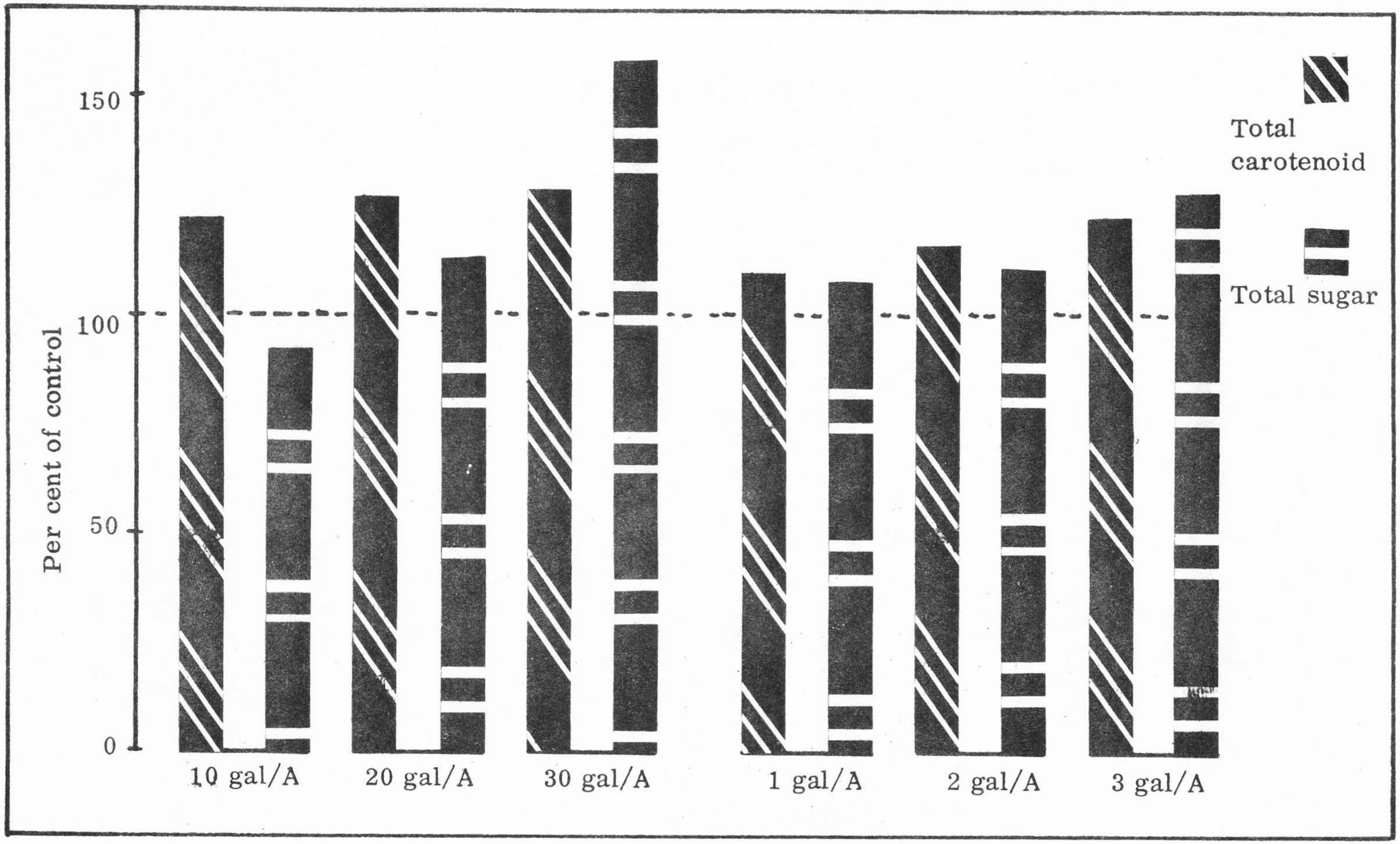

Figure 3. Effects of Telone and Nemagon on total carotenoids and total sugars of the seeds of sweet corn, 1969 experiment.

