RESIDUAL EFFECTS OF CARBON DIOXIDE GAS ADDITIONS TO SOIL ON ROOTS OF LACTUCA SATIVA[1]

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(WITH FIVE FIGURES)

Variations in the development of roots of plants, when carbon dioxide gas is added subterraneously, have been described and reported in a previous paper.[2] The plants subjected to the carbon dioxide gas treatments were *Capsicum annuum abreviatum*, *Lactuca sativa*, *Raphanus sativus*, and *Phaseolus vulgaris*. The last three species were grown in the same soil, with fertilizer and manure treatments in addition to the check treatment already reported upon.

The treatment of the soil in the pots subsequent to the removal of the *Phaseolus vulgaris* plants in June 1917 was as follows. The soil in each pot was emptied into a large pan, thoroughly mixed, and returned to the pot. The water content was brought up to optimum, and one seedling of *Lycopersicum esculentum* placed in each pot. *L. esculentum* is considered a heavy potash feeder, and the plants were grown without carbon dioxide gas treatments in an endeavor to ascertain through plant growth the plant food made available by the previous gas treatments. The *L. esculentum* plants were harvested in November (5 months later), and the pots kept at near optimum moisture content until February 1, when they were again set to *Lactuca sativa*. The object of this test was to discover whether, on the addition of available nitrogen (in which the soil was lacking), more mineral plant food, made available by the carbon dioxide treatments of the previous spring, could be utilized by the growing plants. The moisture content of the soil in the pots was maintained at optimum by weighing and adding distilled water. Available nitrogen in the form of ammonium nitrate in quantities equivalent to 50 pounds of sodium nitrate per 2,000,000 pounds of soil was applied (with the distilled water added)

[1] Contribution from Purdue University Agricultural Experiment Station, La Fayette, Indiana.

[2] BOT. GAZ. 66:364. 1918.

on four dates, February 1, 9, 23, and March 27. The plants were harvested April 15 and the roots removed April 20, 1918.

The roots of the plants grown in the pots that had received the carbon dioxide gas applications the previous year had the malformations attributed to carbon dioxide in the previous paper. Where the soil had never been subjected to carbon dioxide treatments, the roots were well spread and extended considerably into the soil. Where carbon dioxide had been applied, the roots were shorter, spread out horizontally just beneath (0″ to 2″) the surface

FIG. 1.—Roots from unfertilized soil: left to right carbon dioxide treatments of soil were 0, 8, and 24 hours per day.

of the soil, and had tap roots that were abnormally short, crooked, and branching. The data with the fertilizer treatments are given in table I. The results show that something was left in the soil, due to carbon dioxide gas additions to the soil the previous year, which both shortened the tap roots and the distance below the crown at which the roots curved or split up into smaller roots. The residual effects of the gas were greater for the continuous than the intermittent treatments. The roots of the plants where the 24-hour treatments of carbon dioxide has been given were more affected under the manure than the fertilizer treatments.

