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ROOT ROT OF SNAP BEANS IN NEW YORK

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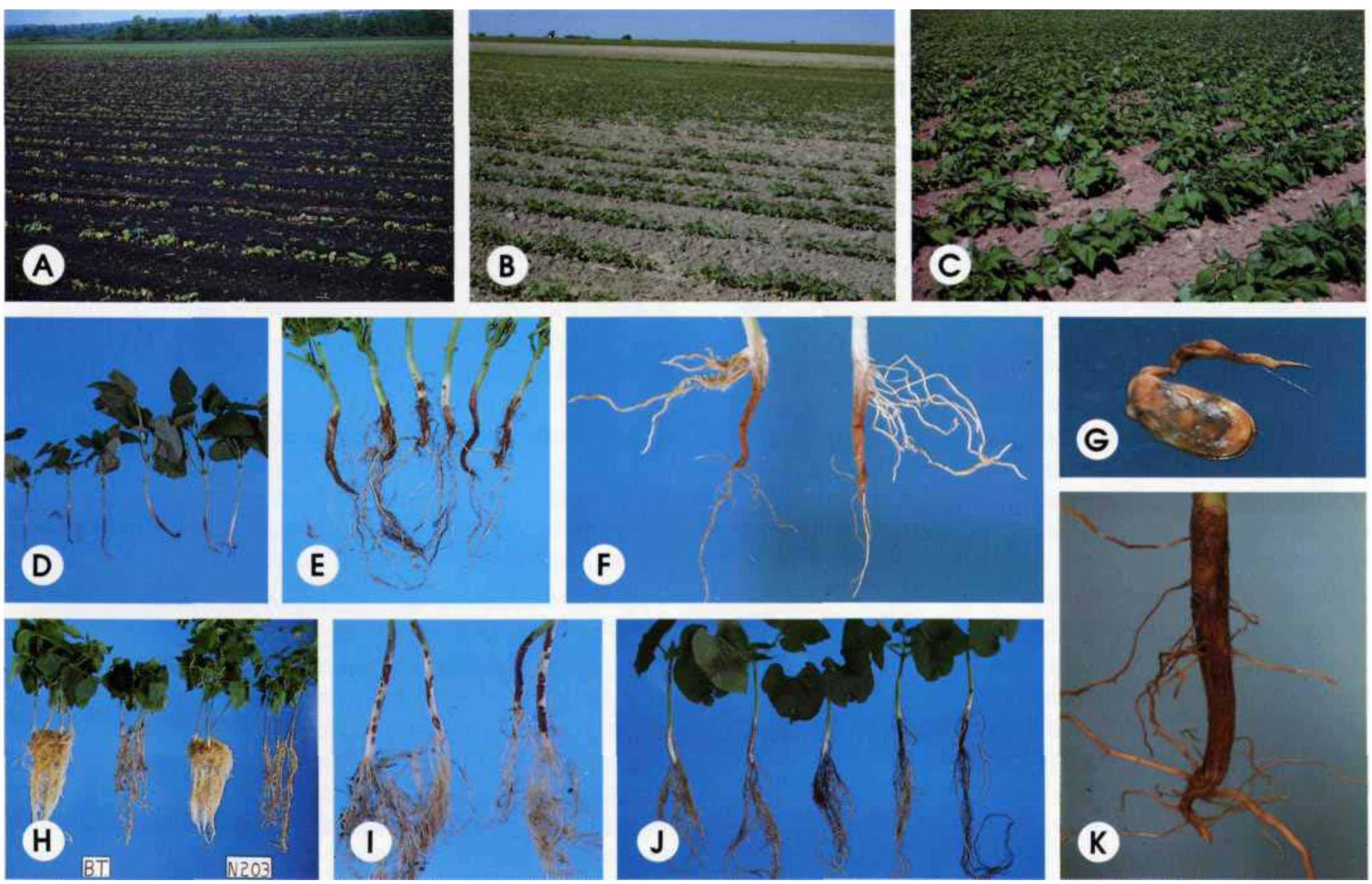

Figure 1. Symptoms of root rot and its damage to snap beans. A) Severe root rot incidence resulting in complete crop loss in a muck soil. B) Affected area showing reduced stand and uneven growth. C) Missing plants and uneven growth at a later growing stage. D,E) Seedlings and older plants with severe root rot. Note reduced size and discoloration of roots. F) Root system with dead tap root and numerous adventitious roots. G) Infected seed with young root. H-K) Characteristic symptoms of Pythium, Rhizoctonia, Thielaviopsis and Fusarium rots, respectively.