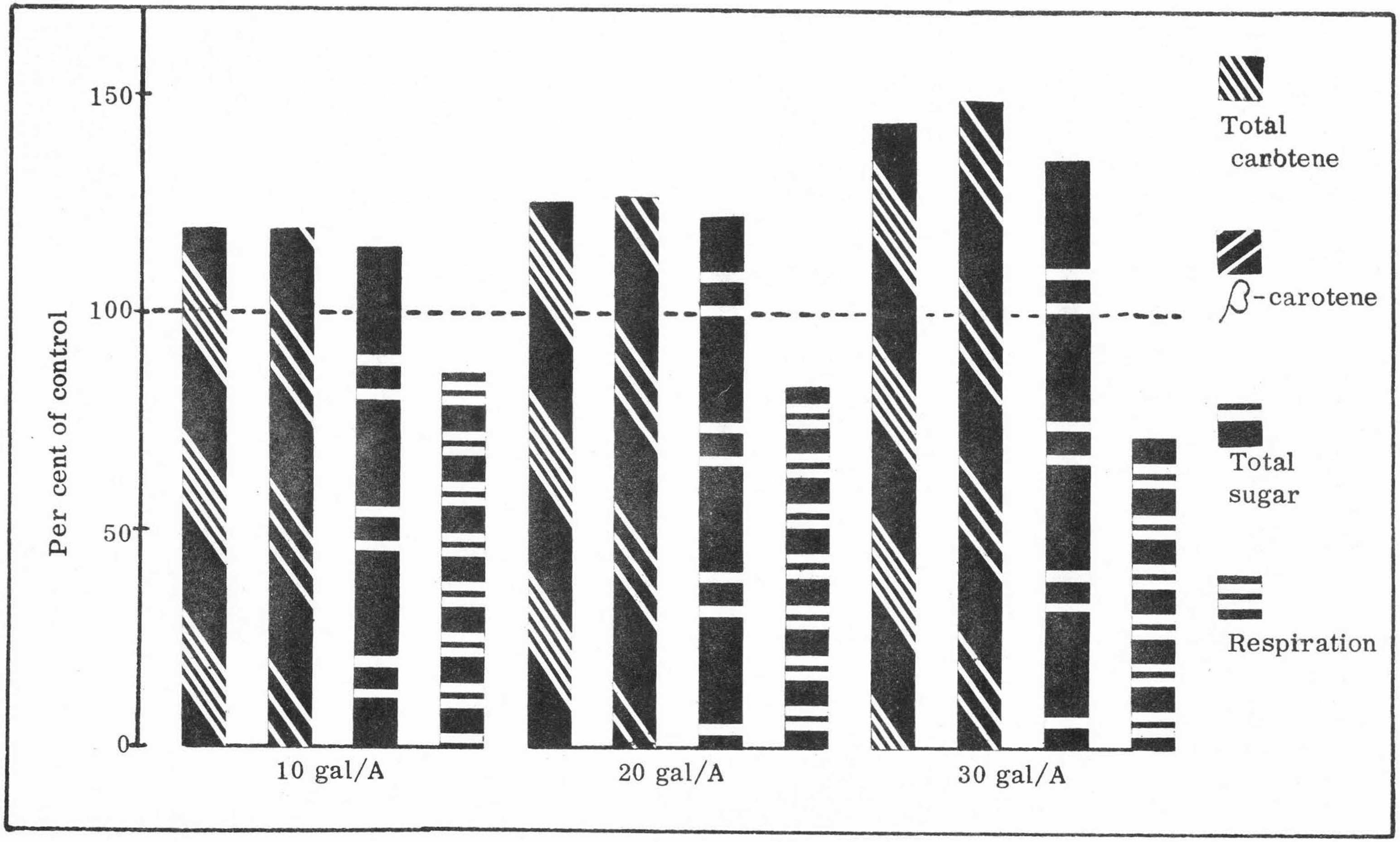

Figure 4. Effects of Telone on total carotenes, β-carotene, total sugars, and respiration of the roots of carrots, 1970 experiment.

