Chemical Control of Nematodes

effective nematocides relatively few in number but available in several forms for field use on perennial and annual crops

Bert Lear and N. B. Akesson

The degree of control required from nematocidal treatments, application methods and rates vary from crop to crop. Less than 10 nematocides are available commercially, and only three or four of those were introduced within the past 15 years. Some nematocides are distributed in the soil by diffusion in the gas or vapor state, by water solutions or emulsions, or by mechanically mixing the chemical into the soil. Whatever the method, the chemical must be dispersed through the soil to kill nematodes to the desired depth, without leaving a phytotoxic residue.

Nematocides volatile enough to move through the soil in the vapor or gaseous state are most effective and include ethylene dibromide, dichloropropene, dichloropropene-dichloropropane mixtures, and dibromochloropropane. These materials may be applied without surface cover or water seals; rolling or harrowing the soil following treatment to fill in injection furrows is sufficient.

Ethylene dibromide—1, 2-dibromoethane—a heavy, colorless liquid with a chloroform-like odor, is very effective against nematodes, wireworms, and certain insects. First reported as an effective nematocide in 1945, ethylene dibromide has become one of the most widely used preplanting soil fumigants. For the application of doses of 1–4 gallons per acre, various formulations are available, containing from 5% to 83% ethylene dibromide by weight. The diluent is usually some inexpensive petroleum thinner or xylene.

Dichloropropene — 1, 3-dichloropropene—is available by itself or as a mixture containing 1, 2-dichloropropane. The dichloropropene-dichloropropane mixture, first reported as a nematocide in 1943, is a standard field nematocide. This material is a clear to amber colored liquid and weighs about 10 pounds per gallon. This was probably the first material cheap enough and effective enough for field-scale use and is more effective than ethylene dibromide against certain nematodes, such as the cyst-forming species.

Dibromochloropropane—1, 2-dibromo-3-chloropropane—the newest member of this group of chemicals, was introduced in 1955 and, for the first time, an effective nematocide that can be injected into sites of certain living plants without injury, became available. This is a heavy, straw-colored liquid with a very low vapor pressure. It is an effective nematocide at rates as low as one-half gallon per acre. The most common formulation, among many available, contains 25% by volume in petroleum thinners.

Applications of these three chemicals usually are made by chisel injection of the liquids 6″–8″ deep in rows or furrows. For a broadcast application—also referred to as solid, and over-all application—the furrows are 12″ apart. In some cases, as in citrus where large doses are applied, the chisel spacing may be as much as 18″ to 24″.

Chloropicrin — trichloronitromethane —and methyl bromide—bromomethane —are highly volatile materials and to obtain maximum control some type of surface seal, such as covering the treated area with gas-impervious cover or sprinkling the surface with water, must be used. These chemicals are expensive and their use has been limited to crops of high value such as those in plant beds and greenhouses.

Chloropicrin is a tear gas, toxic to humans and to a wide range of organisms including nematodes. Introduced about 25 years ago, this material probably was one of the first commercial soil

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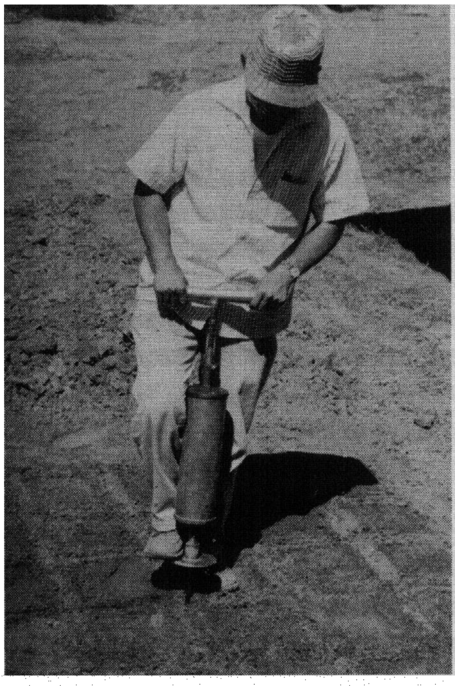

Hand-operated spot injector.

Experimental pump-pressure orifice system.

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fumigants. Its use was limited to greenhouses, and to certain specialized field applications. It is a colorless liquid whose vapor causes intense irritation of eyes and throat.