Root rot is a major disease on snap beans and occurs throughout the bean-growing areas in New York. Over the years, monoculture of beans, improper crop rotations, and increased soil compaction have intensified the prevalence and severity of bean root rot. Economic losses due to this disease have been considerable although they are variable among fields during the same growing season, and in the same field from year to year. Generally, root rot is most severe and causes the greatest damage to beans when cool and wet weather occurs from seeding time to about three weeks after planting, followed by hot dry weather.

Bean root rot in New York can be caused by species of the plant pathogenic fungi *Fusarium, Rhizoctonia, Thielaviopsis,* and *Pythium* as well as by the lesion nematodes *{Pratylenchus spp.).* These pathogens may infect beans singly and independently or in any possible combination resulting in disease complexes. However, each pathogen causes a distinct disease on beans with many possibilities for interaction with other pathogens and with nonpathogenic organisms in soil. Considerable yearly variations in root rot incidence, severity, and symptomatology are often observed within and between bean fields with a history of severe root rot. This variation is partly due to the effect of the prevailing environmental and soil conditions, and also due to the type and number of root rot pathogens present and active in initiating the disease during such conditions.

General Symptoms (Fig. 1, A-K)—Above-ground symptoms in a field with severe root rot include poor seedling establishment, uneven growth, and yellow and premature defoliation of severely infected plants. Occasionally an entire field or one planting within a field becomes severely infected, resulting in complete crop loss (Fig. 1 A). However, usually, several infested areas (bad spots) of different sizes become evident (Fig. 1B) and the yield of plants in these areas will be very poor. Outside the bad spots or in other fields, damage may show later in the season and only as missing plants and with a generally reduced stand (Fig. 1C).

The poor seedling establishment and reduced stand are the result of seed rot and damping-off diseases (Fig. 1G, Fig. 2A) caused mainly by the fungi *Pythium* and *Rhizoctonia.* This condition exists when germinating seeds and young seedlings are attacked shortly after planting and during the following two to three weeks. However, later infections of plants result in reduced vigor, discoloration, and slow rotting of the root and stem tissues. For the proper examination of bean roots, the plants should be dug up carefully and the soil removed with little disturbance to the fibrous root system—PULLING UP PLANTS OFTEN REMOVES EVIDENCE OF ROTS.

Roots of severely infected plants are reduced in size, discolored, and exhibit different degrees of decay (Fig. 1D, E). The tap root of severely infected plants often dies, although, during moist conditions such plants produce large numbers of coarse adventitious roots from the hypocotyl areas above the infected tissues (Fig. 1F). These roots generally become infected later but their production continues. If moisture continues to be available and the roots are not injured by cultivation they can sustain the plants. The shape and color of young lesions on root and stem tissues are specific and characteristic of the attacking pathogens (Fig. 1H-K). Variations are due to weather and soil conditions. The symptoms of the various root rot diseases of beans and the biology of the causal pathogens are described below.

Pythium Rots (Fig.2, A-I)—Depending on the time of attack, species of the fungus *Pythium* cause seed rot, pre- and postemergence damping-off, root rot, foliar blight, and pod rot diseases. Seeds may be invaded and killed by the fungus very shortly after planting and before germination (Fig. 2A). The fungus can attack all parts of seedlings up to about eight days old, resulting in preemergenceand postemergence damping-off. On older plants, *Pythium* causes reduction and discoloration of the root system (Fig. 2B), and complete rotting and decay of the fibrous rootlets (Fig. 2C, D). Elongated, water soaked areas also appear on the stems. The cortical tissues of both root and stem tissues of severely infected plants become very soft, brownish, and eventually collapse.

During continued wet weather conditions the fungus spreads upward infecting stem branches, petioles, leaves (Fig. 2E), and at times may reach the growing tip. The latter may result in a wilting-type symptom and plant death (Fig. 2F). Also, during cool and prolonged moist conditions, pods in contact with the soil often will become infected, exhibiting water-soaking and fluffy white fungal growth resembling a brush (Fig. 2G). This phase of the disease may be mistaken for the early stages of the white mold disease caused by *Sclerotinia sclerotiorum.*

Pythium ultimum was found to be the most important *Pythium* species causing damage to snap beans in New York. *Pythium irregulare* and *P. oligandrum* also were found associated with beans in New York, but for several reasons are considered of little importance. *P. ultimum* produces thin-walled vegetative spores called sporangia (Fig. 2H) and thick-walled sexual spores called oospore (Fig. 21). The thin-walled sporangium can survive in soil for a few months, whereas the thick-walled oospore can survive for many years. Survival of the fungus is also enhanced by its wide host range: it attacks many crop plants (beets, cabbage, peas, melons, etc.), and many weeds, and it also colonizes crop residues in soil during high moisture conditions.