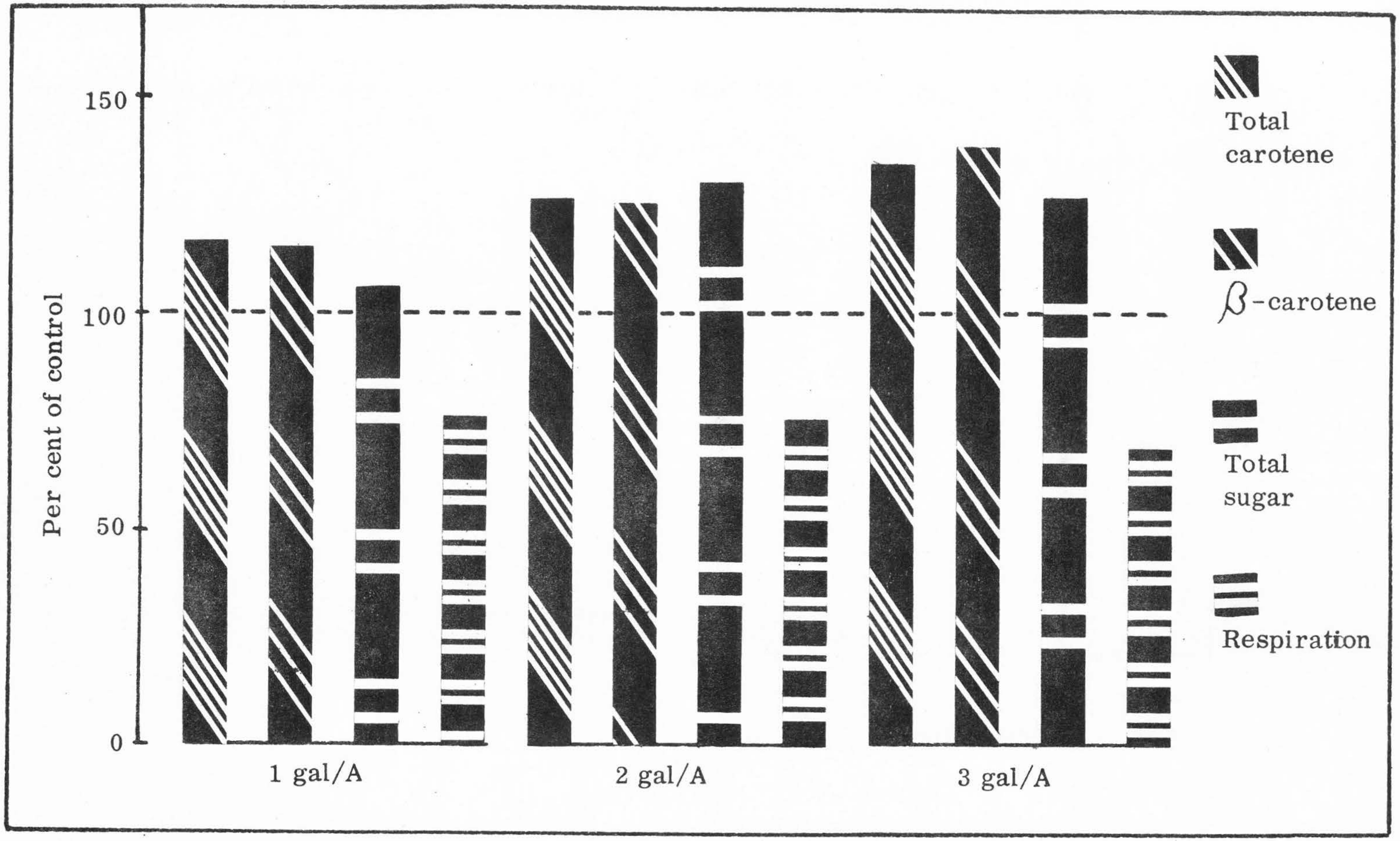

Figure 5. Effects of Nemagon on total carotenes, β-carotene, total sugars, and respiration of the roots of carrots, 1970 experiment.

