Chemical Control

The golden nematode is one of the most difficult of all crop pests to kill by fumigation, since the unhatched nematode is protected by both the shell of the egg and the tough, leathery cyst wall of the female.

Many chemicals have been tested by ARS (*8*, *12*) and Cornell University for control or eradication of the golden nematode (*27*). The nematocide dichloropropene-dichloropropane has consistently given the most promising results (*42*).

The first large-scale attempt at chemical control or eradication of the golden nematode was in 1946, when the soil fumigant D-D was applied to 1,500 acres of infested land in Nassau County, N.Y. The chemical was applied at the rate of 45 gallons per acre in a single application. Although this application reduced viable nematode populations to a very low level, complete control was not achieved. The concentration of fumigant in the upper inch or two of the soil was not sufficient to kill the organism at this level (*39*).

Scientists generally agree that the dispersal rate of soil fumigant vapors on reaching the soil surface increases because of lack of restraining pressure, and the organisms on or near the surface are not exposed to toxic gases long enough for all of them to be killed.

This factor was taken into account when field tests were resumed by the author in 1955 (*42*). (See table 3.). The same soil fumigant, D-D, was applied, but this time at the rate of 90 gallons per acre in two applications of 45 gallons each, 10 days apart; the soil was turned between applications. These tests, conducted over a period of 5 years, demonstrated that the golden nematode could be controlled, and served as the basis for the treatment program inaugurated on Long Island in 1960 (*41*) (fig. 33).

TABLE 3.—*Number of infested fields and net acreage treated with nematocides and treated acreage released for use, Long Island, 1955–67*

Year	Treated with nematocides		Gross acreage released for use
	Number of fields	Net acreage	
1955	3	35.05	0
1956	3	47.78	10.00
1957	1	7.00	0
1958	1	13.50	10.61
1959	4	62.83	67.32
1960	13	574.93	656.31
1961	17	1,163.53	1,275.63
1962	23	783.42	783.11
1963	15	489.20	511.50
1964	15	498.96	360.04
1965	15	381.31	240.87
1966	21	764.52	429.14
1967	6	267.72	44.20
Total	137	5,089.75	4,388.73

A group of farmers and businessmen representing the potato industry on eastern Long Island inaugurated a treatment program in 1960 on potato fields exposed to infestation. This organization, known as the Suffolk County Agricultural Commission, was created through the assistance of the county executive and the Suffolk County Board of Supervisors.

The purpose of this organization is to apply nematocides, as a preventive measure, to po-

N-38173

FIGURE 33.—Applying nematocide to infested field on Long Island.

tato fields exposed to infestation but in which no infestation can be detected.

Many growers have multiple farming operations. Upon the discovery that one of these fields is infested, all the other fields farmed with the same machinery are classified as exposed to infestation. Certain potato fields in close proximity to known infested fields may also be classified as exposed.

The nematocide Vidden D applied in a single treatment at 45 gallons to the acre is used. The treatment program is supervised by a representative of the New York State Department of Agriculture and Markets and the Agriculture Department of the Suffolk County Extension Service. The program is financed from funds available through county and local sources. A total of 2,226 acres of exposed land was treated from 1960 through 1966.

Research by Cornell University nematologists has shown that the chemical 1,3-dichloropropene, 1,2-dichloropropane, and related hydrocarbons (80 pct.), and methyl isothiocyanate (20 pct.), marketed under the trade name Vorlex, is effective against the golden nematode. When applied in a split application of 10 gallons each for a total of 20 gallons per acre, Vorlex results in nematode control equal to D-D and Vidden D applied in a split application of 45 gallons each for a total of 90 gallons per acre.

Vorlex, like D-D and Vidden D, is a corrosive material, and natural or synthetic rubber tubing and gasket on applicators must be replaced with chemical-resistant materials. The volatility of Vorlex is similar to D-D and Vidden D. Unlike D-D and Vidden D, Vorlex has the advantage of effective nematocidal action at temperatures as low as 40° F. However, when the fumigant is applied at lower temperatures, 2 or 3 weeks must be allowed for the fumigation period. At temperatures of 60° F. or above a fumigation period of only 7 days is needed.

The chemical is injected into the soil at a 6-inch depth with chisel spacing on the applicator set for 8 inches. Mechanical adjustments to the applicators are needed for this low-volume rate.

Field tests are being conducted with Vorlex during 1968.

Chemicals To Be Used

A chlorinated propane-propylene mixture—consisting of chlorinated C_3 hydrocarbons (100 pct.), 1,3-dichloropropene, 1,2-dichloropropane, and related compounds—is available commercially as D-D and Vidden D.

This chemical is toxic to living plants. Do not apply it within 18 inches of planted crops. The fumigant is toxic to humans and animals if they are exposed directly to it. However, there is no hazard to animals or human health and no residue will result on crops when the chemical is applied as directed on the label.

The fumigant is highly corrosive to metals, particularly aluminum, magnesium, or their alloys. Rubber or rubber-based hoses cannot be used with this fumigant. Only chemical-resistant plastic tubes should be used. Applicators should be thoroughly cleaned of all fumigant before storage. The system should be flushed with equal parts of lubricating oil and kerosene.

Dosage.—Ninety gallons (900 lb.) of approved fumigant per acre (1 gal. weighs 10 lb.) should be applied in two equal treatments of 45 gallons (450 lb.) each, 10 days apart.

Seasonal limitations.—Fields are normally fumigated in the summer and fall and are not available for potato planting until the following spring. This permits the chemicals to dissipate so that toxic amounts will not injure plants or impart off-flavor to tubers and other root crops.

At least 2 months should elapse after the 90-gallon treatment before any crop is planted. A longer period may be necessary if there is much rain following treatment or if the soil temperature drops.

The soil should be fairly moist but dry enough to be tillable. If a ball of soil barely holds its shape when compressed in the hand, its moisture content is acceptable for treatment. Do not apply the chemical when the soil is too wet or too dry.

The temperature of the soil at the time of treatment must be at least 60° F. Best results are obtained at temperatures of 70° and above. Since the air and soil temperatures seldom coincide, temperature readings should be made several inches below the soil surface (*43*).

Equipment Needed

The following equipment is needed to prepare a field for treatment: General farm-type tractor, disk cultivator, moldboard plow equipped with coulter and jointer, and spike-tooth harrow or pulverizer.

The disk cultivator is used to chop stubble and stalks before plowing or to break up clods after plowing. The harrow and pulverizer follow the plow and prepare the seedbed.

To apply the fumigant, the following equipment is needed: (1) A tractor with dual rear wheels, (2) a shank-type applicator with either (3) a gravity-flow system or (4) a variable

N-38184

FIGURE 34.—Additional equipment, such as platform lift for moving drums of chemical, is useful.

displacement piston pump to move and meter the fumigant to the shank outlet, and (5) a furrow sealer (figs. 34, 35, and 36).

(1) The tractor used for applying the fumigant should have sufficient power to operate without difficulty at a minimum of 3 m.p.h. The tractor should be equipped with a standard three-point hitch, dual rear wheels, and two 50-gallon spray tanks mounted forward of the rear wheels.

(2) The shank-type applicator presently used in the golden nematode program was originally designed for application of liquid fertilizers. It is composed of a toolbar on which nine spring standards are mounted. Forward-swept shanks and rearward-swept shanks are available; they are interchangeable on the spring standards. The standards should be spaced so that the shanks are 10 inches on centers. A No. 1 integral tool carrier, clamped to the toolbar, permits attaching the applicator assembly to any tractor equipped with a three-point hitch and hydraulic lift control.

(3) The gravity-flow system of moving and metering the liquid fumigant to the shank outlet utilizes a specially vented tank and flow-control coils. This unit eliminates the need for small restricting orifices and pressure pump, and because of the open system, it is less apt to clog. An overflow of the liquid at the vacuum

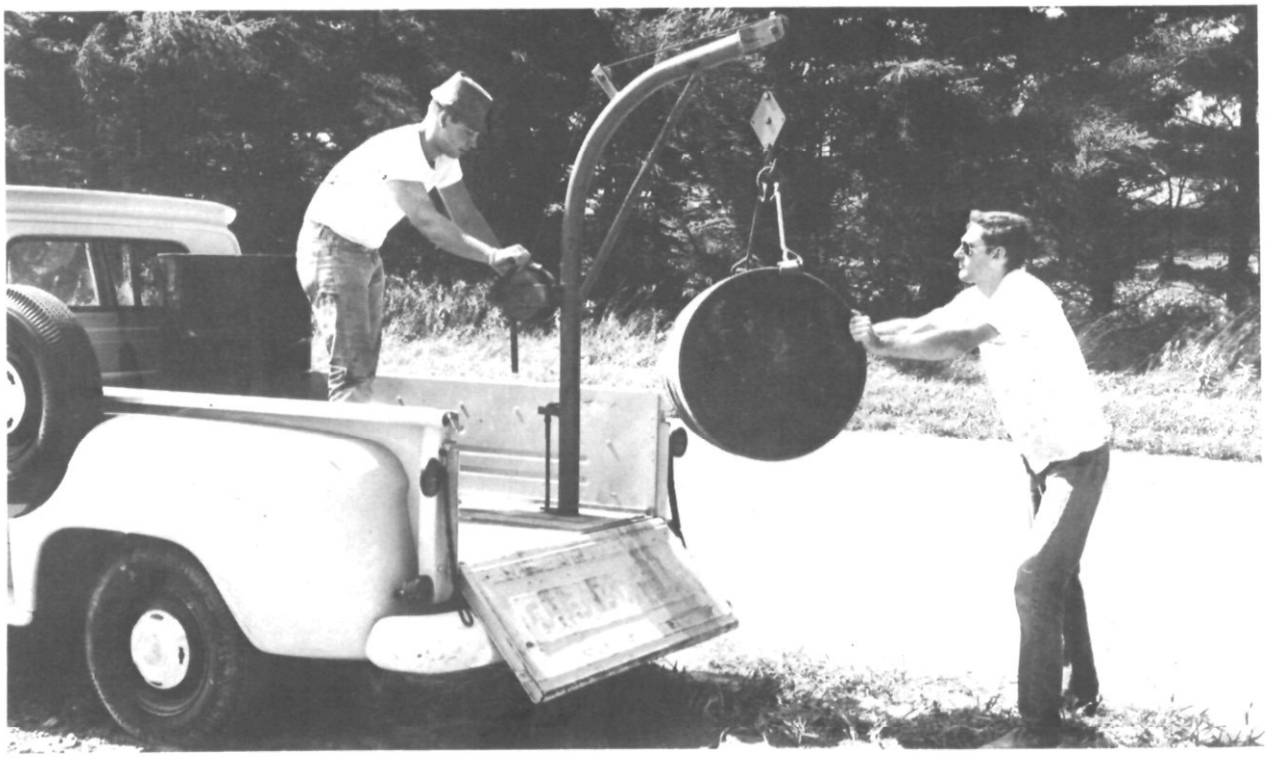

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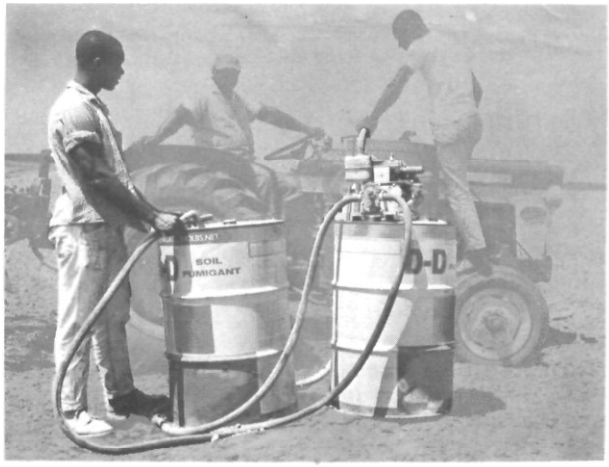
FIGURE 35.—Individual drums of chemical may be moved with a boom mounted on pickup truck.



N–59104

FIGURE 36.—The soil fumigant is rapidly transferred from barrels to tractor by use of an air-cooled gasoline engine.

brake fitting on the assembly will indicate a clogged shank outlet. An instrument panel can be constructed and placed in view of the tractor operator; the panel will indicate immediately a clogged flow line.

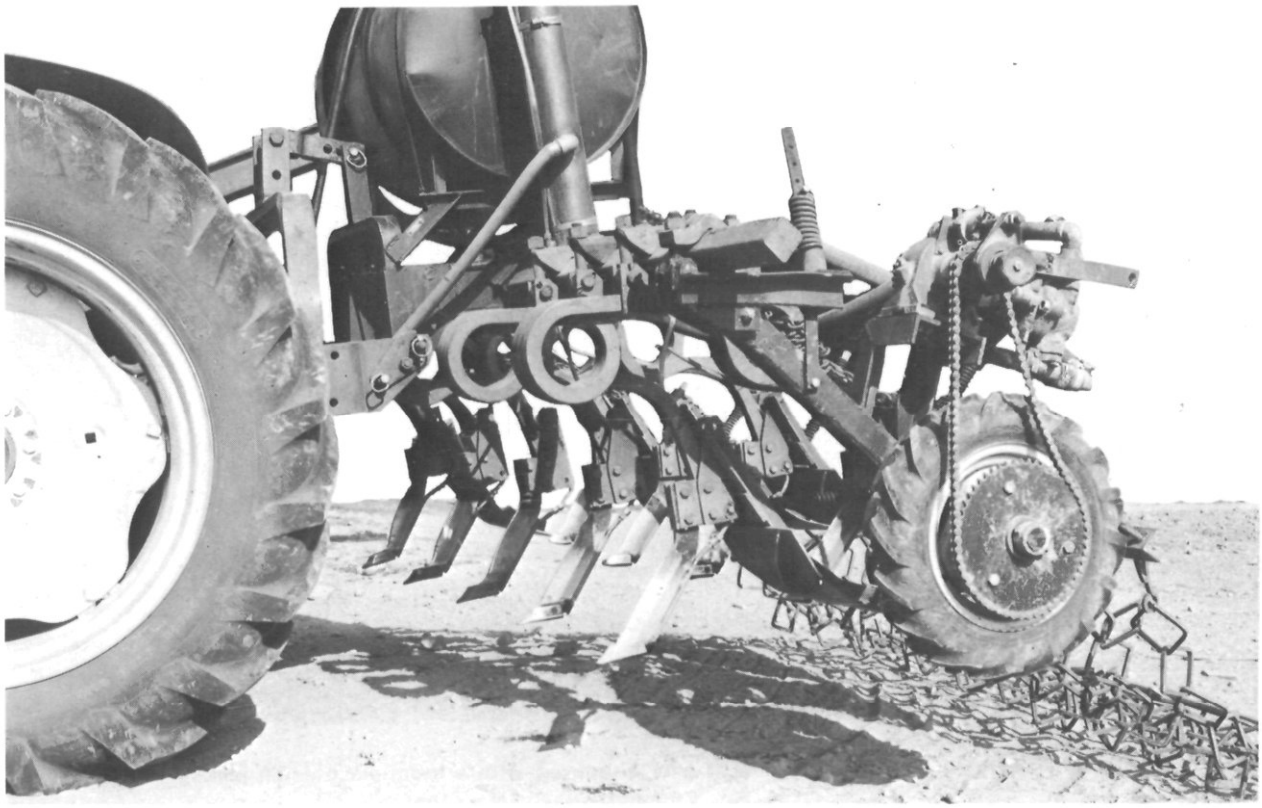
(4) The variable displacement piston pump is driven by a trailing ground wheel, or by a sprocket attached to the axle of the tractor (fig. 37). The trailing wheel has wider utilization and is preferred. The liquid is pumped through a flow divider, which distributes the material equally to all discharge lines (fig. 38). Irregular speeds of the tractor do not cause improper discharge; the trailing wheel operating the pump compensates for irregular rates of speed.

(5) It is necessary to seal the furrows made by the shanks and to smooth the soil surface to prevent uneven diffusion of the soil fumigant. The selection and use of a sealer will depend on the types of soil being treated. A Scotch harrow or a suitable drag is attached to the tractor or toolbar and towed behind the unit to smooth and seal the furrows opened by the shanks (fig. 39).

In sandy loam soils on Long Island, a full-length Scotch harrow is used to effect a satisfactory seal.

In fine-textured soils, it may be necessary to use a spike-tooth harrow to obtain the desired seal.

(6) To avoid skips or excessive overlap-



N-38206

FIGURE 37.—Tractor applicator, showing shanks and ground wheel that operates variable displacement piston pumps. The wheel compensates for irregular speed of tractor and results in even discharge of chemical.

ping in application, the tractor operator should use a row marker as a guide. The row marker is attached to the toolbar.