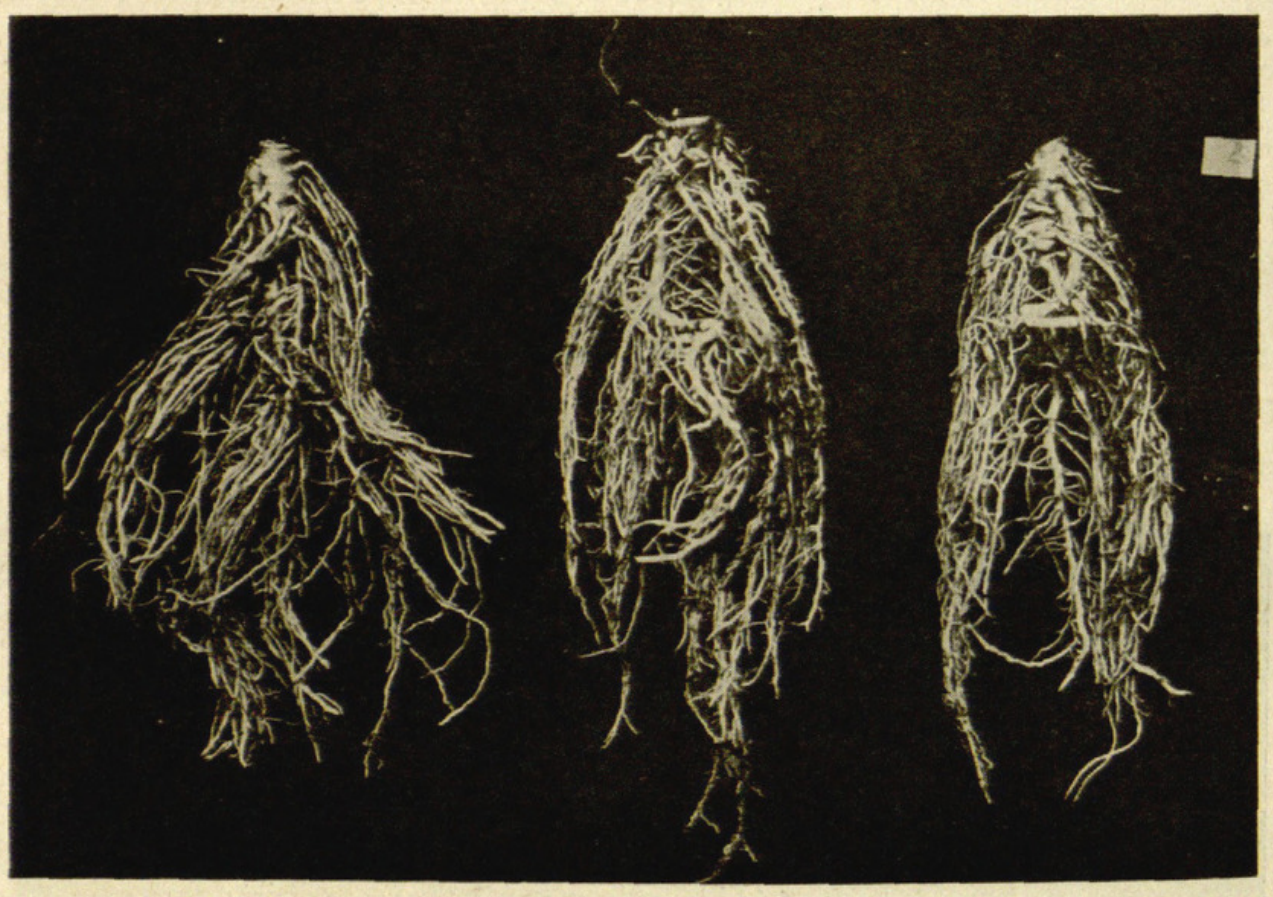

FIG. 2.—Roots from soil fertilized with 5 tons of manure: left to right carbon dioxide treatments of soil were 0, 8, and 24 hours per day.

FIG. 3.—Roots from soil fertilized with single application of complete fertilizer: left to right carbon dioxide treatments of soil were 0, 8, and 24 hours per day.