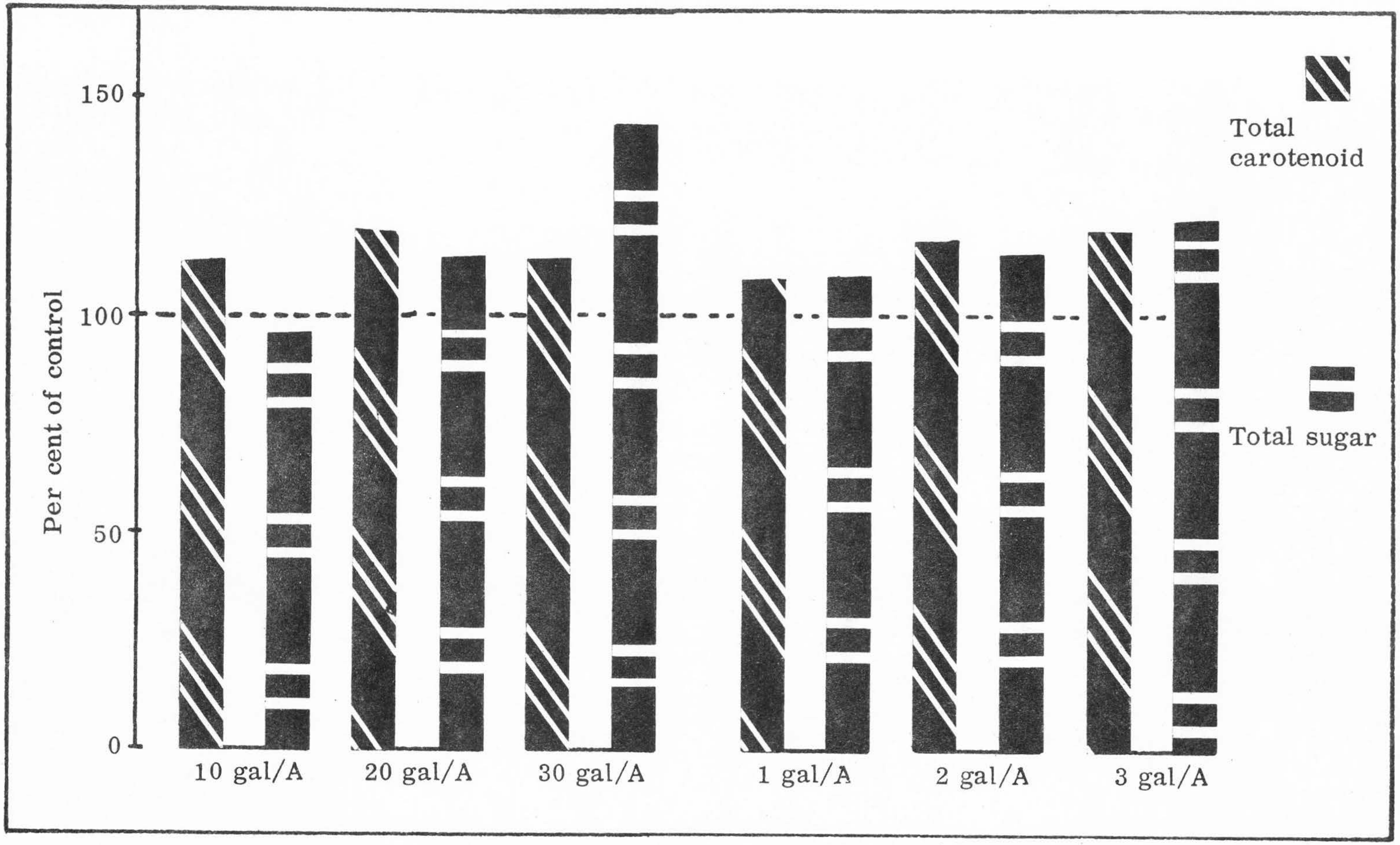

Figure 6. Effects of Telone and Nemagon on total carotenoids and total sugars of the seeds of sweet corn, 1970 experiment.