Calibration of Fumigant Metering Systems

Gravity-flow system.—The gravity-flow system can be calibrated by using the following tabulation to determine the milliliters of fumigant per shank for the desired application:

Speed	*Fumigant required*[1] *Ml. per min.*
2.0 miles per hour	573
2.5 miles per hour	717
3.0 miles per hour	860
3.5 miles per hour	1,003
4.0 miles per hour	1,147

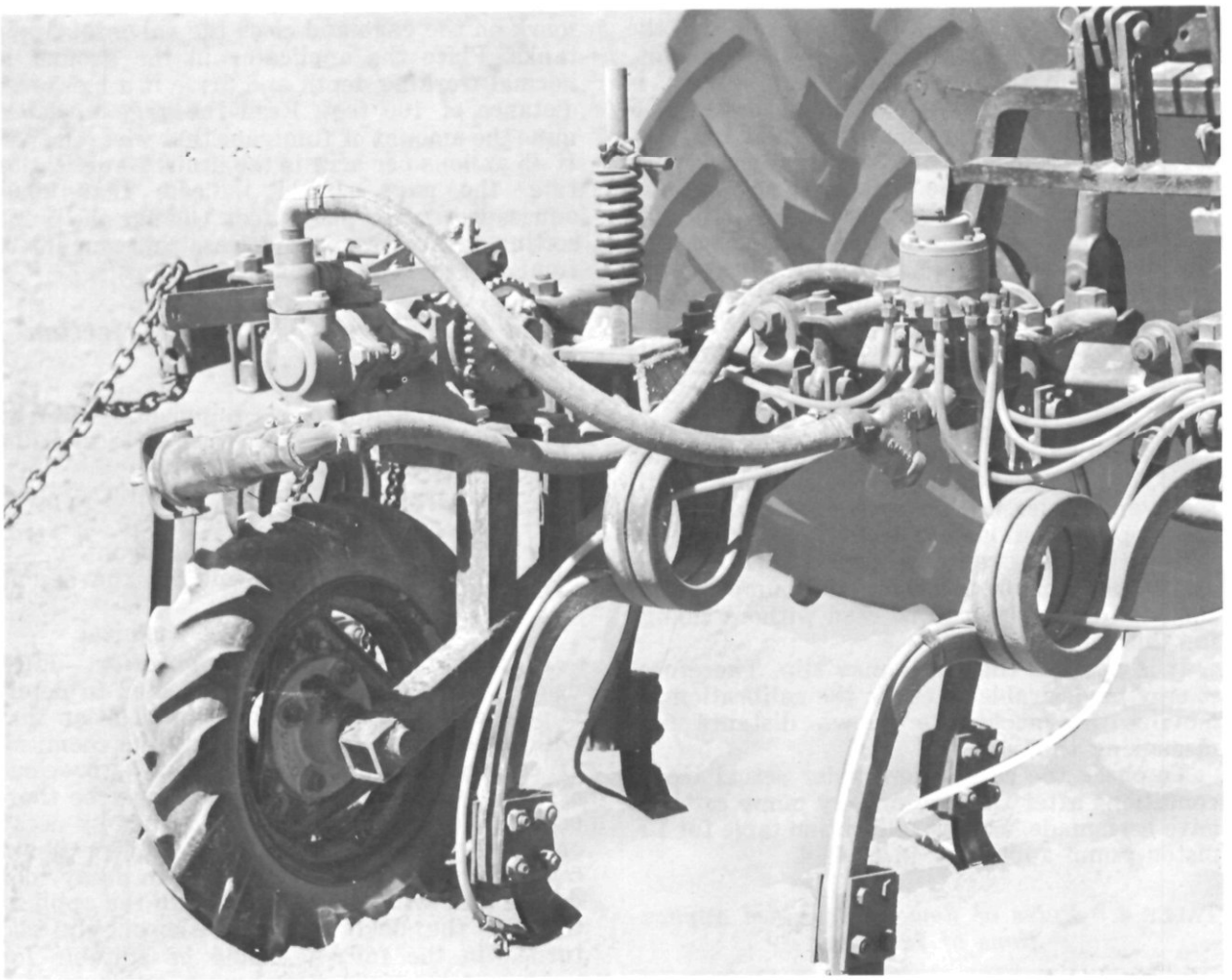
[1] Milliliters required per shank per minute for 45 gallons of fumigant per acre—10-inch shank spacing.

Example: For a 45-gallon-per-acre application with shanks spaced 10 inches apart and the tractor traveling at 3 miles per hour, a flow of 860 milliliters of fumigant is required per shank per minute.

Fill the tank on the applicator approximately half full of fumigant. Make certain the filler cap is screwed on tight so that air cannot enter the tank. Open the control valve and permit the system to run until air can be heard gurgling through the liquid in the tank.

Quickly place a suitable container under one of the shanks for 1 minute, then quickly remove it. Using a graduated cylinder divided into milliliters, measure the amount of fumigant collected. If the amount is less than that specified on the chart, lower the coil flow boom assembly. If the flow is too great, raise the assembly. Continue taking 1-minute samples of the flow until the proper flow rate has been obtained. If the application rate is greater or less than required, the tractor speed may be changed to provide the proper dosage. If this is not practical, another set of flow regulating coils may be installed. Longer coils will reduce the flow rate and shorter coils will increase it.

Variable piston pump system.—The variable displacement pump is calibrated by changing its piston stroke. The piston stroke adjustment



N–59118

FIGURE 38.—The chemical passes through the flow divider, which distributes material equally through each shank.

N–59111

FIGURE 39.—Tractor applicators working in tandem. Scotch harrow pulled by each tractor seals the furrows opened by the shanks.

is conveniently located on the side of the pump.

Calibration of the piston pump system is simplified by using the John Blue Company LF Pump Setting Chart,[6] Blue Part No. LF–416–B. Use the front side of the computer only, as the information on the back does not apply to this installation. For this treating machine, the loaded radius of the wheel is 13.5 inches and the sprocket ratio 3 to 1. With the nine shanks installed, 10 inches on centers, the swath is 90 inches. These three values will always remain the same for this machine, unless a different size of tire is used, a shank removed, or the spacing of the shanks changed.

Using the LF Pump Setting Chart, set the loaded radius 13.5 inches opposite the sprocket ratio, 3 to 1. Set 90 inches on the swath width scale, and under the arrow read the pump setting opposite gallons per acre.

Since loaded radius, sprocket ratio, and swath will remain the same, the pump setting for any application can be read without changing the computer.

It is possible that tires may slip. Therefore, it may be desirable to check the calibration by moving the machine a known distance and measuring the output.

To check the calibration under actual travel conditions after the preliminary pump settings have been made, use the calibration table for LF piston pump applicator in table 4.

TABLE 4.—*Rates of flow for specified applications of fumigant*

Gallons per acre	Flow requirements for 90-inch swath for distance of 100 feet		
	Gallons	*Ounces*	*Milliliters*
1	0.0172	2.201	65.1
5	.0860	11.005	325.5
10	.1720	22.01	651.0
20	.3440	44.02	1,302.0
30	.5160	66.03	1,953.0
40	.6880	88.04	2,604.0
45	.7740	99.04	2,929.5
50	.8600	110.05	3,555.0
60	1.032	132.06	3,906.0

For other application rates and other distances of travel, compute as follows: Length in feet × rate in gallons per acre × 0.651 = volume of output in milliliters.

Each applicator is equipped with a calibration tank and gage. The gage is graduated in ounces. Refer to table 4 to determine the ounces of fumigant required for a particular application rate. Fill the calibration tank to the zero mark on the gage and close the valve to supply tanks. Place the applicator in the ground to normal working depth and drive it a measured distance of 100 feet. Read the gage to determine the amount of fumigant that was released. If 45 gallons per acre is the desired application rate, the gage should indicate that 99.04 ounces were used in 100 feet. Change the pump setting, if necessary, to release this amount of fumigant in 100 feet of travel.

[6] Chart available from John Blue Company, Huntsville, Ala.

Field Operations for Shank Injection Equipment

When shank injection equipment is used to apply the nematocides, four separate and distinct field operations are necessary:

1. Preparation of the soil for first application.
2. First application of the fumigant.
3. Preparation of the soil for the second application.
4. Second application of the chemical.

Preparing soil for first application.—Each field to be treated must be inspected to determine the type and amount of preparation that will be necessary before applying the chemical. If coarse stubble or stalks from a previous crop or weeds are present, they must be thoroughly chopped or disposed of either by decay or by other means. Normally, it requires about 6 months for stalks and stubble to decay to a degree that will not interfere with the application. If the field is disked thoroughly and turned in the fall, it should be suitable for treatment the following spring or summer—with an additional disking and plowing just before treatment.

The type of soil, depth of top-soil, and the normal depth of previous cultivations must be considered when plowing the field. Normally, a depth of approximately 8 inches is sufficient for preparing the soil for treatment. If the soil has been plowed previously to a depth greater than 8 inches, then the soil must be plowed to that depth in preparation for treatment.

Preparation of the soil for the first application of the chemical will usually require the following operations to condition the soil for reception of the chemical:

1. Disked one or more times, depending on trash present.
2. Turned with a moldboard plow to a depth equal to maximum penetration in past cultural operations. Do not plow when soil is too wet or too dry.
3. Disked lightly to smooth ridges and clods.

The soil is ready for treatment when it has

been properly plowed and is relatively loose to permit maximum diffusion of the chemical, when it is free of ridges, clods, and debris, and when it contains sufficient moisture to be tillable.

First application of fumigant.—The fumigant should be applied immediately after the soil conditioning operation has been completed, if the correct soil moisture and soil temperature conditions prevail.

The entire area must be covered with fumigant; skips may result in failure. When all the field has been fumigated, make one or more round trips at each end to insure treatment of as much of the headlands, turnaround and other border areas as possible.

Make sure that the fumigant is flowing continuously to each shank. If clogging occurs, stop immediately and make adjustments. When the trouble has been corrected, turn the tractor around and re-treat all the area that may not have received proper treatment. When lowering the shanks into the soil, keep the tractor moving to prevent clogging the flow line outlet with soil.

Preparing soil for second application.—At least 10 days should elapse after the first application before preparing the soil for the second application. As a result of the first application, the texture of the soil is usually in a more suitable condition for treatment. The soil is turned with a moldboard plow at a depth of 1 to 2 inches deeper than the first plowing. The moldboard plow *must* be equipped with a suitable coulter-jointer for this operation. The coulter-jointer is adjusted so that the top 3-inch layer of soil is cut and turned into the bottom of the furrow and covered with the lower layers of soil. This is most important since the fumigant dissipates rapidly near the soil surface, and cysts occurring there during the first treatment may not be exposed to a lethal dose.

A frequent check should be made in the second plowing operation to determine if the top 3 inches of soil are properly turned and covered. This can be accomplished by spreading a 6-inch band of lime on the surface of the soil in advance of and at right angles to the plow (fig. 40). After the plow has passed, dig into the turned limed area to determine whether the lime has been covered to the required minimum depth of 3 inches (fig. 41).

The soil surface should be comparatively smooth after this operation. If it is not smooth, a harrow, drag, or roller should be employed. In any event, the soil should not be disturbed below a depth of 3 inches.

Second application of fumigant.—The second application of fumigant is made 10 to 14 days after the first. The same procedure and technique is used as in the first application. It might be desirable to make the second application at right angles to the first. This will result in a checkerboard treatment of 10-inch squares. The topography of the field will determine which direction to make the second application.

Treatment of border areas.—Any golden nematode cysts remaining along the border of treated fields serve as a potential source of reinfestation. Accordingly, on Long Island the chemical sodium *N*-methyldithiocarbamate, sold commercially as Vapam, is applied to headlands, roadsides, farmyards, and farm roads adjacent to fields that have been fumigated. The object is to kill the nematodes on the soil surface. The Vapam is mixed with water and applied as a drench at the rate of 50 gallons of Vapam in approximately 3,000 gallons of water per acre. Since Vapam is most effective when the soil surface is moist, it is generally applied after a rain. Any apparatus affording high gallonage and low pressure can be used. A boom-type nozzle has been found most practical.

Decontamination of Equipment

All equipment used in the preparation or treatment of an infested field, must be thoroughly disinfected before it is moved from the field to another location. The equipment should be subjected to the prescribed cleaning procedures using steam or methyl bromide fumigation (fig. 42).

Precautions

If pesticides are handled or applied improperly, or if unused parts are disposed of improperly, they may be injurious to humans, domestic animals, desirable plants, and pollinating insects, fish, or other wildlife, and may contaminate water supplies. Use pesticides only when needed and handle them with care.

When using nematocides, follow the manufacturer's directions exactly. Variations in soils and climate may affect the action of the nematocides.

Handle nematocides with extreme care. Avoid prolonged breathing of the fumes. Do not allow the liquid to come into contact with the skin. If the liquid is accidentally splashed on

N-38175

FIGURE 40.—A 6-inch band of lime is placed on the surface of soil to check efficiency of plowing operation.

N-38178

FIGURE 41.—Inspection of the plowed ground determines whether the lime has been covered to the required minimum depth of 3 inches.

N–38183

FIGURE 42.—All equipment used on infested land must be thoroughly steamed clean or fumigated before it is moved to another location.

clothing, including gloves or shoes, remove the garments without delay; do not wear them again until they are washed, cleaned, or at least thoroughly aired for a day or two. Never risk getting the material in your mouth. If it is splashed in your eyes, wash it out with large quantities of water and consult a physician.

Keep children and pets away from fumigated soil. Potting and rooting soil that has been treated with nematocides should not be used until all traces of fumigant odor have disappeared.

Careful disposal of empty pesticide containers and surplus pesticides is an important part of safe pesticide use. Large metal drums can be disposed of more safely and easily by returning to the supplier or selling them to a cooperage firm equipped to handle toxic materials. Small metal drums should be rendered unusable by chopping holes in them or crushing them and then burying them at public dumps.

Resistant Potato Varieties

The potato is one of about 2,000 species in the family Solanaceae. This family includes such plants as tobacco, tomato, eggplant, pepper, horse-nettle, bittersweet, ground cherry, and petunia. Botanically, the potato cultivated in North America, Europe, and other lands is *Solanum tuberosum* L. (fig. 43). There are nearly 160 wild species and 20 cultivated species of the tuber-bearing *Solanums*. All

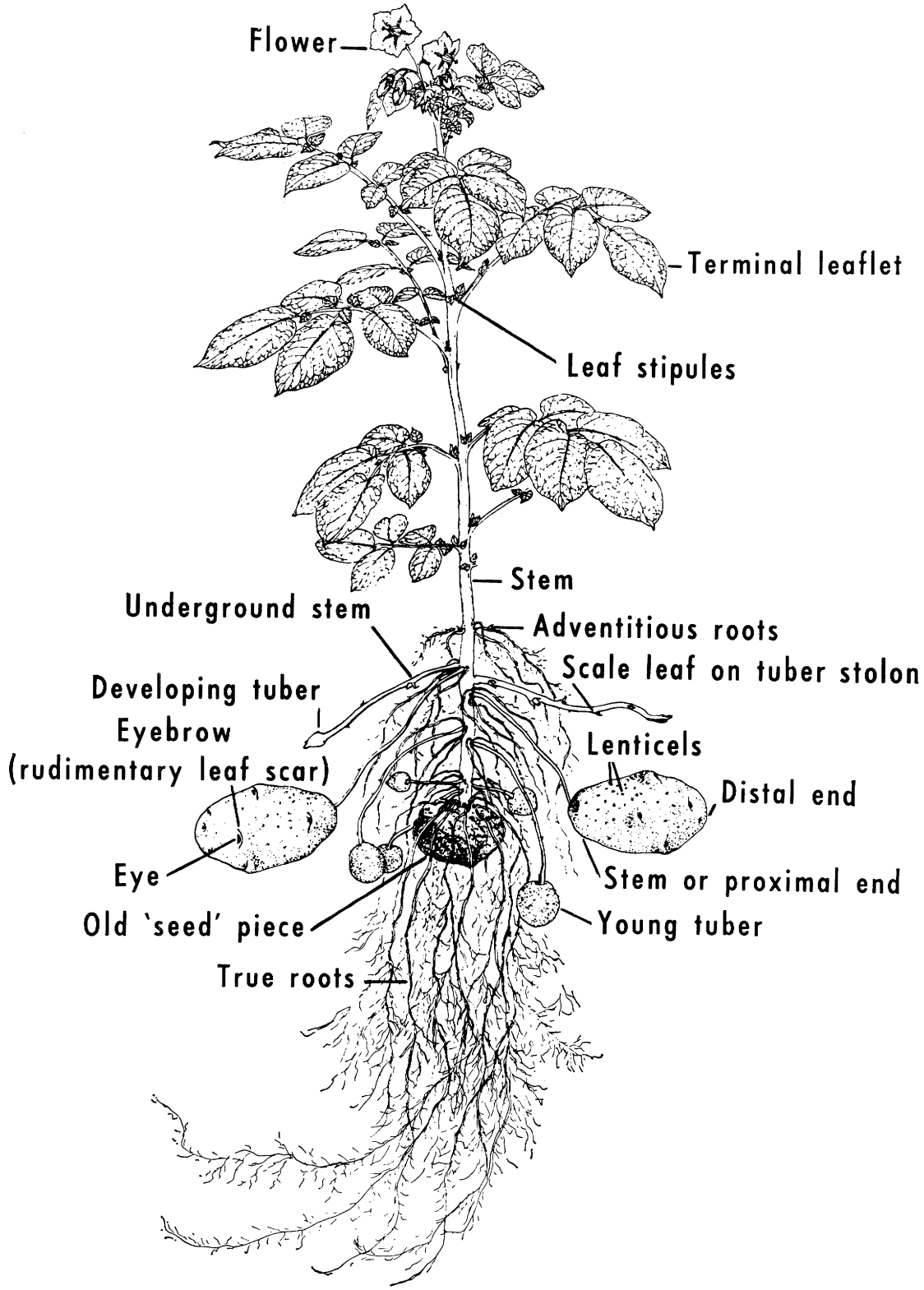


FIGURE 43.—Diagram of the parts of a potato plant. Note that the stolons and tubers arise from stem tissue, and the true roots arise at the base of the stem.

these relatives of the potato are of New World origin. Probably the closest wild relative is *S. andigenum* Juz. & Buk., which produces acceptable yields under the short-day conditions of the Andes Mountains. Some botanists consider *S. andigenum* to be a subspecies of *S. tuberosum.*

A potato breeding program to find resistance to the golden nematode has been carried out extensively in Great Britain, Holland, and Germany, since 1945 when Ellenby, a British scientist, screened many *Solanum* spp. and discovered that *S. vernei* and *S. tuberosum* spp. *andigena* were resistant to the golden nematode (*50, p. 252*). In the United States, Cornell University scientists confirmed Ellenby's findings and, in addition, found that *S. sucrense* also had resistant characteristics. However, *andigena* seem to offer the best basis for a potato breeding program because the resistance of *andigena* potatoes is due to a single dominant gene (*38, p. 265*). A breeding program for resistance involves backcrossing, which is not too involved in this case because no sterility barriers exist between *andigena* and *S. tuberosum.* Furthermore, since potato varieties are reproduced vegetatively there are few problems in fixing the resistance in varieties once it has been transferred from the resistant parent (*38, p. 265*).