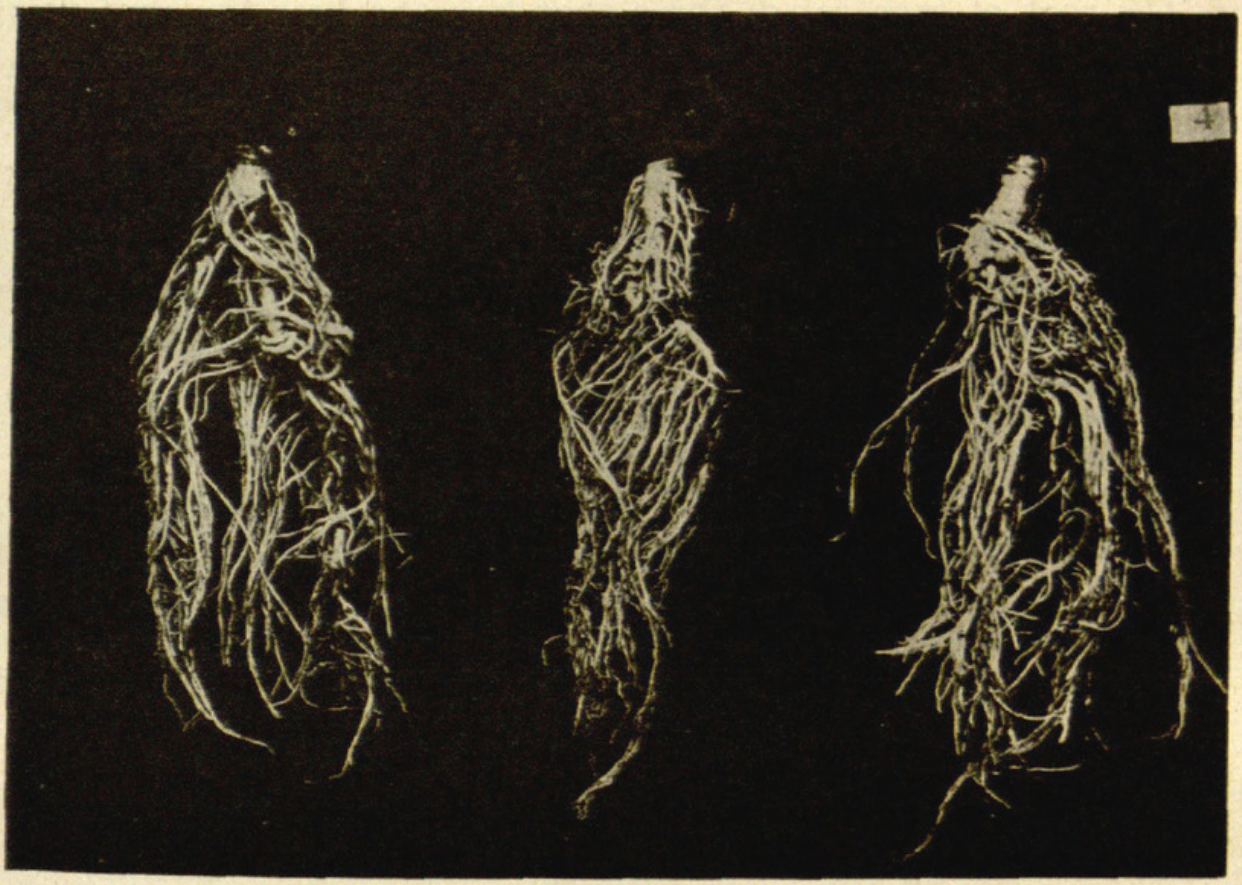

FIG. 4.—Roots from soil fertilized with 10 tons of manure: left to right carbon dioxide treatments of soil were 0, 8, and 24 hours per day.

FIG. 5.—Roots from soil fertilized with double application of complete fertilizer: left to right carbon dioxide treatments of soil were 0, 8, and 24 hours per day.

The root of each set of three that had the best tap root was photographed, and is shown in figs. 1–5. The left hand root in each figure was grown in soil that did not receive carbon dioxide treatment; the middle one shows the residual effects of the 8 hours; and the right hand one shows the effects of 24 hours of gas treatments. With no gas treatment the roots of plants grown in manure tend to resemble those in which carbon dioxide gas was applied to the soil. This is confirmation of the statement made in the previous paper, namely, that "the results obtained in these experiments lead to the belief that the carbon dioxide content of garden soils is sometimes detrimental to the root development of some of the plants growing in the garden."

TABLE I

RESIDUAL EFFECTS OF CARBON DIOXIDE GAS ADDITIONS TO SOIL ON DEVELOPMENT OF TAP ROOTS OF *Lactuca sativa*

PREVIOUS FERTILIZER TREATMENTS*	NO CARBON DIOXIDE GAS TREATMENT		8 HOURS' CARBON DIOXIDE TREATMENT DAILY		24 HOURS' CARBON DIOXIDE TREATMENT DAILY		FIG. NO.
	Length (in inches)	Distance to first curve (in inches)	Length (in inches)	Distance to first curve (in inches)	Length (in inches)	Distance to first curve (in inches)	
Nothing	5.2†	3.0†	3.7	1.3	2.8	0.9	1
Five tons dry manure‡	.05	5.0	4.7	1.6	4.5	1.4	2
Complete fertilizer (single application)§	4.9	2.3	4.5	1.7	4.2	0.9	3
Ten tons dry manure	4.4	3.4	3.9	2.0	1.9	1.3	4
Complete fertilizer (double application)	4.0	1.7	3.2	1.9	3.0	0.9	5
Average	4.7	3.1	4.0	1.7	3.3	1.1	.....

* In addition nitrogen was applied in ammonium nitrate on four dates at rate equivalent to 50 pounds sodium nitrate per 2,000,000 pounds soil.

† All figures are the average for three plants. ‡ Application per 2,000,000 pounds of soil.

§ Made from dried blood, dicalcium phosphate, and potassium chloride containing equal nitrogen, phosphorus, and potassium; nitrogen equal to one-third that in the 5 tons of dry manure.

These residual effects of carbon dioxide additions to soil obtained over 9 months after the treatments were discontinued were unexpected, as the soil had been removed from the pots and mixed, and all water lost by evaporation added subterraneously. The explanation is not easy. The data are reported as a contribution to the knowledge of root growth, and it is hoped that it may help some workers in explaining odd tropic phenomena or throw some light on what is known as "soil toxicity."

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