Methyl bromide is a colorless gas and almost odorless. This extremely volatile chemical may be applied to the soil surface under gas-impervious covers such as polyethylene films. Also it may be dissolved in diluents such as petroleum thinners having higher boiling points, thus allowing its injection by conventional methods. A surface cover is essential to obtain control with this material. Methyl bromide was first reported as a nematocide in 1940 and its use is confined—because of high cost—mainly to high value crops. It is toxic to a wide range of fungi, weeds, and nematodes, and has excellent penetrating abilities into roots and other plant tissues. Some formulations contain a trace of chloropicrin as a warning agent.

The use of irrigation water to carry nematocides into the soil has resulted in control with some newly introduced water soluble materials such as sodium methyl dithiocarbamate. Limited distribution of this chemical has been obtained by diffusion through injection. Applications in water, furrow, overhead sprinkler, and flooding have given control. However, best control resulted when the material was flooded onto the soil in water contained by basins. Emulsifiable concentrate formulations of other materials, especially dibromochloropropane fumigants, are being used by mixing them in the irrigation water as it enters the field. The method of applying nematocides in irrigation water is still under investigation.

Chemicals in granular form which must be mixed with the soil have not been so successful as other types. Potting soils have been successfully treated in this manner because thorough incorporation in the soil is possible. Mechanical tillers and discs have been used, with some success, to apply such chemicals to seedbeds. Sometimes deeper penetration has been accomplished by a combination of mixing and subsequent application of water either from rainfall or irrigation.

Crops

Application rates are usually designed for a minimum dose to permit an economic crop. Because of the narrow margin of profit in annual vegetable and field crops — for example — treatment costs make the use of higher doses of nematocides impracticable. However, it is recognized that treatment is necessary before each planting and savings are sometimes realized by row or spot applications.

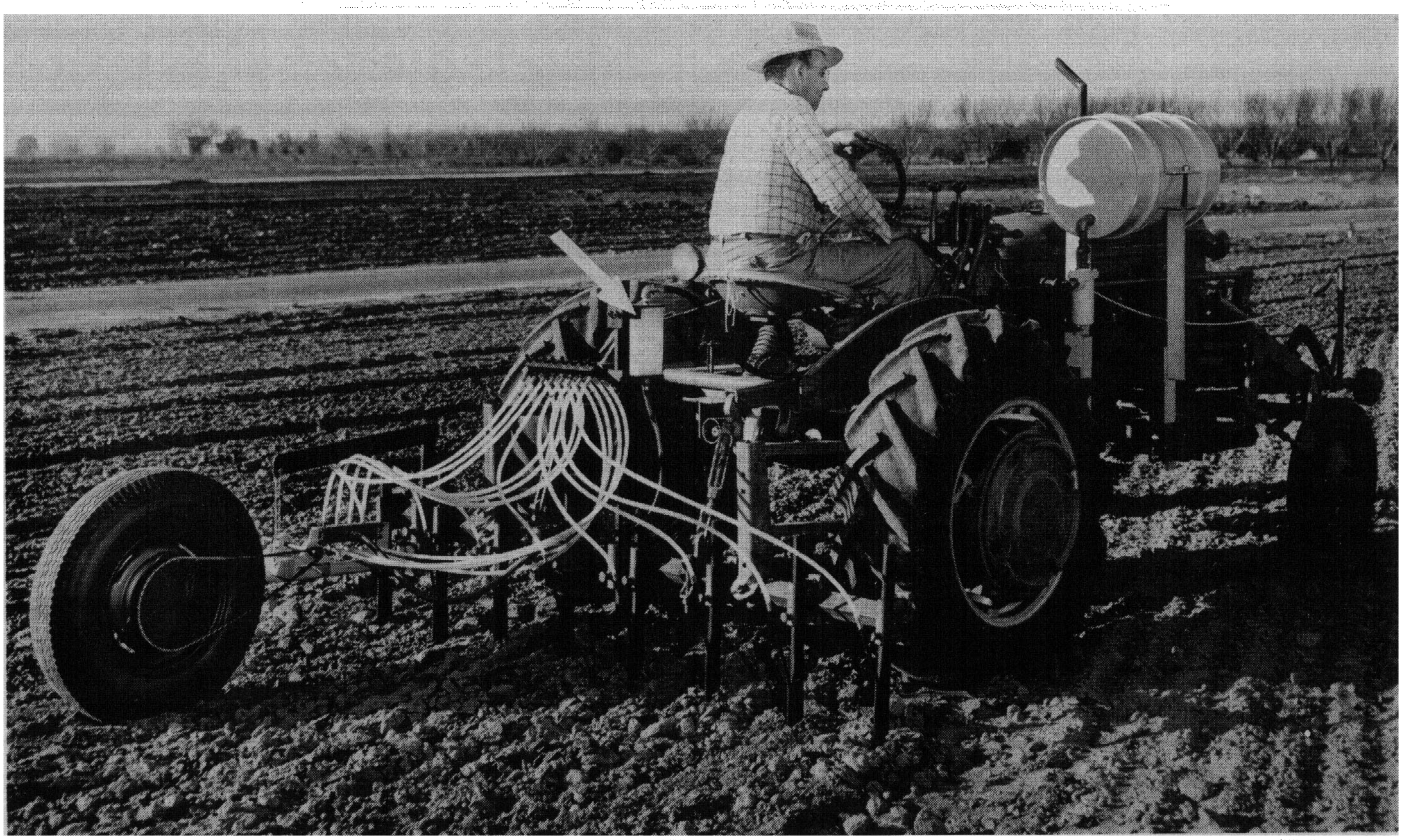
High costs of establishing perennial plantings, such as tree and vine crops, make expenditures for soil treatments feasible. Some of these crops are in production for 20 years or longer and it is important that a productive planting be established. Removal of plants after two or three years and replanting cause losses that justify considerable expenditures for nematocidal treatments. Tree and vine crops also offer the most opportunities for post-planting side-dress treatments.