Resistant varieties, like susceptible ones, produce a substance that has a high hatching quality. The roots are invaded by the larvae of the nematode in a manner similar to that of larvae invading susceptible varieties. Some males are produced, but few females complete their development to form cysts. Thus, the growing of resistant potatoes on infested land results in a decrease of nematode populations in the soil (*38, p. 265*).

Until the 1950's it was assumed that there was no particular physiological variation in the golden nematode's ability to attack the resistant host (*20, p. 414*). However, in breeding varieties for resistance to the golden nematode, it has been shown that within the nematode species there exist populations with ability to break the resistance and complete their life cycle on the resistant variety. These populations are referred to as resistance breakers or resistance-breaking biotypes (*20, p. 414*). Scientists investigating resistant potatoes in Europe found that the golden nematode from Peru was capable of breaking resistance in 82 Dutch tuber lines bred from C.P.C. 1673 (*20, p. 414*). The names of biotypes are not yet established; however, European workers report that they have obtained evidence of at least six biotypes (*38, p. 265*).

The widespread occurrence of biotypes in several European countries presents serious problems for maintaining potato varieties that are resistant to the golden nematode. *S. vernei* is resistant to all known biotypes; however, plant breeders have found this species difficult to use in a breeding program. The resistance of *S. vernei* is thought to be due to many genes, some of which may be lost in backcrosses of cultivated varieties (*38, p. 265*).

In the United States, both the U.S. Department of Agriculture and Cornell University have programs seeking to develop nematode resistant potatoes. Since the work started (about 1950), these agencies have tested thousands of new potato lines. In February 1966, a new commercial potato variety resistant to the golden nematode was announced. The new variety, named Peconic (fig. 44), is a product of the work of Cornell plant breeders and plant pathologists.

Peconic compares favorably with the popular Long Island variety Katahdin (fig. 45). Peconic is free of defects such as hollow heart and misshapened or oversized tubers. Peconic has been tested and found to be resistant against the race of golden nematode occurring in Newfoundland, Canada (*32*).

Peconic derives its resistance to the golden nematode from the subspecies *andigena.* Resistance-breaking biotypes that are capable of breaking resistance of this type occur in Europe. There is no evidence to date, however, that more than one form of nematode exists on Long Island. The *andigena* resistance is effective against the golden nematode on Long Island (*32*).

In expectation that resistance-breaking biotypes might be developed, plant breeders are conducting research with other species of *Solanum* to find other sources of nematode resistance. In the meantime, the growing of Peconic as a commercial variety will be restricted to infested potato fields that have been fumigated and released to growers for potato production. Peconic may also be used on land exposed to infestation but on which the nematode population has not developed to a level that can be detected by the usual survey procedures.

Thus, the future control program of the golden nematode on Long Island will be soil fumigation of all known infested fields followed by the use of resistant potato varieties.

Peconic is expected to be ready for limited use on Long Island in 1968.

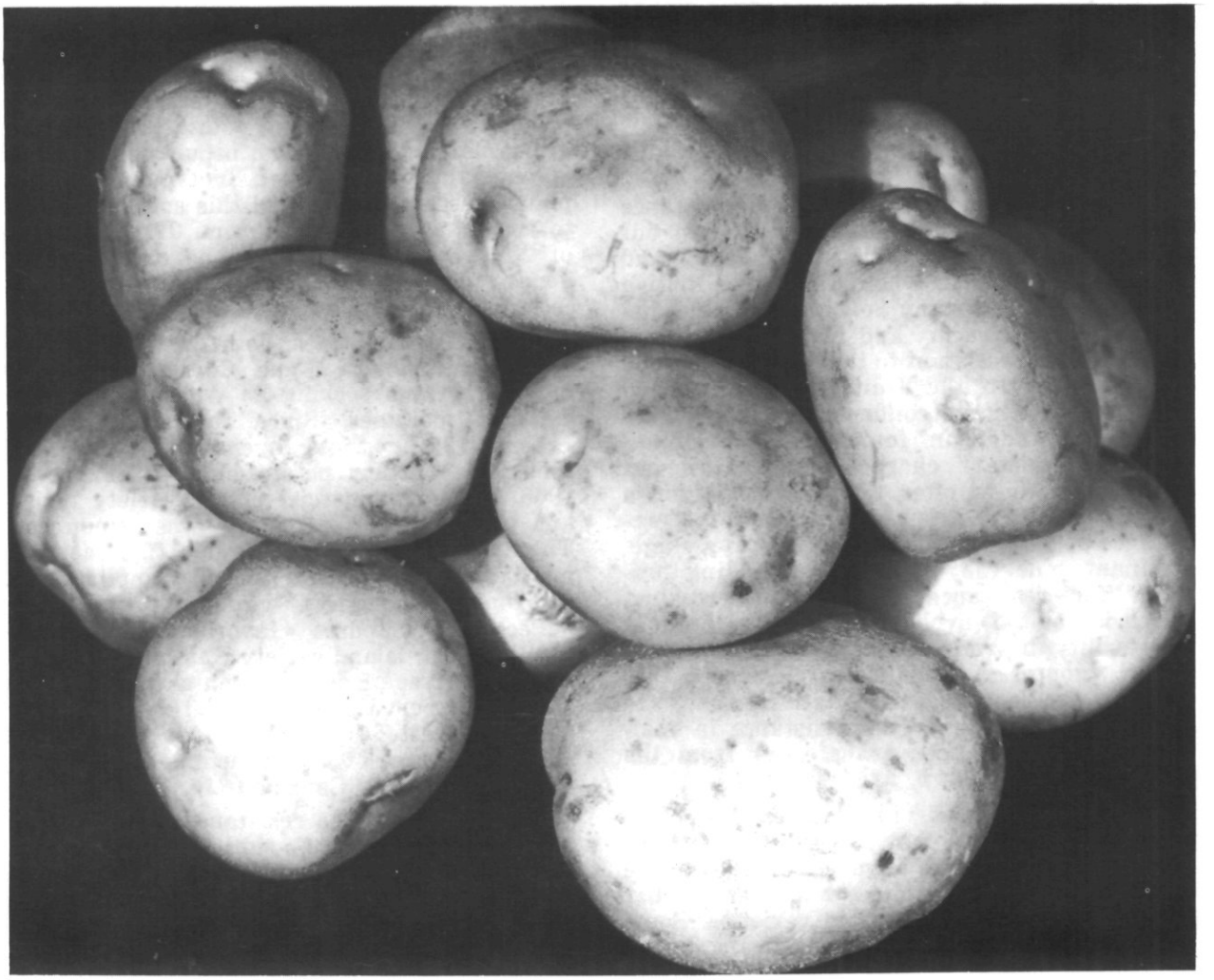


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FIGURE 44.—Peconic, a new variety resistant to the golden nematode, was released February 1966. Peconic has many of the same characteristics as the Katahdin.

BN-30077

FIGURE 45.—Tubers of the Katahdin variety. This variety is widely grown on Long Island and the Atlantic coast.

BN-32356

FIGURE 46.—Wauseon, a new variety resistant to the golden nematode, was released November 1967. Wauseon is also similar to the Katahdin.

USDA plant breeders, in cooperation with Cornell scientists, released in 1967 a second variety resistant to the golden nematode. The new variety named Wauseon is a selection from a cross between B4159–8 and Katahdin. It is resistant to common scab, moderately resistant to Verticillium wilt, highly resistant to the common races of late blight, resistant to latent mosaic and mild mosaic, and to the golden nematode. Its tubers are resistant to net necrosis following leafroll infection. The tubers of Wauseon have smooth skin, are round to oblong, and have shallow eyes and creamy-white flesh (fig. 46).

THE INTERNATIONAL PROBLEM OF CONTROL

The golden nematode is a pest of global concern (figs. 47–51). It is frequently the subject of both domestic and international regulations. The international spread of the golden nematode is a target of import regulations of many countries.

The long-distance shipment of nursery stock, plants, plant parts, corms, and tubers is increasing. The use of air transport to move these products has multiplied the risk of long-distance spread of not only the golden nematode but other insects and plant diseases.

Effective nematocides, such as dips for nursery stock, bulbs, corms, and tubers are urgently needed. The hazards of spreading nematodes are not restricted to plant material alone, as will be seen later in this chapter.

Most countries that have regulations against the golden nematode require that imported agricultural products be free of soil. Most countries have very strict regulations about the importation of potatoes from countries where the nematode is known to occur. Many countries require a phytosanitary certificate showing that the potatoes originated in fields that have been soil sampled with negative results or from a portion of the country where all survey data indicate that the nematode does not exist. In some instances, potatoes are embargoed from countries where the golden nematode occurs. The movement of bulbs, corms, and nursery stock is usually subject to rigid requirements.

The need for uniform measures concerning the control of the golden nematode has been recognized by the European Economic Community (EEC). On October 14, 1966, the EEC Commission submitted proposals to the EEC Council for consideration and adoption.

These proposed regulations were the mini-

FIGURE 47.—Golden nematode infestations in the Western Hemisphere.

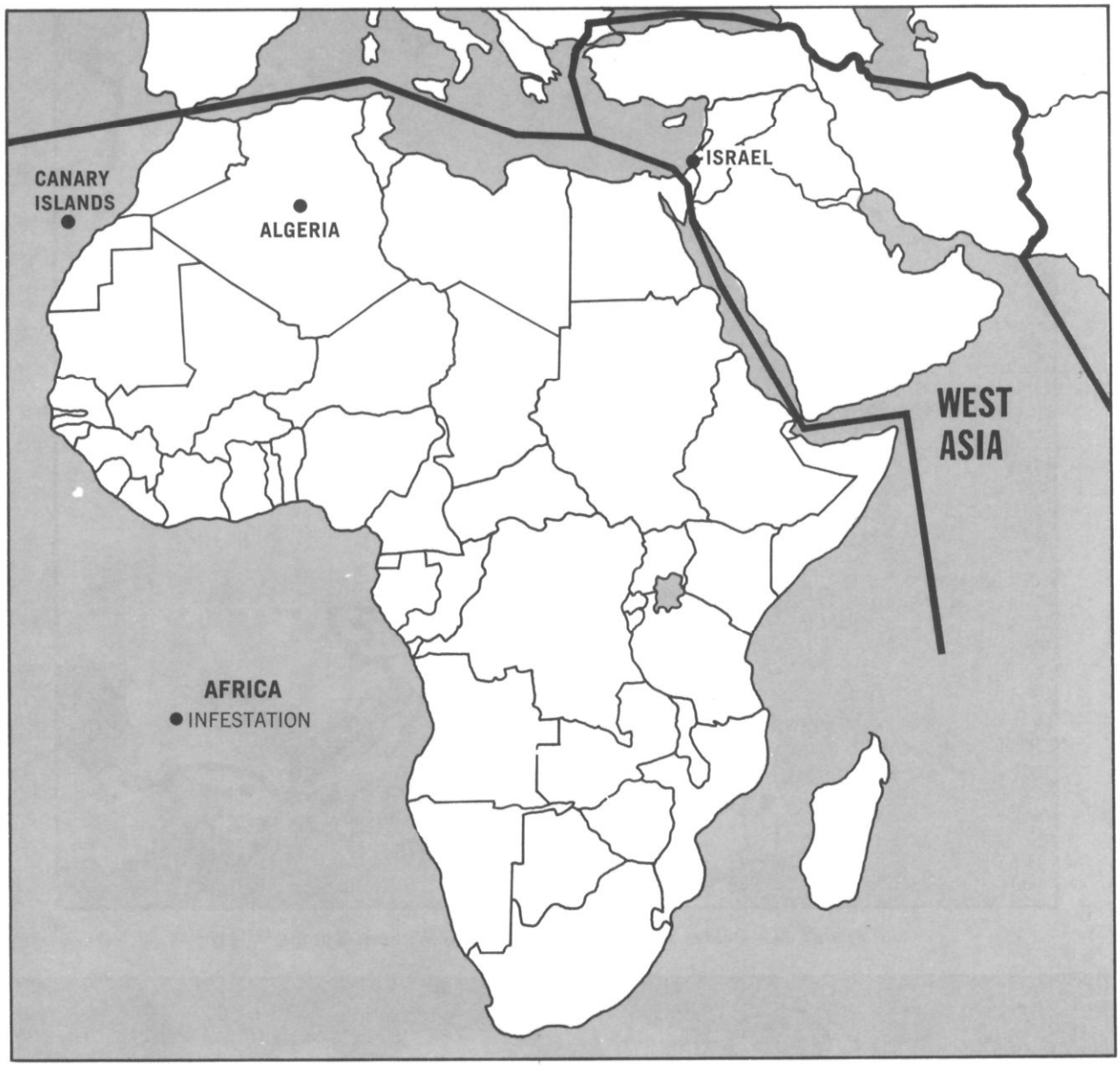

FIGURE 48.—Golden nematode infestations in Africa and West Asia.

mum requirements for the control of the golden nematode and prevention of its spread in member countries. The council recommended that seed potatoes be produced only in areas that have been carefully surveyed and officially declared free of the golden nematode. Upon discovery of an infestation, member countries will conduct such surveys as necessary to find the limits of the infestation. Member countries will prohibit the growing or storage of potatoes or plants for transplanting on infested premises. Member countries will prescribe that potatoes recognized as being contaminated with the golden nematode shall not be used for seed purposes.

These regulations should remain in effect until a determination is made that the nematode no longer exists. The council also recom-

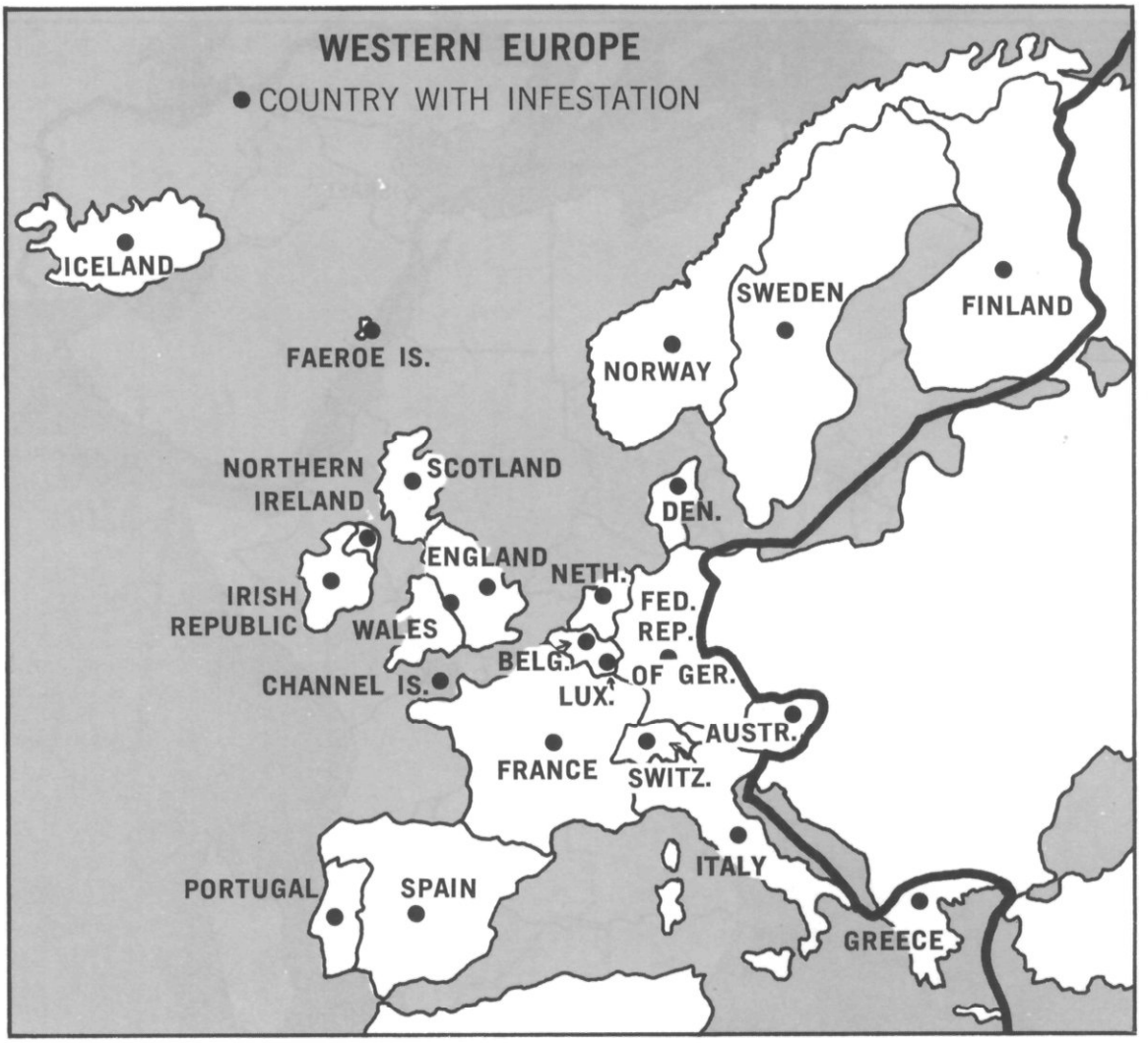

FIGURE 49.—Golden nematode infestations in Western Europe.