Results of a recent survey of bean soils in central and western New York showed that *P. ultimum* was present

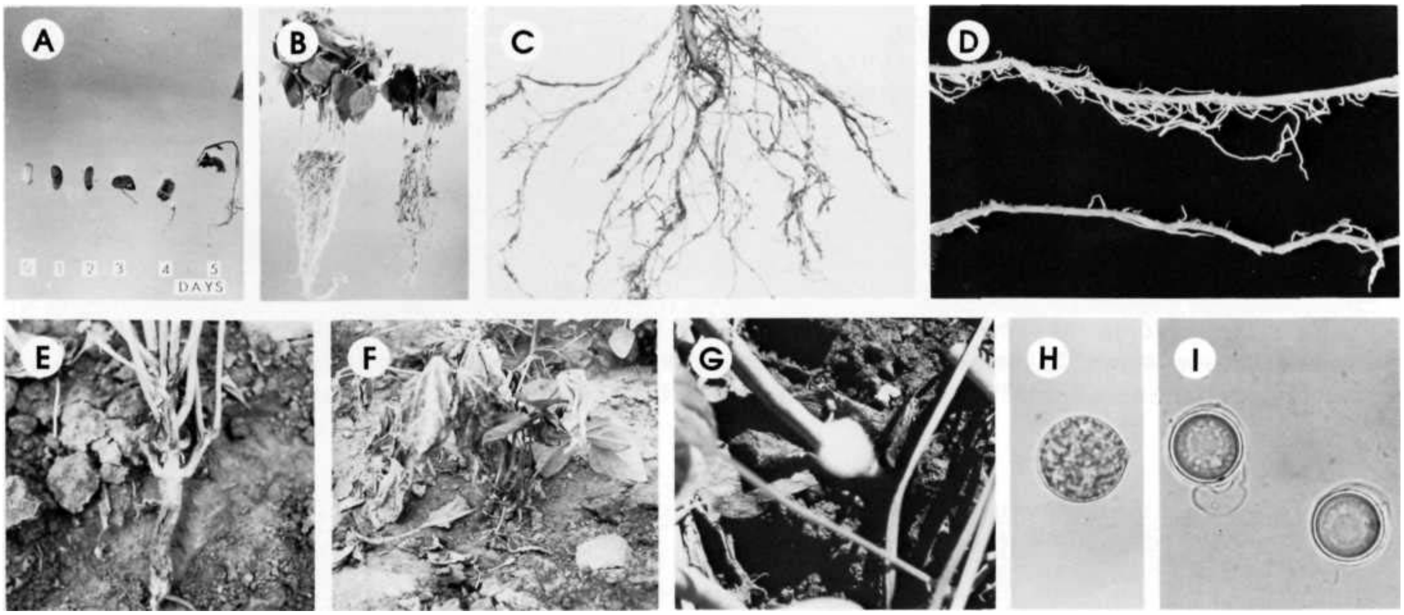

Figure 2. Pythium rot symptoms and pathogen. A) Seed decay and damping-off symptoms. B) Root rot phase symptom. C,D) Close-up of root rot damage. E) Upward movement of Pythium and damage to stem and branches. F) Wilting symptoms. G) Pod infection. H) Thin-walled spores (sporangia). I) Thick-walled spores (oospore).

in all fields and samples examined. The average soil population density of *P. ultimum* per fields varied between 344 and 1,066 growth-generating units per gram of soil. The overall average was 599. The number of P. *ultimum* units per gram of soil of individual samples ranged from 37 to 2,426 illustrating the uneven distribution of this fungus within and among bean fields.

Pythium ultimum is most damaging to snap beans during cool and prolonged wet soil conditions. Damage to snap beans was most severe at about 60 F and decreased as soil temperatures were increased. Soil moisture contents close to field capacity and wetter are most conducive to the activity and damage to beans by this fungus.

Rhizoctonia Rot (Fig. 3, A-D)—The characteristic symptoms on infected plants are the reddish-brown, sunken lesions that are generally produced on the stem and tap root (Fig. 3A). Lesions that are close together may coalesce and girdle the stem (Fig. 3B), and eventually kill the plant. Rhizoctonia can also cause seed rot and damping-off diseases on young seedlings. This results in the reduced seedling establishment and stand observed in severely affected fields. The characteristic reddish-brown lesions may also be produced on snap bean pods in contact with the soil or infected debris (Fig. 3C).

