RETURN OF NEMATODES FOLLOWING FUMIGATION OF FLORIDA SOILS

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Soil fumigation, as practiced on a field scale, does not eliminate all nematodes from a soil. A few always escape destruction and from these, new populations are gradually built up again. In some instances investigators have observed that a year or so after fumigation the soil population of certain plant-parasitic nematodes was higher on fumigated than on unfumigated plots. This occurrence of above normal build-up of plant nematodes following treatment has been a deterrent to the practice of soil fumigation in Florida. Vegetable growers have been reluctant to begin the practice, lest, if once begun, it must of necessity be continued.

The rate of this reestablishment or build-up of nematode populations depends upon many factors and of these factors one of the most important is the kind of nematode involved. It is a well-known fact that some species reproduce and reestablish themselves much more rapidly than others. Usually the saprophagous forms, or those that feed upon decaying organic matter, are the first to become reestablished in large numbers. If an organic fertilizer such as castor pomace has been added to the soil and temperature and moisture conditions are favorable the saprophytic forms may be so numerous within a few days that total nematode counts of fumigated plots will almost equal those of unfumigated plots.

The predaceous nematodes, or those that feed upon other living nematodes, and most of the plant-parasitic forms reproduce much more slowly than do the saprophytes. As a result, populations of these are not, with some exceptions, reestablished very rapidly. Since the time required for reestablishment of populations varies for different species, some of the important plant nematodes in Florida are discussed separately and in order of their importance to Florida vegetable growers.

The Sting Nematode. The sting nematode, *Belonolaimus gracilis* Steiner 1949, is an ectoparasitic nematode that requires healthy plant roots for existence. It is considered one of the most important plant nematodes in Florida because it causes extremely severe damage to plants, it attacks a wide variety of plants, including most vegetable crops, and it has been found in most sections of Florida. Not much is known of the life cycles of the ectoparasitic nematodes. Most of them, and almost certainly the sting nematode, deposit their eggs in the soil at random so that the eggs are easily reached and inactivated by the fumigants. Each female of the sting nematode probably does not produce a large number of eggs, at least not within a short period of time. Thus the rate of reproduction is comparatively slow and populations do not reach damaging proportions within a short period of time after being effectively controlled.

The soil fumigants are especially effective in controlling the sting nematode. Oftentimes it is difficult to find even a few specimens in a fumigated field for several months after treatment. Christie[1] reports that an application of 21 gallons of 40 percent ethylene dibromide (EDB) applied prior to planting peppers in a field near Sanford in the spring season of 1952 gave good protection to a bean crop grown in the same field during the fall season of 1952. Untreated portions of this field were heavily infested with the sting nematode and contained root-knot nematodes as well. Other reports indicate that much lower rates of the fumigants than are normally recommended may effectively control sting nematodes for one or more crops. In several years of soil fumigation tests, we have never observed any indication that an above normal build-up of sting nematodes occurs as a result of soil fumigation.

The stubby root nematode. The stubby root nematode, *Trichodorus* sp., is another of the ectoparasitic forms. It can cause just as severe damage as does the sting nematode and is even more widespread in Florida It can account for large crop losses and is almost certainly a close second in importance.

Soil fumigation will control the stubby root nematode but for only a short period of time.

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[1]/Christie, J. R. 1953. The sting nematode can be controlled by soil fumigation. Down to Earth IX (1): 8-9.

The organism apparently reproduces very rapidly under favorable conditions. Each female that escapes destruction finds an abundant supply of food on the healthy root systems of crops after fumigation. Eggs are deposited at apparently a very rapid rate and hatch soon thereafter. These newly hatched larvae also find a good food supply and mature to the adult egg producing stage within a short time. Within two months, populations may build up so that several hundred percent more specimens are found in fumigated plots than in unfumigated plots.

Christie and Perry (unpublished report) have observed such a build-up of the stubby root nematode in several instances. In one case the same plots were fumigated during September or October of each year for five years. The plots were not usually plowed for aeration between application and planting; as a consequence, and also because of heavy rains after application, the chemicals were retained in the soil, with a resulting fumigant injury to the crops. This chemical injury and a later injury due to a build-up of the stubby-root nematode apparently prevented normal yields of beans and garden peas. Christie and Perry attribute this unusual build-up to the destruction of natural enemies, including predaceous nematodes, by the fumigants. Every time we have conducted fumigation experiments at the Central Florida Experiment Station and examined the nematode populations two months or more afterwards, this build-up of the stubby root nematode has occurred.

The first vegetable crop following fumigation is not usually injured seriously. Some injury may be expected during the latter stages of growth, especially if the crop requires more than two to three months to reach maturity. Normally, however, the plants are able to establish good root systems during the first few weeks when nematode populations are low. The stubby root nematode is most damaging to seedlings.

Serious injury to the second crop following fumigation on the sandy, irrigated lands of Florida may be expected, provided, of course, it is susceptible to stubby root—most vegetables are. For example, when the growers in the Sanford area have attempted, since the discovery of DDT insecticides, to grow sweet corn in the spring following fall crops of cabbage, celery, escarole, etc., they have found that their sweet corn yields have been drastically reduced by the stubby root nematode. Some investigators have estimated that this reduction in yield exceeds 75 percent. The damage is apparently most severe following a fall crop for which the fumigants were applied, although some fields of sweet corn in which the fumigants have never been applied are very severely damaged.