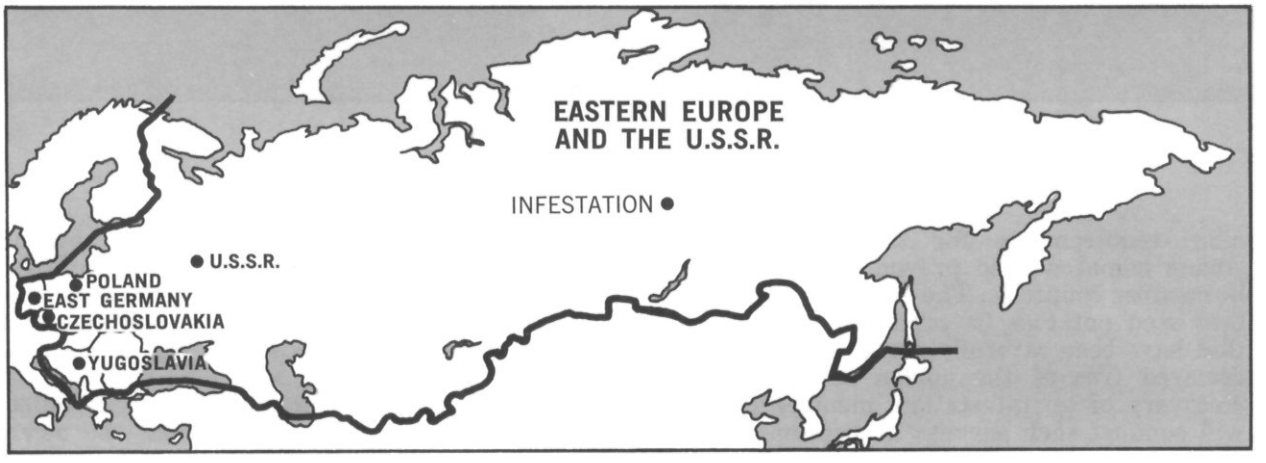

FIGURE 50.—Golden nematode infestations in Eastern Europe and the U.S.S.R.

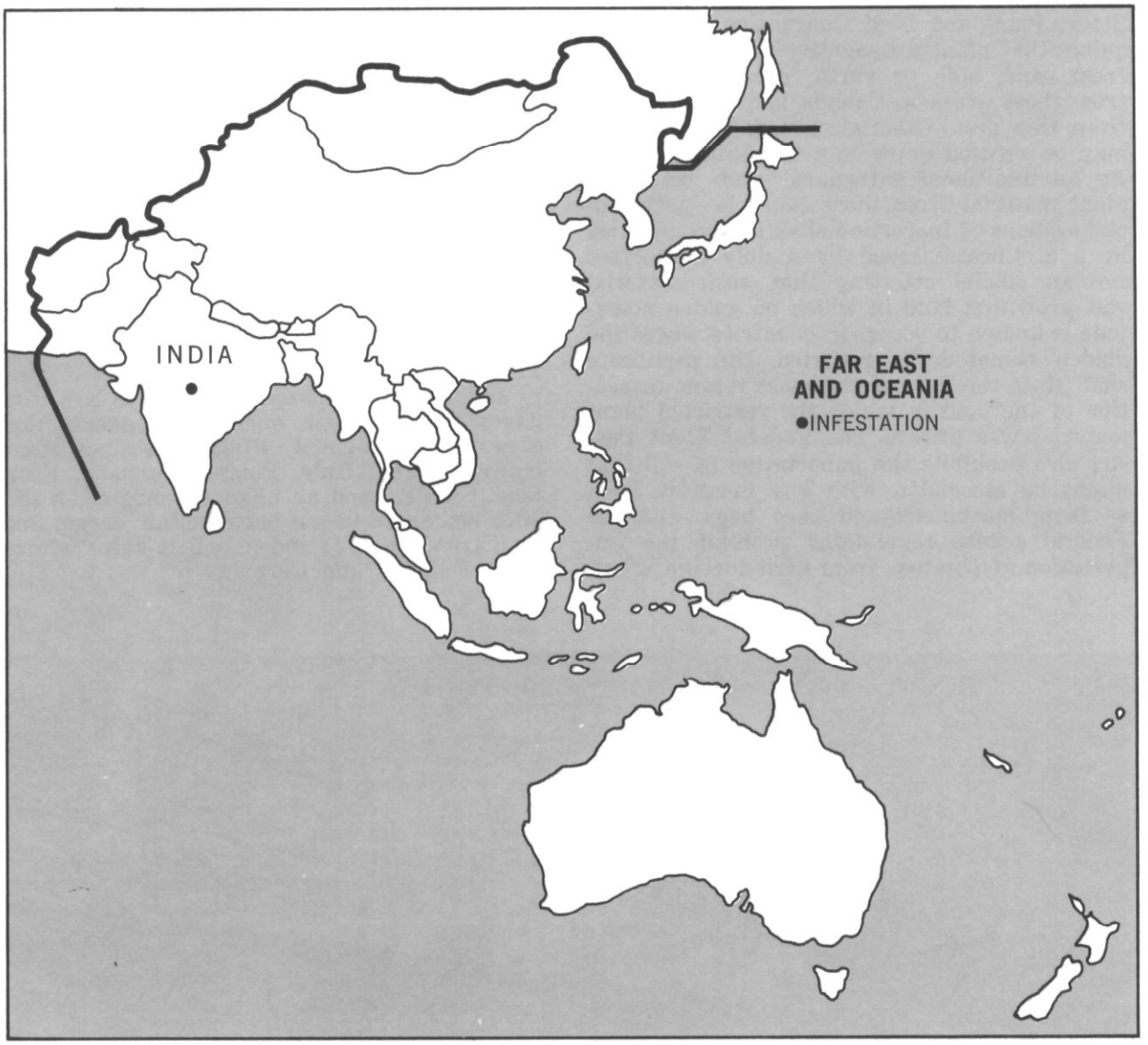

FIGURE 51.—Golden nematode infestations in the Far East and Oceania.

mended that stricter or supplementary regulations be enacted to control or prevent the spread of the golden nematode where local conditions warrant.

The EEC Commission will publish before November of each year a list of resistant potato varieties and the biotype of nematode against which the resistance applies.

The European and Mediterranean Plant Protection Organization, Paris, France, generally referred to as EPPO, has been the leader in Europe in establishing guidelines to be followed in preventing international spread of the nematode (*34, p. 29*). The golden nematode was the subject of a special conference sponsored by the EPPO in the Netherlands in 1955. At that time the member countries recommended requirements for export certification of potatoes. The conferences also recommended the use of a standard soil sampling technique based on the Dutch and United Kingdom methods, which are widely used in European countries (*17*). (See Appendixes II and III.)

To avoid possible importation of the golden nematode into the United States, the Nursery

Stock, Plant and Seed Quarantine No. 37 requires that plant propagative material be free from sand, soil, or earth, except shipments from those areas in Canada known to be free from this pest. Otherwise, such importations may be refused entry into the United States. As an additional safeguard, such restricted plant material from those countries with official systems of inspection shall be accompanied by a certificate issued by a duly authorized foreign official attesting that such material was grown on land in which no golden nematode is known to occur. In countries where the golden nematode is reported, the certificate shall state the date of the most recent inspection of the land in which the restricted plant material was grown. The Federal Plant Pest Act also prohibits the importation of soil that might be associated with any material, such as farm machinery and used bags, and the Federal potato regulations prohibit the importation of potatoes from most foreign areas.

The enforcement of various Federal plant quarantine regulations results in the interception of the golden nematode each year on a wide variety of products and materials. During 1965, the golden nematode was intercepted more than a hundred times: In soil mailed from Ireland; in soil with automotive equipment: (fig. 52); in bagging, conex box, and tractors (fig. 53) in cargo from England, Germany, and Italy; in soil with horseradish in air mail and in ships' stores from England and an unknown origin; in soil with potatoes in air baggage, cargo, and ships' stores from England, France, Germany, Italy, Netherlands, Peru, Scotland, Sweden, and unknown origin; in soil with propagative material in air baggage, air mail, air quarters, baggage, and cargo from England, Finland, France, Germany, Ireland, Italy, Poland, Portugal, Scotland, Sweden, and an unknown origin; in soil with shamrock in air baggage, air cargo, and mail from Ireland; and in soil in ships' stores from England and Germany.

BN-22749

FIGURE 52.—USDA Plant Quarantine inspectors check a returning tourist's car for golden nematode. Contaminated equipment must be steamed clean before entry into the United States.

BN-28128

FIGURE 53.—Although reconditioned and painted, these tractors from Europe were contaminated with golden nematode. Cysts were found on small particles of soil under the paint.

WORLD DISTRIBUTION OF THE GOLDEN NEMATODE

Algeria

In March 1953, symptoms of golden nematode damage became apparent near Algiers. A survey was made of all potato- and tomato-growing areas in the vicinity of Algiers. This was a plant-root survey with some soil samples taken. Eight communes in the vicinity of Algiers were found infested. This is a coastal zone where often two and sometimes three successive potato crops are grown in one year on the same field. Accordingly, several periods of cyst formations are observed from March to December.

About 1,900 hectares (4,750 acres) of winter potatoes (harvested March to May) and 930 hectares (2,325 acres) of summer potatoes (harvested November and December) are produced in this area. The country produces approximately 10,700 hectares (26,750 acres) of winter potatoes and 13,500 hectares (33,750 acres) of summer potatoes.

In certain communes where infestations are heavy, potato production has been reported to be reduced 50 percent, from 130 to 150 quintals per hectare to 50 quintals per hectare (from 28,660 to 33,069 lb. to 11,023 lb. per acre).

Regulations are in effect for the movement of commodities capable of carrying the pest. There has been some decrease in the intensity of the infestation. This decrease is attributed to the general application of soil treatment, mainly with D-D but also with products of the Vapam type, which were officially approved in Algeria in 1960. A decree of September 6, 1954, stipulated that all soils used for nurseries must first be examined by the Plant Protection Service. The decree has since been amended limiting this requirement to horticultural nurseries growing vegetables.

A decree of February 17, 1961, regulates the importation of plants and plant products that might carry the pest.

The National Institute of Agronomical Research is conducting studies of the nematode.

[7] Information contained in this chapter was prepared on the basis of reports of foreign governments, reports of U.S. agricultural attaches, EPPO reports, results of office research, correspondence, and related information.

Argentina

The following summary of the golden nematode situation in Argentina (fig. 54) is based on a translation of a report by Dr. Enrique Brücher (*3*):

"In our discussions with North American and European colleagues on the biological relationship between *Heterodera rostochiensis* and the South American Solanaceae, we have always been of the opinion that the center of origin or natural habitat of the parasite should not be far from regions of a wide genetic and physiological diversification of the generic group *Tuberarium* (the tuber-bearing species of the genus *Solanum*) and from places where we have collected carriers of genes of natural resistance against this nematode.

"As we have explained in a previous preliminary publication (Brücher 1960), it must be supposed that the true origin of this nematode would be South America and, more precisely, the high valleys of the boundary zone between Argentina and Bolivia. All our searches for years in the northern Provinces for the purpose of finding in the soil of the wild tuberous species of *Solanum,* cyst of the golden nematode, were in vain until for the first time, in February 1955, in the high valley of Purmamarca (Province of Jujuy) we observed protuberances on roots of a wild species of *Solanum* which appeared to be caused by the golden nematode.

"We passed years in doubt, until on the occasion of the 'International Expedition of Genocentros, 1958,' we had the opportunity to confirm definitely the findings. We found thus in the soil of Tascal at 3,600 m. alt., in the mountainous part in the north of the Chani Mountains, cysts typical of *Heterodera rostochiensis* on a wild species of *Solanum* (Tuberarium). Some weeks later we discovered other foci of infection in the eastern part of the Department of Tilcara in a valley leading from Abra Remate (4,000 m. high) to Durazno, and another in a valley in the north of the Cerro Sisiler (4.700 m.).

"In both cases the cysts of *Heterodera rostchiensis* were found in humus where *Solanum acaule, S. gourlayi,* and *S. alticolum* were numerous. In the finding at the Valley Durazno there were small patches with *S. vernei* in abundance, also, *S. infundibuliforme, S. acaule, S. alticolum,* and an undetermined species in the environs and, besides, abandoned plantings of native potatoes. The finding at the Valley Durazno was sent for definite confirmation to the Istituut de Nematologia de Holland, our determination being affirmed by the Director, Dr. Oostenbrink, in a letter dated January 24, 1959. We are convinced that with adequate survey and personnel training, many more natural foci in wild species of *Solanum* (Tuberarium) could be discovered in the Provinces of Salta and Jujuy.

"But the proof of the existence of these minute cysts on roots in the soil is a task difficult enough when one is not adequately prepared. Therefore, one must suppose that the distribution of the golden nematode must be much greater in northern Argentina than our casual findings indicate.

"There is not the least doubt that the great potato-growing region of Argentina (south of the province of Buenos Aires) is equally threatened by this enemy of the potato."

Austria

The golden nematode was first found in Austria in 1940 and is known to occur in six of nine Provinces; namely, Vorarlberg, Salzburg, Upper Austria, Lower Austria, Carinthia, and Styria. The extent of distribution of the potato root eelworm is not exactly known because regular soil examinations are carried out only in the seed-potato-producing areas (fig. 55).

Existing provincial plant quarantine legislation provides sufficient legal authority for the adoption of measures to control the golden nematode. To contain the spread of the nematode in Austria, the Federal Institute for Plant Protection has worked out recommendations for growers to follow.

If soil surveys reveal an infestation level No. III (see Appendix II), a minimum of 5 years should elapse and the field should again be soil sampled before potatoes are planted. At level No. IV there is an added requirement that the entire potato crop of the affected farm be examined each year until the outbreak is wiped out. At level No. V the farmer should be made to discontinue potato production until the outbreak has been greatly reduced. In home gardens and on small plots or in mountain locations where rotation or chemical control is impracticable, resistant potato varieties are recommended. In areas devoted to seed production with infestation levels No. III and IV and where the level is No. V, the use of suitable nematocides, preferably in combination with the single-time use of nematode-resistant potato varieties, is recommended.

The resistant potato variety Antinema and the varieties Apis, Amelio, and Amaryl are being grown in Austria.

FIGURE 54.—Infested areas in Argentina and Bolivia.