Key to the labelling of Figures 7 to 9:

Cr: pigment crystalloid

CrR: pigment crystalloid remnant

CW: cell wall

ER: endoplasmic reticulum

GI: globule

M: mitchondrion

PE: plastid envelope

Pl: plasmalemma

T: tonoplast

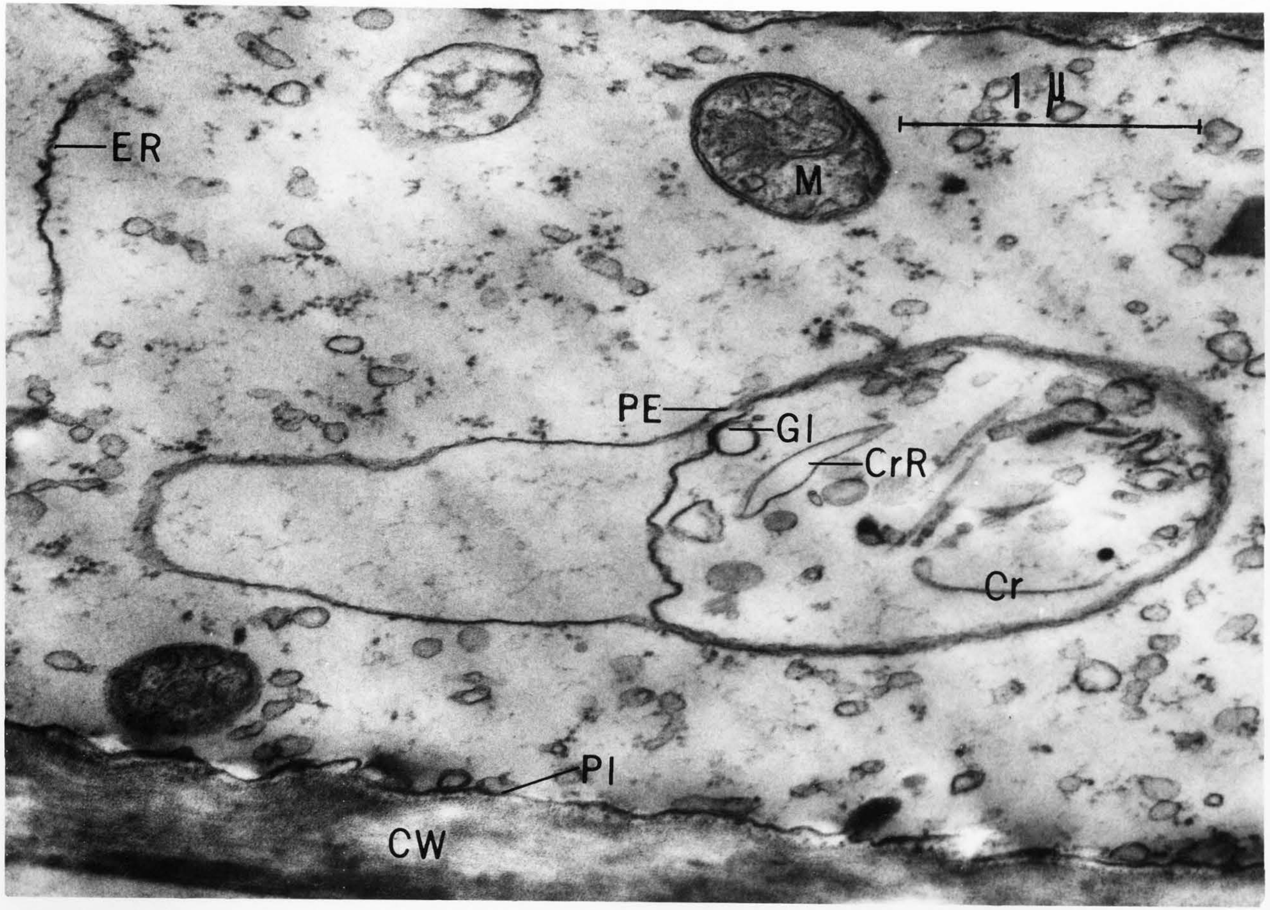

Figure 7. Ultrastructure of chromoplasts in carrots grown on unfumigated soil.

Figure 8. Ultrastructure of chromoplasts in carrots grown on Telone-fumigated soil (30 gal/acre).