Most nursery plantings—trees, vines, ornamentals, strawberries, and tomato transplants—are of relatively high value. Consequently, treatments with methyl bromide, chloropicrin, and more recently, sodium methyl dithiocarbamates, are routinely applied even though the cost per acre may be in the range of $500. Because California's quarantine laws prohibit the movement of plants infested with nematodes, plant nurseries fumigate with high rates of nematocides so their crops may be marketed without restriction.

Soil type, tilth, moisture, and temperature are factors influencing nematode control with chemicals. The kind of nematodes present, and nondecomposed root tissues in the soil also are important factors.

Soil type is probably the most limiting factor associated with efficacy of a fumigant. Chemicals are much more ef-

Tractor equipped with gravity flow system. Arrow indicates float tank.



icient in sandy and sandy loam soils han in the heavier clay soils or in peat or muck soils. Diffusion of chemicals is restricted in clay and silt soils mostly by sorption on the surface of the very small particles. High water-holding capacities of the peat and muck soils also retard the movement of chemicals in these soils, and make it necessary to increase the amount of chemicals applied to obtain control.

Soil tilth by proper preparation prior to treatment is very important to successful application. The soil should be chiseled or plowed to a depth of at least 10″ with all old roots removed and clods pulverized. In other words, ideal seedbed condition will provide the best conditions for treatment.

Soil moisture must be considered because application of chemicals to soils which are excessively wet or dry will result in poor nematode kills. Excess water restricts the movement of nematocides through the soil, whereas too dry a soil allows the chemicals to escape too rapidly. Certain nematodes, such as *Ditylenchus dipsaci*, are more difficult to kill when relatively dry.

Soil temperature also is important. Most effective results have been obtained when temperatures are between 50°F and 75°F. The rate of movement at lower temperatures is slow and at higher temperatures there may be too rapid a movement out of the soil to effect maximum kills.