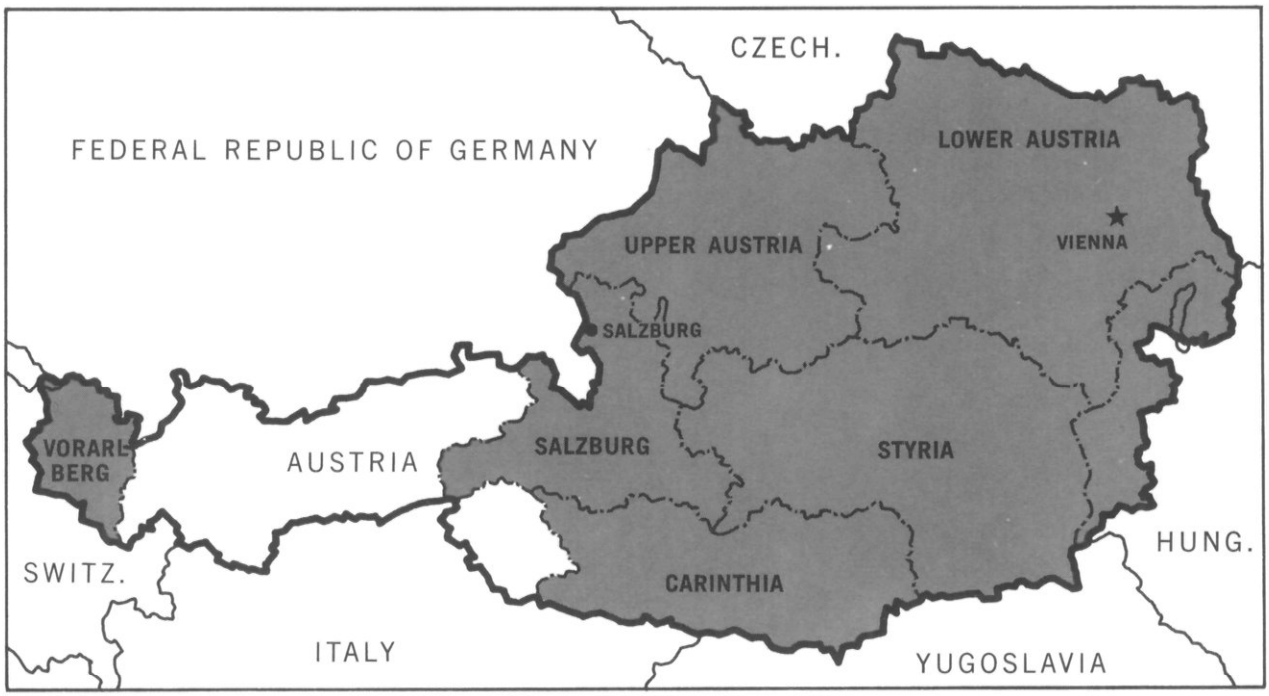

FIGURE 55.—Infested provinces in Austria.

Belgium

The golden nematode was first found in Belgium in 1949. Belgium prohibits growing potatoes and tomatoes on the same land more often than once every 3 years. On infested properties the law prohibits the growing of potato, tomato, and other vegetable plants for transplanting for a period of 5 years. This period can, however, be lengthened or shortened depending on circumstances, such as viable cyst count. The law requires that early potatoes be harvested no later than June 20.

On the Belgium coast where commercial potatoes are grown, the Government has a soil treatment program using D-D at the rate of approximately 63.4 gallons per acre. The Plant Protection Service has a systematic soil sampling survey throughout the country. All samples are processed at Ghent. Studies are underway to determine whether resistance-breaking races occur.

Bolivia

The following description of the golden nematode situation in Bolivia was summarized from a report by Frank H. Bell and B. Alandia Segundo (*1*).

During the period 1952–54, observations were made on the diseases of potatoes in Bolivia that should be of interest to pathologists elsewhere, especially since the area may be one of the ancestral homes of the potato.

One of the more interesting organisms noted for the first time in Bolivia was the golden nematode, *Heterodera rostochiensis*. It was found to be widespread in the Lake Titicaca region of northwestern Bolivia, at an altitude of 12,600 to 13,000 feet (fig. 54). One of the sites where it was noted was on the famous "Island of the Sun" of the prehistoric Incas. It was also found in the Tunari range (altitude 11,000 feet) near Cochabamba. This latter site is 200 miles southwest of Lake Titicaca in mountains that are separated from the main Bolivian Altiplano. The widespread occurrence of this nematode in long cultivated, heavily populated regions of Bolivia substantiates the theory of Ing. de Segura of Peru, where the nematode was noted in 1952 for the first time, that this nematode is indigenous to the Andes and was probably carried from there to Europe and then to the United States. The root-knot nematode, *Meloidogyne* sp., has been found on potatoes in the sandy soils of the Island of the Sun, and in the highlands east of the Cochabamba Valley.

Canada

The golden nematode was first discovered in Canada in the Province of Newfoundland in October 1962, in the community of Manuels on Conception Bay some 14 miles west of the city of St. Johns. The discovery of the pest was not entirely unexpected because no import restrictions were maintained by the colony until 1949, when Newfoundland became a Province of Canada. Potatoes and other vegetables were imported from Great Britain when the necessity arose, and it is possible that the nematode was introduced many years ago.

The importation of potatoes into Canada from Newfoundland has been prohibited since 1910 because of potato wart. Following the confederation with Canada, the regulations under the Destructive Insect Pest Act were amended to continue the prohibition of the movement of potatoes, soil, plants with soil, used bags, and other items, and to prohibit their export to other countries.

The Canada Department of Agriculture's Plant Protection Division, under the authority of the Destructive Insect and Pest Act and the Destructive Insect and Pest Regulations, has broad power to prohibit or restrict the importation of plants with soils or packing materials, containers, machinery, implements, vehicles, and other carriers containing soil or to which soil may adhere. This applies to all countries except the continental United States unless plants with soils have been thoroughly washed or otherwise treated immediately before movement into Canada and unless the importation is accompanied by an affidavit or declaration to that effect.

Canada has been particularly alert for the presence of the golden nematode in the country because of the importance of seed-potato exports. Canada produces annually about 70,000 acres of seed potatoes on nearly 10,000 fields in nine Provinces. A random survey, started in 1959, has been conducted throughout the seed-producing areas.

On June 16, 1965, a potato farmer on Vancouver Island, Saanich Peninsula, near the city of Victoria, British Columbia, brought to the Saanich Peninsula Agricultural Experiment Station a potato plant with soil for examination by the pathologist. The plant and soil were examined by W. R. Orchard and N. Waseem and found to contain a large number of golden nematodes in various stages of development. Specimens were sent to Ottawa for confirmation, which came on June 21.

The infested property belonged to a farmer who had formerly grown bulbs. He had imported bulbs from Europe and had grown the last crop of bulbs on the infested property in 1938. Between 1938 and 1950 he grew various crops and since 1950 he had continuously grown potatoes on the field (fig. 56).

The Canada Department of Agriculture's Plant Protection Division took immediate steps to regulate the movement of crop plants and commodities that might carry the nematode out of the area. In consultation with the author of this handbook, a program to combat the nematode was developed. A laboratory was established, surveys instituted, and quarantine regulations established.

By 1966, surveys conducted throughout the Province of British Columbia showed that the golden nematode was confined to a small area on the Saanich Peninsula. Cysts of the golden nematode have been found on approximately 150 acres.

All infested lands are removed from production and fumigated with dichloropropene-dichloropropane at the rate of 50 imperial gallons per acre. At least two applications are given each field. In addition, some 300 acres exposed to infestation have been removed from potato production and fumigated. The Canadian Government compensates growers for their losses.

Canary Islands

According to a report by R. Chamberlain, University of Belfast, and Iuan Valladares Barbuxano, they discovered the golden nematode in La Victoria de Acentejo and in other districts in Tenerife, Canary Islands, on December 27, 1960 (*6*). According to Chamberlain, the discovery was made at latitude 28° 25′ north. This appears to be the most southern occurrence as yet recorded of *H. rostochiensis* in the Old World. (See Spain.)

Chile

In October 1966, the Minister of Agriculture, Santiago, Chile, telephoned me and advised that a shipment of 3,500 metric tons of Irish potatoes from Europe were in port and had been found to be contaminated with the golden nematode. Safeguards were discussed and agreed upon for the safe disposition of the potatoes. All the potatoes, except a few bags, were washed and sold for consumption in metropolitan areas. The unwashed potatoes were later moved to a farm. In December 1967, I was advised that representatives of the De-

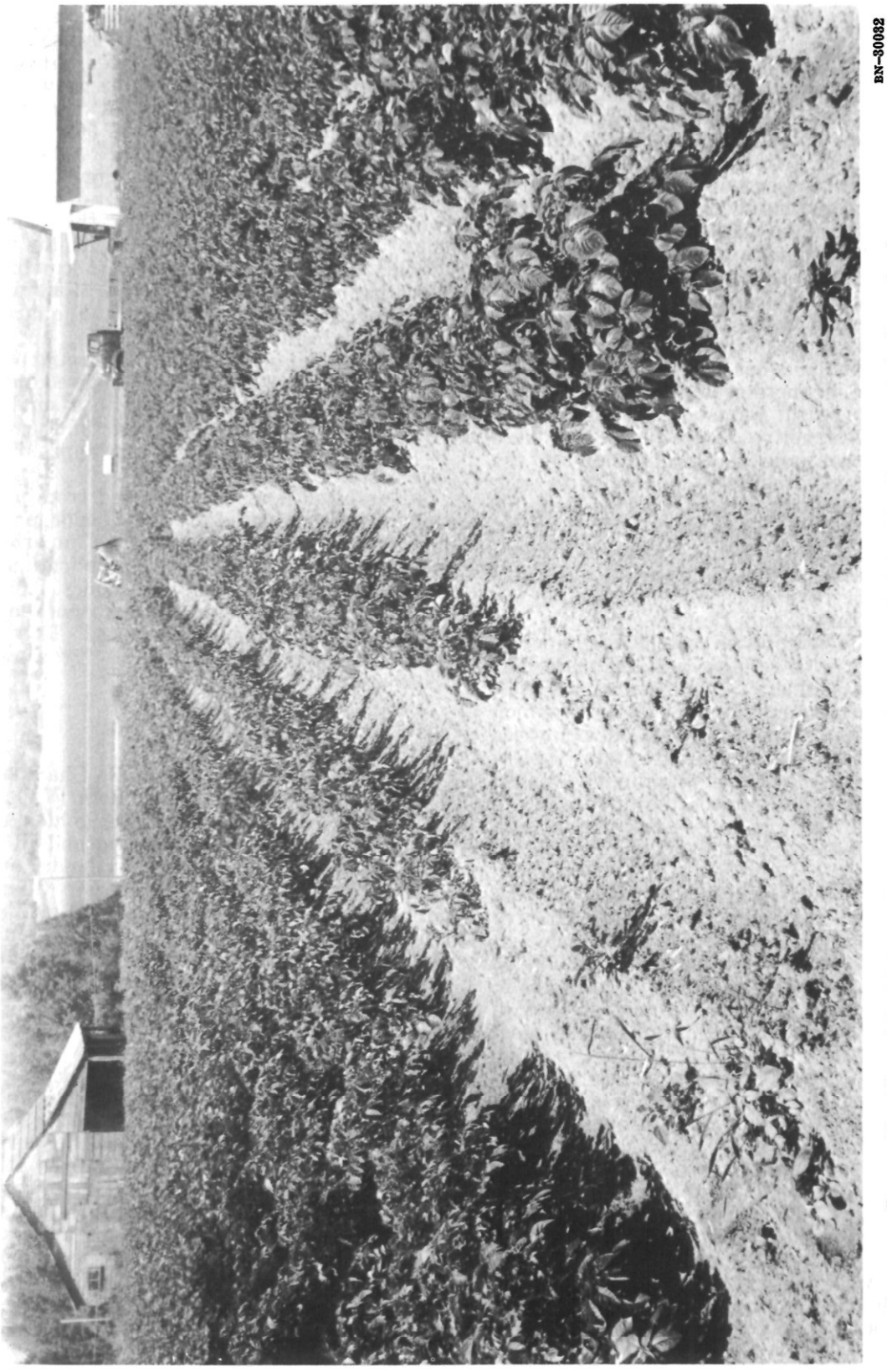

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FIGURE 56.—The original infested field on Vancouver Island, British Columbia. The property had previously grown bulbs imported from Europe. The farmer first noted stunted potato plants in 1964. When this photograph was made by the author on June 23, 1965, the entire field showed evidence of damage.

partment of Defensa Agricola had inspected a farm in an isolated valley in Aconcagua Province, where the potatoes had been used for seed, and had confirmed the presence of the golden nematode.

Czechoslovakia

The golden nematode was first recorded in Czechoslovakia in 1954.

Infestation in Czechoslovakia consists mainly of isolated pockets in private gardens where crop rotation is not properly observed. The intensity of attacks is low. Infestations occur in Bohemia and northern Moravia. The Government regulates growing of potatoes and other host crops on infested land. This regulation prohibits growing of other host crops on infested land for 5 to 7 years, requires crop rotation, and severely restricts the utilization of potatoes grown in infested communes. Imported potatoes are carefully inspected. The Quarantine and Plant Protection Service enforces Decree No. 1, 1959. Research is being conducted to detect biotypes of the nematode.

Denmark

The golden nematode has been known to exist in Denmark since 1928. The State Plant Pathology Institute examines soil samples for cysts of the golden nematode in connection with the certification of seed potatoes and other plant products for export. Sampling in potato fields and examination of soil samples for cysts comply with the approved international rules.

Only a few attacks of the nematode are found annually in cultivated agricultural land. Most of the infestations observed from 1964 to 1966 were in the northern part of Jutland (fig. 57).

In certain contaminated areas, mostly gardens, series of samples have been investigated to determine the degree of infestation and stop the spread of the nematode to adjoining seed-potato fields. Growing of potatoes on infested land is prohibited for a number of years under regulations of the State Plant Protection Service.

Potato growing has been prohibited for many years in nurseries. Most nurseries have been found free of the nematode. Areas where the nematode has been found are under frequent observation and production is controlled. Analysis of samples from these areas are the basis for deciding whether potatoes and nursery plants may be grown there.

Altogether, the Government's Plant Protection Service has recorded infestations in 25 counties, as follows:

	No. of infestations
Private gardens	106
Commercial cultivated agricultural land	160
Commercial horticulture and gardening	37

Under systematic investigations 64 agricultural holdings, where the Government's Plant Protection Service had recorded potato root nematode from 1956 to 1964, were investigated to determine if the pest had spread to other fields. The purpose of this investigation was to test the Protection Service's usual practice of recording only the affected areas on individual holdings. The investigation showed that 61 percent of the holdings where the nematode had been recorded in one part had newly infested parts.

In Denmark the work of producing varieties resistant to the golden nematode has been very intense, and it is expected that commercial varieties will be available for growers on a limited scale by 1969. These investigations are conducted at the Potato Improvement Research Station in Vandel. The testing is done at the State Plant Pathology Institute at Lyngby.

Investigations over the past 3 years (1964–

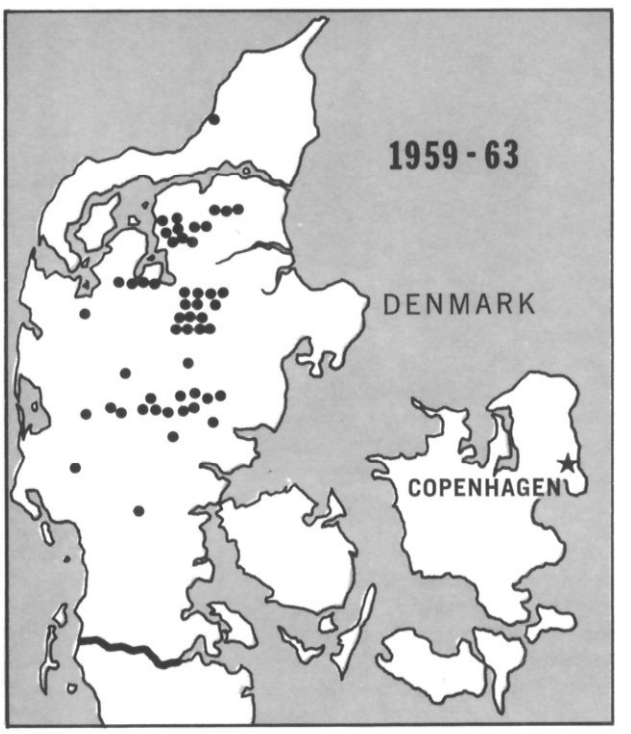

FIGURE 57.—Occurrence of the golden nematode on potato farms in Denmark.

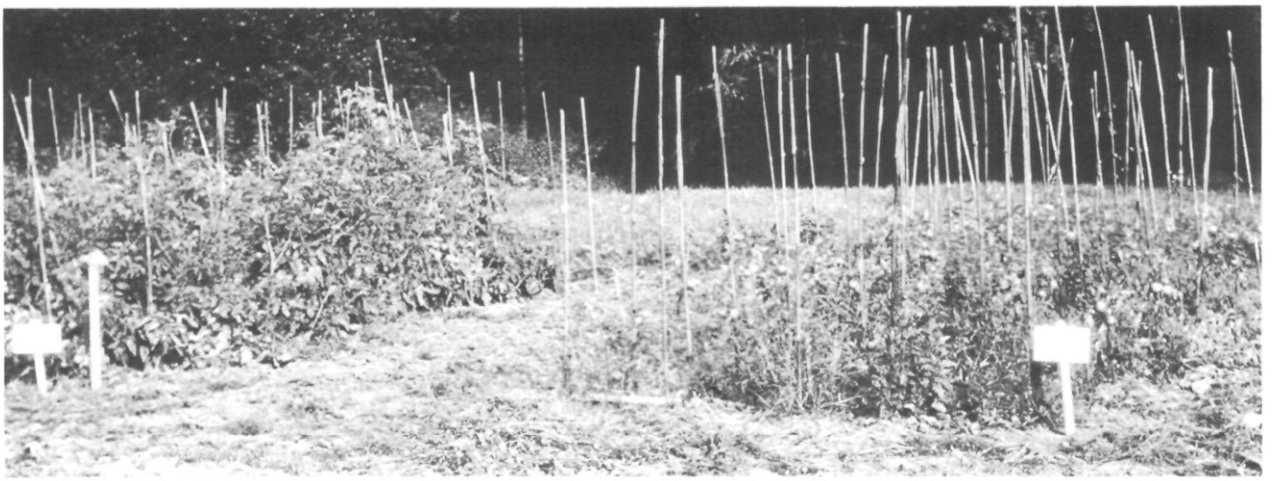

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FIGURE 58.—Test plots showing the effects of golden nematode on tomatoes at Imperial College field station, Sunninghill, Ascot Burkes, England.