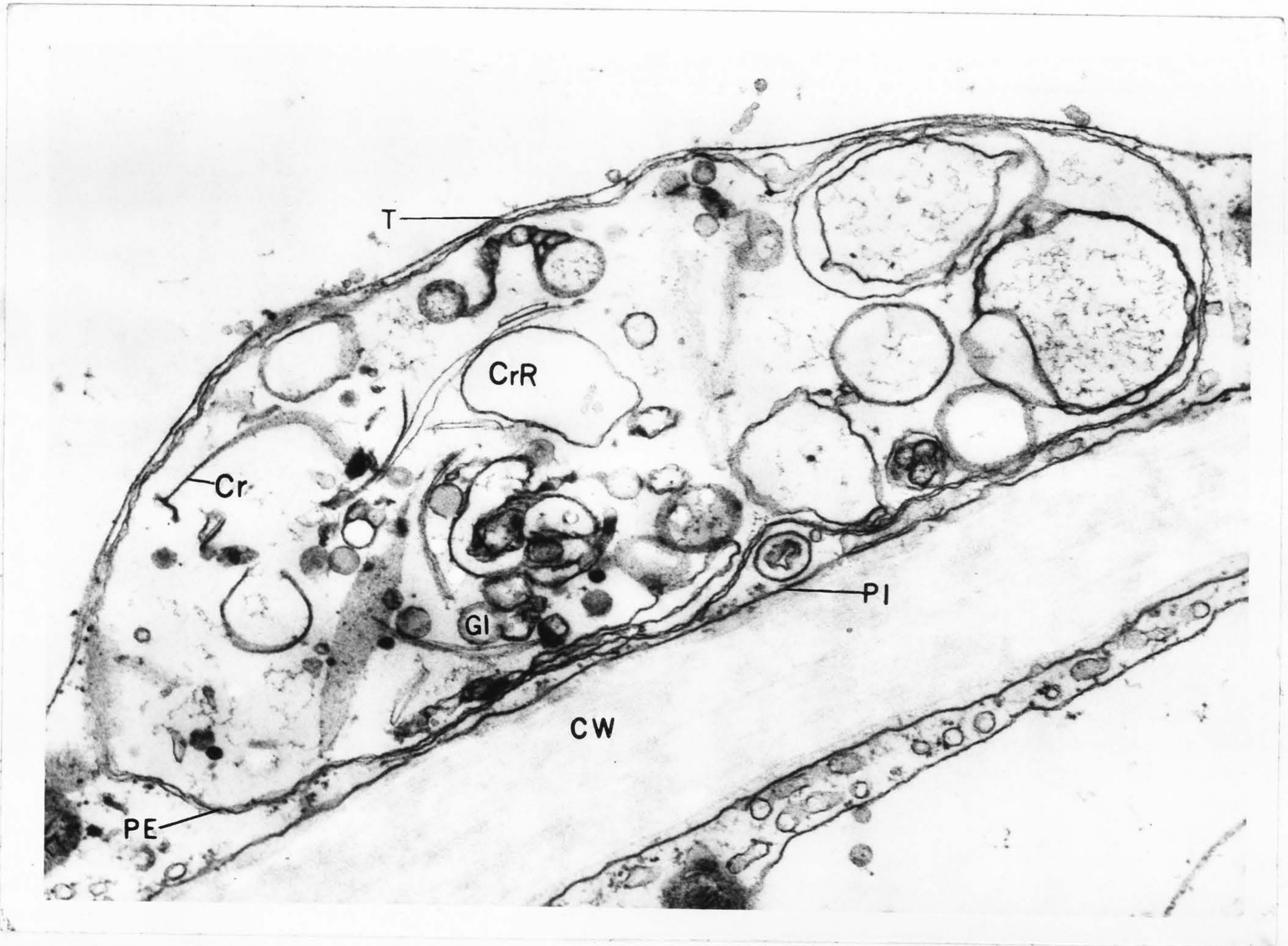

Figure 9. Ultrastructure of chromoplasts in carrots grown on Nemagon-fumigated soil (3 gal/acre).

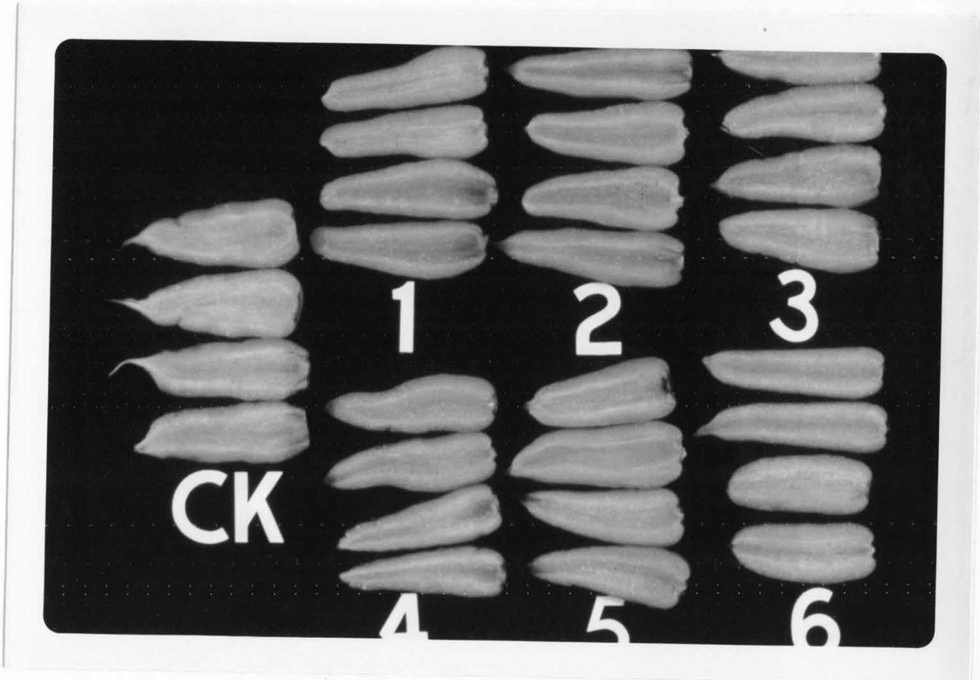

Figure 10. Transections of fresh roots of carrots grown on fumigated and unfumigated soil.

CK: control, unfumigated, 1: Telone (30 gal/acre), 2: Telone (20 gal/acre), 3: Telone (10 gal/acre), 4: Nemagon (3 gal/acre), 5: Nemagon (2 gal/acre), 6: Nemagon (1 gal/acre).