Root-Knot Nematodes. The root-knot nematodes, *Meloidogyne* spp., are endoparasites that become sedentary after entering the roots. They deposit eggs inside the well-known root-knot galls. Root knot is widespread in Florida and causes severe damage on sand, muck, and most other soil types.

When applied properly and under favorable moisture and temperature conditions the soil fumigants will effectively control root knot for a period of several weeks or in most instances, months. Since eggs are deposited inside the roots, all previous crop residues should be well decayed so that the fumigant gas may penetrate to the eggs. The root-knot nematodes do not migrate very far in the soil and row or spot fumigation is effective for some crops.

Some investigators and growers have reported that root knot is more severe on the second crop following soil fumigation than on similar untreated areas. We have never observed this at Sanford and certainly an above normal build-up of root knot has not occurred in our experimental plots. We have observed in some cases that effective control was not obtained due possibly to faulty application, insufficient chemical, and unfavorable weather conditions.

Meadow Nematodes. Meadow nematodes, *Pratylenchus* spp., cause severe damage to certain crops in some areas of Florida. They may be effectively controlled by the same rates of the soil fumigants that are recommended for root knot. We have observed no evidence that an above normal build-up of these nematodes occurs as a result of soil fumigation. Unless good control is obtained, however, meadow nematodes, root-knot nematodes, and others may reestablish populations rapidly on the more healthy root systems produced as a result of soil fumigation. If the root systems of plants grown in untreated areas are severely depleted, a reduction in plant nematode populations may result. At the same time the nematodes that escape in treated areas may flourish on the abundant food produced by the healthy plants. Thus, it seems probable that in some instances the second or third crop grown in fumigated plots may be more severely injured than in untreated plots.

Awl Nematode. The awl nematode, *Dolichodorus heterocephalus* Cobb, is very similar to the sting nematode and similar results may be expected from soil fumigation. There is some indication that the reproduction rate of the awl nematode is somewhat faster than that of the sting nematode, hence populations may be reestablished more rapidly. There is no indication that an unusual build-up of awl nematodes results from soil fumigation.

Several other nematode species are known to parasitize plant roots in Florida and new nematode diseases are being discovered each year. At present we have no proof that populations of any plant nematode other than the stubby root nematode increase above normal expectation as a direct result of soil fumigation.

PLANT RESPONSE TO ALUMINUM SULPHATE

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It is generally considered that the presence of soluble aluminum in the soil is toxic to plants. Considerable work has been done to show that the ill effect of low soil pH is partly or entirely due to soluble aluminum (2, 3, 4, 5, 9, 11, 16, 17, 22, 26). The amounts of aluminum necessary to cause the injury is evidently very small being as little as 5-10 p.p.m. in the soil solution (19). Aluminum is considered a plant poison with as little as 0.5 p.p.m. causing injury in solution cultures (1). The sensitivity to aluminum varies with different crops being greater with such plants as lettuce, beets and less with turnips and redtop (20). Liming gives a favorable response by reducing the amounts of soluble aluminum in the soil (23, 11, 17) while applied phosphorus benefits by reducing aluminum in the soil or in plants (3, 5, 11, 12, 18, 22, 23). One of the benefits of soil organic matter lies in its ability to reduce available aluminum (5, 12).

While most of the work to date stresses the importance of this aluminum as causing negative effects on yield, there is some evidence that in certain cases this element may be beneficial. Small amounts of aluminum in the substrate have increased growth of rhododendron, catawbiense (7), white pine (14), citrus (10, 15), corn (27), millet (29) and cyperus malaciensis (32).

Some of this work points to essentiality of aluminum at least to the Pteridophytes (30) but most of the results can be attributed to side effects. Salts of aluminum have been commonly applied to soils with good effects for such calcifuges as azaleas, rhododendron, and laurel. It has also been used in a limited extent for celery, roses and grapes. The latter were grown on soils of high pH. The beneficial effect of aluminum applications seem to be the lowering of pH with resulting increase in amounts of iron (6, 8, 25).

Other effects attributed to beneficial response of aluminum have been the antagonism to copper (15), the increase of phosphorous in leaves, shoots and roots of citrus (10) and improvement in frost resistance (28, 30).

Recently, the author has observed several instances of favorable plant reaction to aluminum sufficiently to question our present ideas on aluminum applications for soils and plants. The first case involved growth of gladioli on a flatwood sand in Florida. Gladioli growing alongside a ditch showed considerable chlorosis and poor growth whereas the rest of the field was normal. Sometimes ditching will remove shells and other calcareous materials which increases pH. Soil pH readings showed a slightly higher pH value 6.2 in the poor area compared to rest of field which had a pH of 6.0. A deficiency of iron was suspected as being the cause but sprays of ferrous sulfate (0.025%) by weight gave only slight improvement.

Samples of leaves of both chlorotic and normal plants were dried and analyzed spectrographically. Results pointed to a two fold difference in aluminum content being in order of 0.00X% of dry leaves of normal plants as compared to 0.000X% in chlorotic leaves. Subsequent analysis of the soil by a rapid method (31) showed that soils supporting normal growth had 4 lbs. of available aluminum per 2,000,000 lbs. of soil, as compared to 1 lb. per 2,000,000 lbs. of soil in the affected area.