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FIGURE 59.—A potato field in England, showing heavy damage caused by golden nematode. [British Crown Copyright; reproduced by permission.]

66) have been carried out to see if resistance-breaking biotypes can be found. None have been found to date.

The use of soil fumigants is primarily on the Amager island southeast of Copenhagen where there is a heavy concentration of vegetable farming. The nematocide D-D is used at the rates of 45 to 60 cubic centimeters per square meter for fumigating soil in greenhouses. In cultivated fields 400 to 500 liters per hectare (about 2½ acres) of D-D is used. The cost of fumigating one hectare in 1966 was about 1,500 kroner ($210).

The Government's Agriculture Advisory Service strongly recommends to farmers that do not have infested land a sound rotation program of at least 2 to 3 years for potatoes.

England and Wales

The golden nematode in England and Wales was confined to Yorkshire in 1917, but it had probably been present for 10 to 15 years before that time. It is also reported that the nematode was causing damage to tomatoes (fig. 58) in Yorkshire as early as 1928.

According to Southey (*38 pp. 171, 173, 174*), the nematode is well-distributed in the ware-potato districts of the country. Because of the demand for potatoes during World Wars I and II, the problem was compounded. Southey reports that following World War II the potato acreage rose nearly to the one million mark, and complete or partial crop failures were frequent. In 1949, a conservative estimate was made by the Ministry of Agriculture that losses caused by the golden nematode were about 2 million pounds sterling, or equivalent to about $10 annually on each acre of potatoes (fig. 59).

Despite the situation, England has been fortunate in that the golden nematode is rare in the main seed-producing areas (fig. 60). Surveys are conducted by the Ministry of Agriculture as an advisory service to growers. The Ministry of Agriculture, through the Extension Service, has advised growers on the importance of long rotations, especially in areas where the nematode populations are light. After commercial damage appears in a field, the Ministry of Agriculture advises the farmer to leave it out of production for 6 years or longer to be sure that no economic damage to crops will occur. The Ministry of Agriculture then recommends potato producing on a 1 year out of 5 rotation.

FIGURE 60.—Distribution of the golden nematode on commercial potatoes in England and Wales.

Faeroe Islands

The first report of the golden nematode in the Faeroe Islands was in 1951 when K. Lindhardt (*24*) examined 15 soil samples and found they were all infested. In 1964, another survey was made of the Islands, and 19 of 93 samples collected were found to contain cysts.

The golden nematode may have existed in the Islands before 1940, but it is more likely that this pest was introduced from Great Britain during World War II on supplies for troops. Several infested soil samples from the Islands were found to contain an aggressive biotype that attacks varieties of potatoes containing resistance of *Solanum tuberosum* subspecies *andigena*. Aggressive biotypes are not uncommon in Scotland and some parts of England, but they have not been detected in Denmark.

Although the Ministry of Agriculture of Denmark issues regulatory orders to control the golden nematode, plant diseases, and insect pests, the orders do not apply to the Faeroe Islands.

Potatoes are produced on about 150 hectares (375 acres). Since soil suitable for growing potatoes is limited, some fields have been in potato production for more than 100 years.

Finland

The golden nematode was first reported in Finland in 1946. Nematode surveys are systematically conducted in the country by Tuhoelaintutkimuslaitos, Tikkurila. Infestations are confined to the southern part of the country and do not extend beyond the region of Tampere (61°40′ N.) (fig. 61).

Finnish Government regulations prohibit the growing of potatoes on infested land from 3 to 5 years. Resistant varieties are available. The most common variety in use is "Antinema." Approximately 2,500 kilograms (5,511 pounds) of this variety have been distributed to farmers.

Research is being conducted on the golden nematode problem. Biotypes A, B, C, and D have been discovered.

FIGURE 61.—Infested areas in Finland.

France

The golden nematode was first reported in France in 1947.

A Ministerial Order, dated November 15, 1963, and published in the Official Gazette of November 27, 1963, page 10597, sets forth the requirements for control of the potato root eelworm throughout the country. The main provisions are restrictive measures, including systematic soil sampling of areas surrounding fields in which the pest has been recorded by the Plant Protection Service; prohibition of the growing of seed potatoes on infested soil for 5 years; if infestation exceeds a prescribed level, prohibition also of growing ware potatoes, tomatoes, and all crops for transplanting; prolongation of prohibition for further 3-year periods until samples confirm absence of pest; and directives for the use of underground parts of all crops growing or ready for harvesting in the zones in which restrictions apply.

The intensity of the attack of the nematode varies greatly in different regions. Severe attacks have not occurred in recent years because soil examination is made of fields and when infestations are found to exceed an acceptable level the growing of host plants is prohibited for 5 years. Resistant varieties of host plants are also being tried. In fields where infestation is particularly heavy, total prohibition of host plants is necessary. A race of golden nematode that broke the resistance of the potato variety Antinema has been found in Saint Malo.

Germany (East)

The golden nematode is widely distributed in East Germany. The infestations are most numerous on sandy soil, and for economic reasons potatoes have been grown too frequently. Most communes of the country are infested. In some areas between 2 and 3 percent of the total agricultural area is infested. However, in the northern area (Mecklenburg and Brandenburg) the averages occasionally are as high as 8 percent of the agricultural area.

East Germany also uses resistant potato varieties. Regulations are enforced on crop rotation and the movement of infested commodities. Soil examination of fields is made to

determine when infestations exceed an acceptable level, whereupon the growing of host plants is prohibited for 5 years. Rotation of potatoes and tomatoes is compulsory. Through these measures, intensity of attack is kept at low levels.

Rules governing marketing are contained in a decree published June 29, 1963, in the *Gesetzblatt II.*

Germany (West)

It is from Germany that we first learned about the potato nematode problem. (See History and Origin of the Golden Nematode.)

There are no official figures on the extent of distribution within the German Federal Republic, although it is known that the potato nematode occurs in all States. After a considerable postwar increase in nematode incidence, the infestation intensity decreased especially in recent years mainly because an increase in the standard of living (and associated decline in demand) had caused a decrease in potato cultivation.

The basic legislation on potato nematode control in the Federal Republic is (a) the Ordinance of July 20, 1956, Prevention of Occurrence and Control of Potato Nematodes, and (b) Ordinance Amending the Ordinance on Prevention of Occurrence and Control of Potato Nematodes of July 26, 1961.

According to these ordinances, the production of potatoes and tomatoes as well as the construction of dirt storage pits is, on principle, forbidden in infested areas until the Plant Protection Service has declared the areas to be free of infestation (fig. 62). On the basis of these ordinances, the States have established implementing ordinances, which consider any special local conditions in their areas.

The breeding of nematode-resistant varieties of potatoes is being pursued with great vigor. The Federal Variety Agency (Bundessortenamt) has acknowledged that three varieties are resistant against nematodes: Antinema, Apis, Cobra.

In several localities of the Federal Republic there occurs the resistance-immune biotype B of the potato nematode. It is expected that further resistance-immune biotypes will be discovered.

As a matter of principle, the Government does not interfere with crop rotation on noninfested areas. Farmers are advised, however, to plant potatoes and other nematode host plants only every third year. If an area is considered to be endangered with infestation, the authorities may order that potatoes can be planted only every third year.

FIGURE 62.—Poster used by West German extension service to alert farmers to the golden nematode problem.

The growing of potatoes on infested land is basically forbidden. Upon application, the Government may grant exemptions—for example, for the growing of resistant varieties; for noninfested parts of fields, provided these parts or neighboring fields are not endangered; for scientific and breeding purposes, provided this does not endanger nematode control.

The Plant Protection Offices inspect their areas for the occurrence of potato nematodes and other pests. All enterprises producing for export (horticultural enterprises, tree nurseries) are officially inspected periodically for noninfestation; for example, in North Rhine-Westphalia the total area is inspected every 4 years and the ground storage places every 2 years. Similar regulations exist in the other States.

Before seed potatoes can be grown, an official inspector must declare the area free from

infestation. In addition, random sample inspections for nematodes are carried out in areas considered to be in danger of infestation.

Greece

The golden nematode was found in Greece for the first time in 1951 in the mountainous area of Parnon Arkadia (*2*).

The golden nematode was found in 11 locations administratively belonging to the prefectures of Arkadia, Messinia, Boeotia, Serres, Larisa, Chalkidiki, and the Cyclades islands (Paros, Naxos) after research was carried out by the Benachi Phytopathological Institute. The Ministry of Agriculture has since reported six locations belonging to the prefectures of Elis, Lakonia, Imathia, Lasythion, and the island of Aegina.

The above areas are not entirely infested by the nematode but are limited to spots of up to 500 square meters. Infested areas where potatoes are grown are estimated to be about 30,000 to 50,000 stremmas (7,410 to 12,350 acres). Total area of potato production is about 480,000 stremmas (118,560 acres).

The Ministry of Agriculture recommends to the growers the use of nematocides, which lately are being used on a growing scale. Furthermore, where an infestation has been observed in seed-potato-producing centers, the Ministry of Agriculture requires compulsory washing of seed potatoes with special equipment.

Generally, to control the spread of the nematode and protect the potato crop, a rotation is recommended. Relevant instructions have been issued by the appropriate service of the Ministry of Agriculture.

Nematocides recommended for the control of the golden nematode in Greece are D-D soil fumigant at the rate of 100 to 200 kilograms (220 to 441 pounds) per acre and ethylene dibromide at the rate of 40 to 100 kilograms (88 to 220 pounds) per acre.

There are no resistant potato varieties.

The cultivation of potatoes in infested areas is not legally prohibited, but the Ministry strongly recommends that such fields not be used for potatoes.

Seed-potato-producing centers are immediately abolished upon the finding of the nematode.

Guernsey

The golden nematode was first reported in Guernsey in 1952.

Infestations are now fairly widespread throughout the island of Guernsey. Any apparently new infestations usually indicate a sudden local increase in the pest population as a result of cropping potatoes 2 or more years in succession. Some control measures using D-D are proving highly successful.

Iceland

The golden nematode was first detected in Iceland in 1953. Its presence is limited to a small area in the Westman Islands, and in two small villages on the southwest coast of Iceland—Eyrarbakki and Stokkseyri.

During August and September, roots of potato plants are examined to determine the extent of the infestations. Technical agricultural experts are available in each of the counties, and they endeavor to keep informed on agricultural developments. Resistant potato varieties are not considered suitable for Icelandic soil conditions, and chemical fumigants are not used because they are too expensive. Resistance-breaking biotypes are not known to be present.

Although the Government has no special regulations concerning the rotation of potatoes on land not known to be infested, it advises producers of the desirability of rotating crops. Growers are also advised by the Government officials not to plant on infested fields.

India

The golden nematode was first identified in India in 1961 and is thought to be restricted to certain areas in Nilgiri Hills of Madras State (fig. 63). Intensive field surveys to determine the distribution of the golden nematode in Madras State have been in progress since 1963. The first round of surveys was expected to be completed by June 1967. A total of 946 acres out of 24,000 acres of potato-growing area has been found to be infested.

Research on the problem is in progress under the direction of the Indian Council of Agricultural Research at Ootacamund (Nilgiri Hills, Madras) in collaboration with the Central Potato Research Institute. Research includes search for biotypes, experiments with resistant potato varieties, testing of soil fumigants, and a study of the effect of 1-, 2-, 3-, and 4-year rotation of nonhost crops.

The question of imposing a domestic quarantine against the golden nematode in the infested area is under consideration. The growing of potatoes on infested land is not recommended. Under the Destructive Insect and Pest Act, 1914, the importation of potatoes is pro-

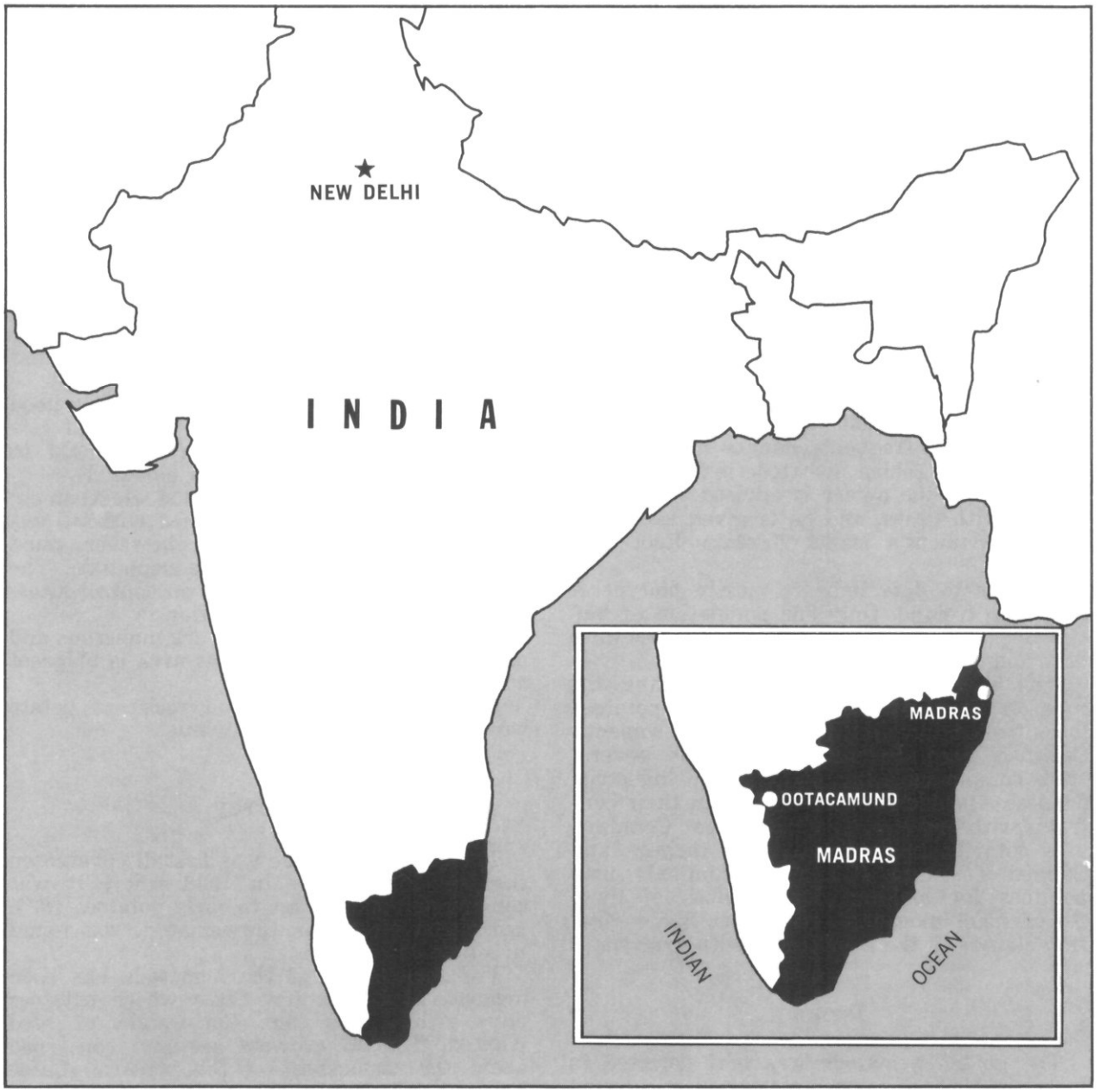

FIGURE 63.—Infested areas in India.

hibited except in small quantities for research or scientific purposes.

Ireland

Distribution of the golden nematode in Ireland appears to be limited although the nematode has been known to be present since 1922. Infestation occurs mainly in pockets of land in districts that were once congested (bogland and hillsides), where a rotation of crops was not feasible under the land tenure system of the 19th century. Most of this land is no longer cultivated. Golden nematode also is frequently found in urban and suburban gardens following poor rotational practices.

The Destructive Insects and Pests (Consolidation) Act of 1958 sets forth regulations concerning the golden nematode. This act em-

powers the Minister of Agriculture and Fisheries to issue various orders. One of these is the Potato Root Eelworm Order of 1951.

Potato varieties resistant to the golden nematode are available in Ireland only for research purposes. No such varieties are available commercially.

Chemical fumigants are not used against the golden nematode on outdoor crops grown in Ireland. However, Dazomet (methyl-iso-thiocyanate) is used to control the golden nematode in tomatoes grown under glass.

Farmland found to be infested with golden nematode must be sown with grass immediately in accordance with the Potato Root Eelworm Order. The Department of Agriculture and Fisheries does not consider it practical to extend this requirement to urban garden plots because of the frequent changes in occupiers. But when the golden nematode is found in urban gardens, the owner is advised to sow the garden with grass, and he is given a copy of the Department's leaflet "Potato Root Eelworm."