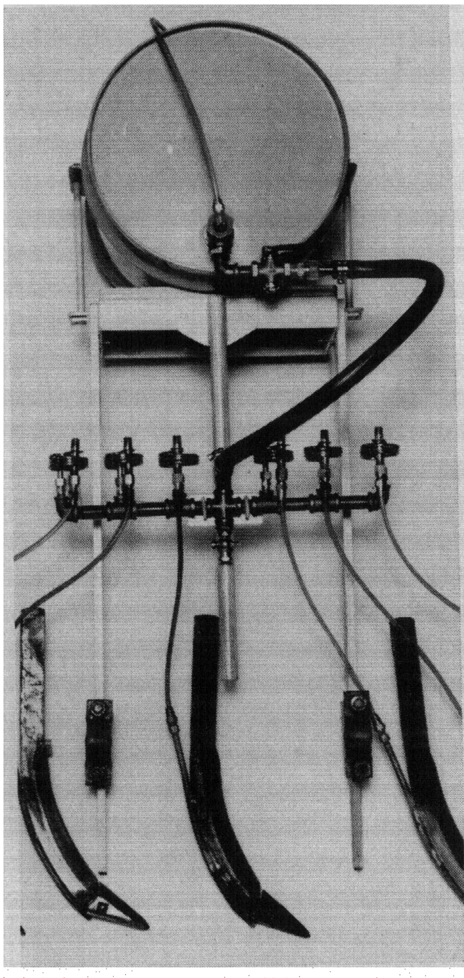
Application Equipment

Equipment for nematocide application follows the general design of pesticide sprayers, dusters, and granule applicators and is also similar to fertilizer application devices. However, one important difference exists which greatly alters the equipment requirements. This is the very low application rate at which it is possible to apply nematocides, particularly in row or band type applications where rates as low as one-half gallon per acre have been used. For area applications, three to 20 gallons per acre are usual, depending on material used and plants being treated. Low application rates make it necessary to use precision metering equipment and to follow careful calibration or determination of application rates.

Most of the early plotwork and trial applications were made with hand-operated spot injectors which are punched into the soil at measured intervals and a metering pump squirts a fixed amount of liquid into the soil through a hollow shank. Hand-operated spot injectors have the advantage of not damaging planted crop roots as do tillage type tools. Two machines for spot injection have been developed. One is a large-diameter wheel with radial, hollow spikes or spoke extensions which penetrate the soil and through which liquids may be injected. The second machine is a high pressure nozzle injector operating at the soil surface to squirt measured amounts of liquid into the soil at given intervals. The two machines are experimental but hold promise for future development.

The most frequently used application system is by means of injection following a chisel furrow opener. The liquid metering system may be: *1*, pressure orifice with gas or pump pressure source, *2*, gravity orifice or gravity capillary tube, *3*, metering pump of either low pressure nonpositive displacement or positive displacement type.

Constant-head tank for gravity flow.



The pressure orifice system depends on compressed gas or a pump handling the liquid for the pressure in combination with a metering orifice which passes a fixed amount of liquid for a given pressure. The machine must be operated at fixed speed across the field in order to obtain the given rate of application. This system is satisfactory for rates above five gallons per acre but at lower rates the very small metering orifices—as small as 0.014″ diameter—easily clog or alter discharge rates with physical variations of the liquid. To handle corrosive liquids, all metal parts should be stainless steel and hoses made of polyethylene.

The gravity flow system may use an orifice or needle valve metering device and, with very low head pressures—of the order of 1′ or 2′—the orifice openings can be larger than with higher pressure devices for a given flow rate. However, the coiled tube of plastic or metal which acts to retard flow provides an even larger passageway for a given flow rate, thus reducing the plugging problem. Gravity flow systems require a constant-head type tank or a float tank, to maintain constant head or pressure on orifice or tube.

The metering pump is commonly used for positive injection of fertilizer liquids, in which case a positive displacement piston or rotary pump is used. However, a loose-fitting nonpositive gear pump with separate gears for each shank has been developed which is low in cost, has low wear features and provides separate metering for each shank. This system is self-compensating for changes in tractor speed, to a limited extent within the range of linear relationship between flow rate and pump rotational velocity. Because of the loose fitting gear system, a constant-head tank must be used. A vacuum break or antisiphoning opening should also be provided or else liquid will be siphoned through the pump when stopped.

In any system of gravity feed and loose-fitting gear, the air vent will prevent siphoning and reduce air lock problems. Also, when the vent is used the pressure head becomes the difference in levels from the tank bleed to the vent.

Dusts are little used for nematocide formulation, but granulars made up in the usual size range of 15 to 60 mesh have been found satisfactory for many applications.

Granular materials are more easily handled than liquids, less volatile, and lend themselves to low metering rates. The usual fluted feed seeder device, augers, chain feeds, endless belts, revolving plates and simple paddle over orifice systems will handle rates as low as two pounds per acre at 12″ spacing. The endless belt and double revolving plate types have perhaps the greatest accuracy of the several systems. In recent years, fertilizers and nematocide materials have been made up in granular combinations. Any of the better fertilizer-type metering devices is suited to these materials; the revolving plate, endless belt, and simple agitator over orifice are commonly used.

Injection into irrigation water may be accomplished simply by dripping the

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nematocide into the flowing ditch at a rate consistent with water flow, or by injecting with a pressure pump and controlled orifice into the sprinkler pressure line. Numerous other systems of injection by aspirators, and differential pressure systems such as are available for fertilizer injection can be used. The principal problem is to obtain a low flow rate for a given volume of nematocide applied over a given portion of the irrigation period. As this is not critical, metering need only be approximate. However, too much material applied in a short time might prove to be phytotoxic to plant surfaces.

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