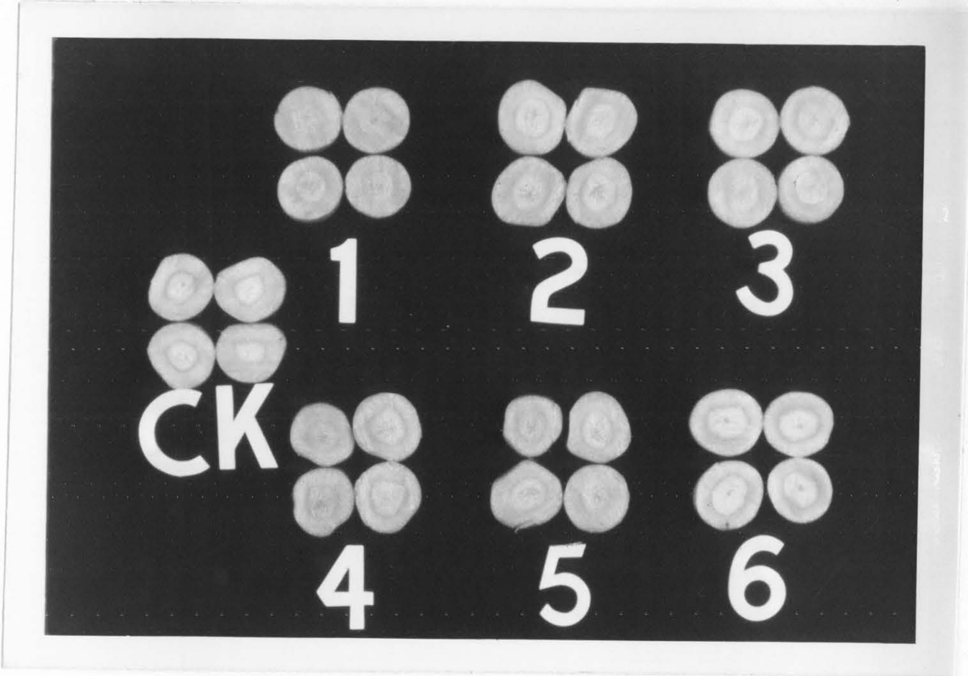

Figure 11. Crossections of fresh roots of carrots grown on fumigated and unfumigated soil.

CK: control, unfumigated, 1: Telone (30 gal/acre), 2: Telone (20 gal/acre), 3: Telone (10 gal/acre), 4: Nemagon (3 gal/acre), 5: Nemagon (2 gal/acre), 6: Nemagon (1 gal/acre).

SUMMARY AND CONCLUSIONS

The purpose of the two-year experiments was to investigate the influence of soil fumigation with Telone (a mixture of 1, 3-dichloropropene and other chlorinated hydrocarbons) at the rates of 10, 20, and 30 gal/acre and Nemagon (1, 2-dibromo-3-chloropropane) at the rates of 1, 2, and 3 gal/acre on total carotene, β-carotene, total and reducing sugars, respiration, and ultrastructure in carrot roots and total carotenoid, starch, total sugars, and total nitrogen in sweet corn seeds.

The soil fumigation with Telone and Nemagon brought about statistically significant increases in the contents of total carotenes, β-carotene, and total sugars of carrot roots; and increased the total carotenoids of sweet corn seeds. The carrots grown on the fumigated soil had lower respiratory rates. The mechanism whereby these two fumigants caused the changes of these two crops is unknown. However, Telone and Nemagon might have influenced the soil microbial activity, and their residue or degradation products in the soil might be absorbed by the crops. Therefore, it is assumed that Telone and Nemagon may affect the biosynthesis and physiological processes of the crops directly or indirectly.

The specific gravity and the size of carrot roots were not changed by the soil fumigation with Telone and Nemagon. During the storage of four months at 3 C in polyethylene bags, carrots grown on the fumigated soil contained more total carotenes and total sugars, had a lower respiratory rate.

Through the electron microscopic study, it confirmed that chromoplasts of carrot roots grown on fumigated soil contained more globuli and crystals where the carotenes were located.

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