Surveys to date indicate mostly biotype A occurs in Ireland. Only one population of biotype B has been found. No other biotypes have been found.

Ireland has no legislation controlling the rotation of crops. Rotation of seed potatoes is controlled, however, under the Government's Certified Seed Potato Scheme, and several Irish companies using potatoes for industrial purposes include rotation clauses in their contracts with growers. The Irish Sugar Company uses potatoes in its potato flake factory, and Ceimici Teoranta (Chemicals Limited) uses potatoes for making glucose. Both of these Government-sponsored companies have rotation clauses in their contracts with growers.

Israel

The golden nematode was first detected in Israel in 1957. A minor infestation was found in the Raanana region, Petach-Tikva subdistrict (15 miles north of Tel Aviv) all within a radius of 3 miles.

The Plant Protection Service of the Ministry of Agriculture conducts systematic surveys of all potato fields in the Raanana region. So far, it has been unnecessary to apply Government regulation. The Extension Service of the Ministry of Agriculture recommends one potato crop in 3 years in the region affected by the nematode. As a rule, farmers comply with the advice given by the Extension Service officer in an effort to control pests of this nature.

There are no resistant potato varieties available and no resistance-breaking biotypes are known. Some experimental work has been done with soil fumigants using ethylene dibromide at the rate of 60 liters to the acre (15.85 gallons).

Italy

The occurrence of the golden nematode in Italy was first reported in 1962. According to the Ministry of Agriculture, infestations are found mainly in the Naples area where early potatoes are grown. Some scientists think that the infested area is much more widespread.

The Naples area has maintained fairly good yields. This may be related to the use of cow manure as a fertilizer, which is thought to inhibit the development of the nematode.

At a potato conference in 1964, Government control measures were petitioned without success. Imported seed potatoes, however, must come from areas free of the nematode. The Government does offer advice on control measures recommending crop rotation.

Fields in the infested area are numerous and small. The potato crop in this area is of great economic importance.

Research is underway on resistant potato varieties and chemical fumigants.

Jersey

The golden nematode was first discovered on the island of Jersey in 1938 where it was causing serious damage to early potatoes (*37*). Later that same year, the nematode was found in a field of tomatoes.

The seriousness of the nematode has been demonstrated in a few cases where potatoes have yielded less than the weight of seed planted. Tomato growers are also concerned about the seriousness of the problem. Cases have been reported where yields of tomatoes have been reduced from 15 tons an acre to less than 2 tons. Soil samples are examined for growers on an advisory basis. In general, more than 50 percent of the samples examined have measurable contamination.

Soil fumigation using D-D, methyl bromide, and Vapam is in use. Under a law that came into force in 1962, approved materials for potato root eelworm control were subsidized. The subsidies being granted were for soil sampling or crop examination, or both, which show whether the pest populations have reached the level sufficient to cause crop damage.

Luxembourg

The golden nematode was found in Luxembourg in 1955. Potato-producing areas are surveyed for the presence of the nematode. However, only 20 hectares (50 acres) are known to be infested.

The soil fumigants Vapam and Nemacur have been tested as control measures for the nematode. Growers, if they choose to do so, may import resistant varieties of potatoes.

Although there are no specific Government regulations against the golden nematode at this time, the Government will implement regulations developed by the European Economic Council.

Netherlands

The golden nematode was first reported in Holland in 1941. Regulatory action was taken shortly after that to restrict and control the pest. These regulations were amended in 1947 and again in 1949. A law was passed to prohibit the growing of potatoes and transplants in infested land and to set up special precautions for the distribution of infested material. Growing potatoes on noninfested land more often than once every 3 years is also prohibited. This regulation alone has had a direct effect on the farming practices of the country.

These regulations have prevented the buildup of the nematode and protected the country's export of many agricultural commodities.

Protective crop rotation is strictly enforced and has the support of farm organizations. Potatoes grown against regulations are destroyed. Bulbs and perennials cannot be grown on land where there is any danger of spreading the golden nematode. Potatoes are prohibited from being grown in the bulb-growing districts of Holland. The towns, communities, and boundaries of areas where growing potatoes is prohibited are specifically outlined in Government regulations.

The growing of resistant varieties of potatoes is a specific part of the Government regulations to combat the golden nematode. Each year the Government designates those parts of infested districts or properties that may be planted to varieties resistant to the golden nematode. In 1966, a total of 3,800 hectares (9,500 acres) was planted to resistant potato varieties. Holland's best varieties for industrial potato are Saturna and Prevalent. The best tablestock potato is Amaryl.

Early potatoes must be harvested before June 26, except in north Holland where the harvesting date is designated as July 6. Harvesting dates may vary from year to year, depending on growing conditions. Potato growers who plant early varieties are permitted under the law to grow potatoes on the same land every other year.

Potatoes and tomatoes are prohibited from being grown in the nursery stock growing area of Boskoop.

The resistant potato varieties that are now available to growers have a resistance to the more common biotype A of the pest only. Growing these varieties is not permitted in fields that are infested with other biotypes. Good progress has been made with the development of varieties with resistance to biotypes other than A. These varieties are also expected to be available commercially within a few years.

Holland has an extensive research program at Wageningen to investigate many aspects of the nematode control problem including biological and chemical control, potato breeding studies for the development of resistant varieties, resistance-breaking biotypes, and other research.

Northern Ireland

The golden nematode was found for the first time in Northern Ireland in 1933 on a potato crop in a garden near Belfast.

Regulations relating to the golden nematode were first introduced in 1945, and the various modifying enactments that followed have been consolidated into a single measure, the Potato Root Eelworm Order, Northern Ireland, 1960. Under the terms of this order, the golden nematode is a "notifiable" pest, and wide regulatory powers are vested in the Ministry of Agriculture for the enforcement of the order by such means as necessary.

A systematic survey has been in operation in Northern Ireland for 20 years. Upon discovery of the golden nematode on any land, certain prohibitions are enforced, such as (a) the removal for planting purposes of any potatoes, tomato plants, or other propagating material; the disposal of such plant or plant products from infested land will be in accordance with directions from the Ministry of Agriculture; (b) the removal of infested soil from any premises whether loose or adhering to the roots of plants, implements, or other articles; (c) the planting of infested property to potatoes, tomatoes, or plant propagating material. These restrictions remain in force until withdrawn by the Ministry of Agriculture. Since the first notices of infestation were issued in 1945, there have been no instances

where resumption of potato growing has been permitted or where any of the other requirements have been released.

Glasshouses in which infestations are found are permitted to resume normal culture of tomatoes or other glasshouse plants provided such establishment can be freed of infestation to the satisfaction of the Ministry of Agriculture. Under such situations, steam sterilization of soil and other cleanup measures are satisfactory to eradicate infestations.

Field infestations of commercial potatoes are for the most part confined to five districts, each of which is designated by the Ministry of Agriculture as a "scheduled area." These areas embrace the infested property and a wide peripheral zone. Within these areas the provisions of the potato root eelworm order apply.

FIGURE 64.—Infested areas in Norway.

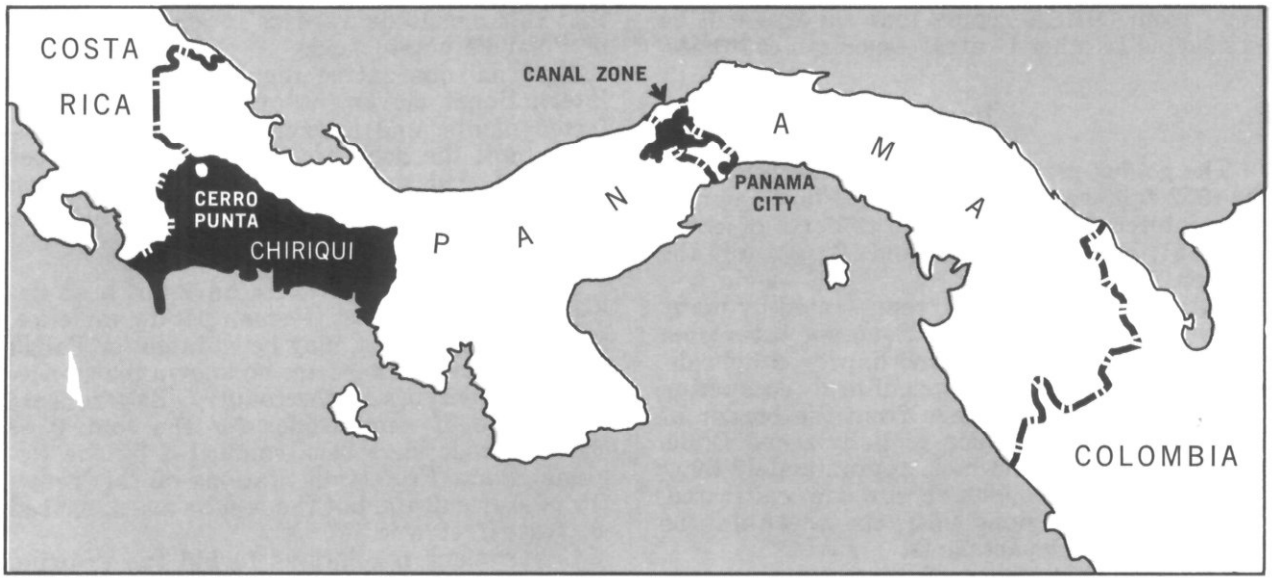

FIGURE 65.—Infested areas in Panama.

In addition, special cropping restrictions require that potatoes shall not be planted on any *noninfested* land in the scheduled area more often than twice in any 8 years.

Norway

The golden nematode was first found in Norway in 1956. The infested farms are located in the coastal counties of Aust-Agder, Vest-Agder, and Rogaland (fig. 64).

The Norwegian Plant Protection Institute, Norwegian Ministry of Agriculture, has issued regulations concerning the control of golden nematode. Regulations include the following: Tractors that might have infested soil must be thoroughly cleaned and washed; the sale of seed potatoes and other plant material from infested areas is prohibited; and the growing of potatoes in infested areas is also prohibited. Exceptions may be made, however, to the last regulation under certain conditions and then only for the growing of potatoes every fourth year. The Norwegian Government's regulations concerning this pest are based on recommendations of EPPO, of which Norway is a member.

The Norwegian Plant Protection Institute, Norwegian Agricultural College, Vollebekk, has developed two resistant potato varieties.

Nationwide surveys for the nematode are being conducted. So far, the southwest, southern, and eastern parts have been covered by this survey.

One resistance-breaking biotype B has been found on one farm. Investigations on resistance-breaking biotypes are continuing.

As a protective measure, the Government strongly recommends to growers that they rotate potatoes on land not known to be infested.

Panama

The golden nematode was discovered in Panama in August 1967 following damage to a potato crop. The infestation is located in Cerro Punta, Chiriqui (fig. 65), according to Dr. Rodrigo Tarte, University of Panama.

The main varieties of potatoes grown in the country are Alpha, Red Pontiac, and Urgenta. Farmers have customarily obtained their seed potatoes from European sources.

Dr. Tarte has organized a survey which is being conducted throughout the potato-growing regions of the country. On October 26, 1967, Mr. Jack E. Lipes, FAO Agricultural Officer, El Salvador, notified the Plant Quarantine Division, ARS, USDA, of the occurrences of the infestation and indicated that OIRSA (Organismo Internacional Regional De Sanidad Agropecuria) was considering placing a quarantine on Panama because of the nematode. Mr. Lipes reported that swollen females were found on the roots of potatoes, and he sent a vial of specimens to the USDA. Dr. A. Morgan Golden confirmed that the specimens were *H. rostochiensis*.

This is the first infestation of the golden nematode recorded from Central America. Offi-

cials from OIRSA report that surveys will be conducted in other Central American countries.

Peru

The golden nematode was discovered in Peru in 1952 following United States Plant Quarantine interception of the pest at ports of entry in 1951. (See "History and Origin of the Golden Nematode.")

Potato culture in Peru, represented by many native varieties, including *Solanum tuberosum* and *andigena* subspecies and improved hybrids, constitutes the main agricultural occupation along the mountain range from the border of the Republic of Ecuador to Bolivia and Chile. It is a vast zone in which approximately 200,000 hectares (500,000 acres) are cultivated, excluding the regions near the ocean in the Central Coast Departments.

The economic value of the potato crop is surpassed only by sugarcane and cotton production. These crops are planted in areas near the ocean and within a few inter-Andean valleys. In the mountain zones the potato crop is largely affected by the endemic plague represented by *Heterodera rostochiensis.*

The species *Solanum* X *curtilobum* and *Solanum* X *juzepczukii* (sour potato type) are immune to golden nematode. These are cultivated at altitudes of 4,000 meters.

Ing. Alberto Martin Ravines, of the Agrarian Experimental Station of La Molina, has been making a study of the golden nematode situation in Peru under United States funds provided by Public Law 480. Ing. Martin reports that most of the cultivated area in the Andean region between 2,300 and 4,000 meters above sea level is affected. The greatest infestation has been found at altitudes from 3,000 to 4,000 meters.

Poland

The golden nematode was first identified in Poland (1967 boundaries) in 1946, although it was known to have existed in the eastern part of prewar Germany (now Poland's western Provinces).

Poland is the second largest potato-producing country in the world. Potato fields occupy about 17 percent of the total land in cultivated crops.

The golden nematode can be found in all parts of Poland, but it is more concentrated in the northern, central, western, and southwestern Provinces. A survey carried out by Professor Henryk Sandner in 1961–62 resulted in an estimate of golden nematode incidence of 2.8 percent throughout Poland. It is also estimated that this nematode appears in about 2 percent of Poland's potato fields.

External quarantine regulations control the international movement of potatoes from infected plants, and internal quarantine regulations limit the domestic movement of potatoes from infested areas. Potatoes may be taken out of such areas only for direct use in processing, and the vehicles used for transport must be disinfected.

Resistant potato varieties have not been developed, but two East German potato varieties, Sagitta and Specula, may be suitable for Polish potato growers. There are no known resistance-breaking biotypes in the country. Experiments in the use of nematocides for the control of the nematode have been conducted by the Regional Plant Protection Stations of the Ministry of Agriculture, but the results are described as "rather erratic."

Government regulations forbid the growing of potatoes and tomatoes for 5 years on land known to be infested with the golden nematode. The Regional Plant Protection Stations of the Ministry of Agriculture conduct systematic surveys annually.

Portugal

The golden nematode attacks potatoes and sometimes tomatoes in Portugal. Although its presence in Portugal was already suspected, it was identified for the first time in 1956 in Serra de Nogueira, near Braganca (northeast Portugal) by M. Neves. A more detailed study, by Macara (*26*), was published in "Broteria" in 1963. In 1958, Entrudo Junior made a study of this pest in the region south of Lisbon.

The golden nematode is found mainly in the areas of Beira Alta, Tras-os-Montes, and Estremadura; the latter is near Lisbon and potatoes are grown intensively, sometimes in successive years on the same plot (fig. 66). Information relating to the golden nematode on tomato plants in Portugal is scanty, but it seems that there is danger of a buildup in the nematode population in certain irrigated areas where tomatoes for the canned paste industry are being intensively cultivated, with very short crop rotations or with no rotation at all.

The average annual area growing potatoes and tomatoes is about 100,000 hectares (250,000 acres), but the golden nematode constitutes a problem in only about 10 percent of this area, especially on sandy soils.

There are no specific official regulations in Portugal concerning the golden nematode; the general plant protection regulations are, of course, applicable to this pest. An educational campaign giving advice to the farmers on the

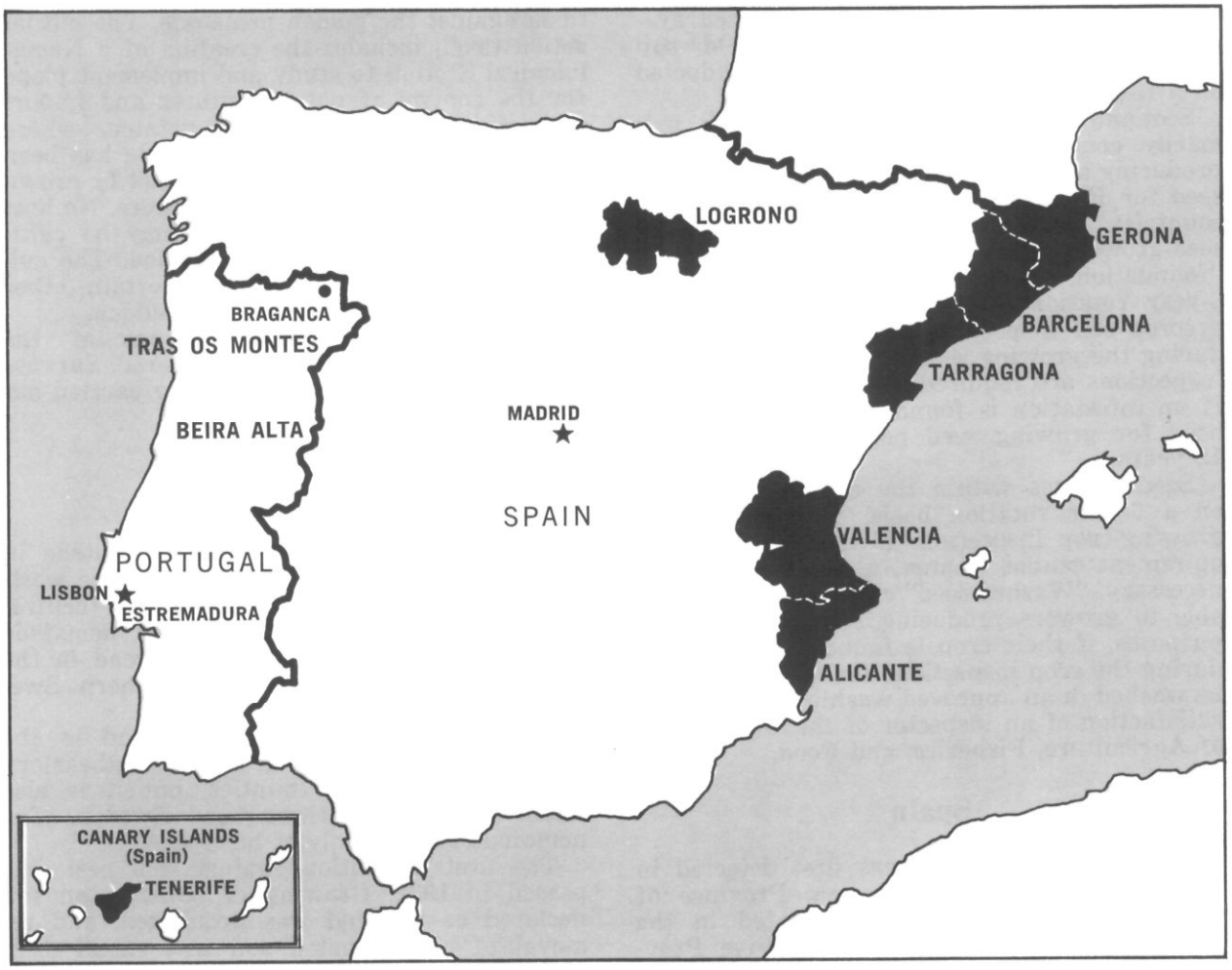

FIGURE 66.—Infested areas in Portugal and Spain.

best way to avoid damages to the crops by the golden nematode has, however, been implemented through the agricultural extension service.

The Plant Protection Service has tried some resistant varieties of potatoes, but they were not found to be satisfactory. Although the Dutch potato variety Amaryl showed some promise, its resistance was later shown to be effective against only one biotype of the several biotypes known to exist in Portugal.

Saarland

The golden nematode was first recorded in Saarland in 1952.

All fields and produce considered to be infested are supervised by the Saarland Plant Protection Service. If one field is found to be infested, the rules apply to all the land of the holding. Use of potatoes from such holdings for seed purposes is prohibited, and these potatoes must be boiled or steamed before being used for the table or for fodder. On fields considered to be infested, potatoes and tomatoes must be grown only once in 3 years. Of plots under 1,000 meters (or parts thereof if used by different owners) not more than one-third can be planted to potatoes or tomatoes, to allow for proper rotation. On land that the Plant Protection Service considers to be heavily infested, the growing of potatoes or tomatoes is prohibited for at least 3 years. If this rule is not obeyed, the crops are destroyed.

Scotland

The golden nematode has been common in Scotland since about 1913. The nematode exists in several locations in the commercial potato-

growing area, but there is no organized systematic survey in those areas. Field soil surveys in commercial districts are conducted on a request basis.

Scotland's Plant Protection Service is primarily concerned with protecting the seed-producing areas. Scotland produces most of the seed for England and several other European countries. Careful surveys are conducted in seed-growing districts. For "virus-tested," "foundation," and "stock seed" certificates, a 6-year rotation is required, together with a precrop soil inspection and a crop inspection during the growing season. Soil tests and crop inspections are required for all seed exported. If an infestation is found, the field cannot be used for growing seed potatoes for at least 12 years.

Seed for use within the country is grown on a 6-year rotation basis, together with a growing-crop inspection. If the rotational requirement cannot be met, a soil inspection is necessary. "Washed seed" certificates are available to growers producing seed for domestic purposes, if their crop is found to be infested during the crop inspection. Such potatoes must be washed in an approved washing plant to the satisfaction of an inspector of the Department of Agriculture, Fisheries, and Food.

Spain

The golden nematode was first detected in Spain in 1953 at La Maresma, Province of Barcelona. Presumably, it originated in the imports of foreign seed potatoes. Five Provinces bordering on the Mediterranean coastline, the inland Province of Logroño, and the Canary Island Province of Tenerife are affected by this pest in varying degrees. The geographical points, areas, or districts involved are the following (fig. 66):

Province	*Point, Area, or District*
Alicante	Novelda
Barcelona	La Maresma and lower Llobregat area
Gerona	S.E. tip of Province
Logroño	Santo Domingo de la Calzada
Tarragona	Cambrils
Tenerife (Canary Islands, 1960)	La Orotava
Valencia	Las Siete Villas

No estimate of the overall acreage affected is available. Barcelona is by far the most heavily infested Province. The infestation covers a strip of land in the vicinity of and running parallel to the seaboard; the strip extends along more than one-third of the seaboard of Barcelona Province.

The Spanish Government has issued regulations against the golden nematode. The official action taken includes the creation of a Nematological Section to study and implement plans for the control of potato cultures and import restrictions. The growing of potatoes where the presence of the golden nematode has been verified must be rotated; they cannot be grown more than once every 3 years or more. No host plants of the golden nematode may be cultivated during the intervening period. The cultivation of seed potatoes and certain other plantings on infested land is forbidden.

No resistance-breaking biotypes of the golden nematode have been discovered. Surveys for the golden nematode are being carried out annually.

Sweden

The first discovery of golden nematode in Sweden was made at Högsjöbruk in the western part of Södermanland county (central Sweden) in 1922. In 1928–32 the nematode was found to be relatively widespread in the northwestern part of Skåne (southern Sweden).

The nematode is frequently found in the factory-potato-growing area of southeastern Skåne and Blekinge counties, but it is also found sporadically throughout Sweden. The nematode is uniformly of biotype A.

The first legislation against this pest was passed in 1932. Growing of potatoes on soil declared as infested was prohibited, and removal of contaminated soil was required in certain instances. When it was found that the parasite had been widely spread and could not be stopped, the legislation was adjusted in 1939 and again in 1962. The law is used primarily to prevent the spread of the parasite to certain areas growing potatoes for special purposes (seed potatoes) and to stop the spread of resistance-breaking biotypes.

Resistant potato varieties, principally of Dutch origin, are available, but their use is generally restricted to factory potatoes. A new Swedish table variety has been developed at the Svalöf Plant Breeding Institute.

The Government has authority under the law to prohibit growing potatoes on land declared as infested. This authority is applied principally to land on which seed potatoes are grown. Seed-potato fields are sampled before the growing and cultivating period. Strict regulations are maintained to see that seed-potato fields are not infested through machinery, tools, bags, and so forth.

The Plant Protection Agency makes continuous surveys and also samples soil from potatoes

delivered to starch factories. On infested properties, growers are requested to apply a rotation to potatoes; they are not to grow potatoes more often than every 3 years in southern Sweden and every 4 years in northern parts of the country. Available nematode-resistant varieties of potatoes are recommended for use.

Switzerland

The golden nematode was found in Switzerland in 1958. Areas reported to be infested in Switzerland are located in the Orbe Plain and near Murten. Other locations include the mountainous cantons of Graubunden, Ticino, and Valais. Although 132 hectares (330 acres) in 8 cantons are known to be infested, the infested lands are small plots in high altitude valleys where potatoes for domestic consumption have been grown continuously. The degree of infestation is rated as EPPO code III and IV.

The golden nematode is considered a particularly dangerous pest in Switzerland. Government legislation, dated March 5, 1962, concerning plant protection, set forth regulations for the control of the pest.

Comprehensive surveys in all fields in the seed-potato-growing areas are made. All potentially affected areas are surveyed every 4 years. The surveys are organized by the Plant Protection Department and the Seed Breeding Society. Survey results are evaluated at the national level by the Swiss Seed Breeding Society.

The growing of host crops, seedlings of any kind, and nursery stock is strongly forbidden on infested land for 4, and in some places 8, years. No soil or refuse can be removed from areas under restrictions. In protective zones, host plants must not be grown more often than every 4 years. There is a special prohibition for exporting host crops and root crops that have been grown in a protective zone.

Switzerland is not breeding resistant varieties but obtains resistant potatoes from other foreign sources. Quantities available, however, are not sufficient to meet needs. Resistance-breaking biotypes have been found. Experiments are being conducted for the control of the nematode with nematocides. Through the agricultural extension service, particular emphasis is placed on advising growers to carry out sound crop-rotation practices.

Union of Soviet Socialist Republics

The potato nematode in the U.S.S.R. was first discovered in 1948 in the Lithuanian Republic. The nematode was discovered in Latvia in 1949 and Estonia in 1953 (fig. 67).

Separate and isolated centers of infection of the potato nematode have been discovered in other western regions of the Russian Federated Soviet Socialist Republic, mainly on the personal plots of collective farmers and market gardens of workers. The potato nematode has been discovered in rare instances in the fields of collective farms, state farms, and other government enterprises.

Aggressive biotypes of the potato nematode have not been found in the U.S.S.R.

A quarantine system of the areas infected with the potato nematode was implemented, and the contamination has remained insignificant. In 1965, the contaminated area consisted of 0.04 percent of the total potato area in all categories of farming, and the economic loss from the potato nematode was of no practical significance.

In the U.S.S.R. a broad investigation of potato areas is annually carried out with the purpose of discovering new centers of potato nematode contamination.

The main means of combating potato nematode are quarantine arrangements; namely, control and restriction of transportation of potatoes, fodder roots, onions, and other bulbous plants from areas under quarantine for the potato nematode; strict observance of rotations, prohibition of the raising of potatoes in contaminated sections, and utilization of such sections for the cultivation of crops not damaged by the potato nematode; chemical disinfection of soils in separate and isolated centers of contamination.

Agricultural institutions have carried out scientific research in an effort to find resistant types of potatoes.

United States

(See pp. 3 and 14.)

Yugoslavia

The presence of the pest was recorded in 1964 for the first time in Yugoslavia. The pest was found in two localities near Kranj in Slovania, where 12 fields were infested, and near Fojnica in Bosnia and Hercegovina, where 3 hectares (7½ acres) were found infested. It is supposed that the attacks in Bosnia-Hercegovina were caused by the seed potatoes used. Six laboratories have been set up for the analysis of soil samples to determine the presence of the pest in different stages. Legislation on the control of eelworms is in preparation.

FIGURE 67.—Infested areas in the U.S.S.R.

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APPENDIX I—WORLD POTATO PRODUCTION

TABLE 5.—*Acreage and production of potatoes in specified countries, average 1960–64 or latest available data*

Continent and country	Acreage	Production
North America:	*1,000 acres*	*Million cwt.*
Canada	295	46.0
Cuba	20	2.5
Mexico	121	7.7
United States	1,382	265.8
Total	1,818	332.0
Europe:		
Austria	415	76.5
Belgium-Luxembourg	182	41.2
Denmark	171	31.6
Finland	190	25.5
France	2,086	312.4
Germany, West	2,351	518.4
Greece	110	11.5
Iceland	3	.2
Ireland	209	42.9
Isle of Man	3	.3
Italy	927	86.1
Jersey	5	1.4
Malta	8	.5
Netherlands	330	86.5
Norway	129	23.8
Portugal	254	23.0
Spain	992	101.8
Sweden	249	34.1
Switzerland	115	31.1
United Kingdom	763	150.5
Total Western Europe	9,492	1,599.3
Czechoslovakia	1,278	130.5
Germany, East	1,821	274.7
Poland	7,062	942.9
Yugoslavia	751	63.6
Bulgaria, Rumania, and Hungary	1,438	113.9
Total Europe	21,842	3,124.9
U.S.S.R.	21,600	1,602.5
Asia:		
Burma	40	1.1
China: Taiwan	5	.4
Cyprus	23	2.9
India	1,013	56.3
Israel	13	2.4
Japan	527	81.3
Jordan	5	.2
Korea, North	363	14.3
Korea Republic	118	9.4
Lebanon	20	1.8
Mongolia	5	.5
Pakistan	175	10.1
Philippines	5	.4
Syria	13	1.1
Turkey	363	37.5
Total	2,688	219.7

TABLE 5.—*Acreage and production of potatoes in specified countries, average 1960–64 or latest available data*—Continued

Continent and country	Acreage	Production
	1,000 acres	*Million cwt.*
South America:		
Argentina	453	35.5
Bolivia	283	15.9
Brazil	496	25.4
Chile	212	16.7
Colombia	328	19.5
Ecuador	93	7.2
Paraguay	5	.2
Peru	575	27.2
Uruguay	63	2.2
Venezuela	36	2.5
Total	2,544	152.3
Africa:		
Algeria	75	5.4
Congo	8	.2
Ethiopia	70	3.0
Kenya	133	4.3
Libya	5	.4
Madagascar	40	1.5
Mauritius	3	.1
Morocco	63	5.0
Mozambique	5	.2
Ruanda-Urundi	43	2.2
South Africa	128	9.0
Tunisia	13	1.7
United Arab Republic	58	8.3
Total	644	41.3
Oceania:		
Australia	103	12.6
New Zealand	30	5.5
Total	133	18.1
Grand total	51,269	5,490.8

APPENDIX II—INTENSITY OF INFESTATION

The code numbers for various levels of infestation intensity, as laid down at the EPPO International Conference on Potato Root Eelworm at Wageningen, Netherlands, 1955, are as follows:

CODE No.

I No observation. (This means that no investigation has been made.)

II Free from infestation, as ascertained by—
- a. Standard sampling and laboratory analysis;
- b. Root examination;
- c. Appearance of crop. (In this case, however, the report has little value, for soil may be infested for several years before disease symptoms appear in the crop, and other factors, even other nematodes, may cause the same symptoms above ground.)

III Slight infestation, that is, 1–2 cysts per 200 cc. of soil in sampling, but no weak spots or other field symptoms.

IV Moderate infestation, that is, several (more than 2 but less than 50) cysts per 200 cc., serious loss of crop, or both.

V Heavy infestation, that is, many (more than 50) cysts per 200 cc., serious loss of crop, or both.

APPENDIX III—SOIL SAMPLING FOR POTATO ROOT EELWORM

To sample soil efficiently for potato root eelworm, you need an accurate sampling technique. It is essential to take representative samples, to process the samples so that the cysts therein can be found, to avoid mixing up the samples, and to have sufficient staff available to handle a satisfactory number of samples.

The accuracy of the method depends on a number of factors, including the number of eelworms present in the field, their distribution, the number of points sampled in the field, and the subsequent laboratory handling of the composite field sample. Rather different methods of soil sampling are used in the Netherlands and the United Kingdom, but they appear to result in similar accuracy. In both countries field sampling is carried to a stage where a marked increase in accuracy could not be achieved even by a very large increase in the intensity of sampling.

The most accurate methods are needed in connection with export and certain certification schemes. Less intensive methods are frequently suitable for purely advisory purposes.

The United Kingdom Method

The United Kingdom method consists in making a number of soil borings 6 to 8 inches (15 to 20 cm.) deep with an auger 1.5 in. (37 mm.) in diameter, or other similar tool, at random over the area being sampled. For plants for export purposes 25 such borings are taken from areas up to ½ acre ($^1/_5$ ha.), 50 from areas of from ½ to 2 acres ($^1/_5$ to $^4/_5$ ha.) and 5 extra borings for each additional acre ($^2/_5$ ha.). Additional samples are taken from places where plants to be exported are growing, from glasshouses, loam heaps, and any ground under suspicion. The borings are bulked and taken to the laboratory where the soil is air dried and thoroughly mixed. Two subsamples of 250 g. are taken and their cyst content estimated by a flotation technique.

The Dutch Method

In the Dutch method, a special tool is used for routine sampling. The tool is designed so that 50 prods with it will extract approximately 250 cc. of moist soil, which will make about 200 cc. of dried soil. The usual rate of sampling is 50 prods per hectare, but for special purposes this is increased to 50 prods per ⅓ hectare (about 0.8 acre). The whole sample is air dried and examined in the laboratory by flotation. Special attention is given to the entrances to fields and clamp sites.

Comparison of the Two Methods

The methods differ in the much larger quantity of soil taken from each field in the United Kingdom, in the depth sampled, and in the amount of handling required in the laboratory. As they appear to be comparable in accuracy, there is no technical reason for preferring one to the other, and the Dutch method is simpler.

It is therefore recommended that for survey work a sample should represent not more than one hectare; that it should consist of at least 50 borings or prods; and that at least 200 cc. of air-dried soil should be examined. Under certain circumstances, it is desirable to decrease the maximum acreage covered by the sample. For example, exporting nurseries and areas under suspicion should be sampled 3 to 10 times as intensively as other areas.

Details of equipment and technique should be left to the country concerned, provided that the results are comparable with those obtained with the techniques mentioned above.

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