The causal organism is *Rhizoctonia solani.* It attacks many crop species, especially vegetable crops such as beets, cabbage, lettuce, peas, and many others. Many forms (isolates) of this fungus that are present in soil differ in their ability to attack and damage beans and other crops as well as in their appearance (morphology). The fungus survives in soil as cylindrical strands (hyphae) with somewhat thickened walls and usually in association with host residues.

The fungus also produces loosely compacted, seed-like structures called sclerotia (Fig. 3D). These are considered to be survival structures. The fungus is widespread in bean fields in New York with an overall average of about 5 growth generating units per 100 grams of soil. The average of the population among the fields ranges from 1 to 9 growth generating units per 100 grams, and among the individual samples examined from 0 to 45.

Damage by *R. solani* to beans is most severe during warm and relatively dry soil conditions. The potential for crop loss is greatly increased if beans are planted shortly after the harvest of a previous bean crop or another host crop known to be attacked by the fungus (peas, potatoes, cabbage, etc.). The optimum temperature for the growth of most of the isolates of this fungus is between 75 F and 85 F.

Thielaviopsis Rot (Fig.4, A-D)—The main symptom of this disease is the production of numerous dark-brown to charcoal-black elongated lesions (streaks) on the stems and roots (Fig. 4B). These streaks often coalesce to form large black areas (Fig. 4A). Early infec-

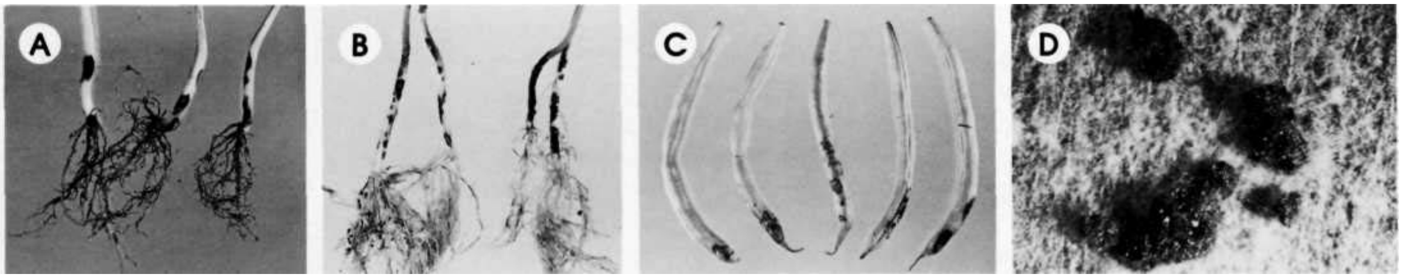

Figure 3. Rhizoctonia rot symptoms and pathogen. A) Typical reddish-brown sunken lesions. B) Coalescing lesions on stems. C) Lesions on pods. D) Fungal resting structure, sclerotia.

tions are limited to the cortical tissues (superficial) and thus cause limited damage to the plants. However, severely infected plants show stunting and premature defoliation, and eventually die.

This disease is often referred to as black root rot and is caused by the fungus *Thielaviopsis basicola.* This fungus has a wide host range that also includes celery, peas, squash, tomato, and many others. The fungus survives in soil for many years in the form of thick-walled, dark brown spores called chlamydospores (Fig. 4C). It also produces thin-walled, cylindrical, hyaline (faint light colors-not dark) spores called endoconidia (Fig.4D), butthesesurviveforonlyashorttime in soil. The fungus is widely distributed in bean fields of central and western New York. However, the soil population of this fungus is quite variable among bean fields, ranging from 39 to 516 growth generating units per gram of soil. The overall average of all fields examined is 223 with individual samples ranging from 0 to 1,213growth generating units pergram of soil. Recent research in New York indicates that this fungus is capable of causing significant yield losses to snap beans when present alone or in combination with other pathogens. In New York, this disease appears to occur most frequently and cause the most damage to snap beans during relatively warm and wet soil conditions.

Fusarium **Rot (Fig.** 5, A-G)—Initial symptoms of this disease appear as longitudinal narrow, brick-red colored lesions or streaks on the stem and tap root (Fig. 5A, B). Later, these streaks become numerous, coalesce, and the entire below-ground stem and root systems may become covered with reddish-brown superficial lesions (Fig. 5A, D). Severely infected plants exhibit stunting and premature defoliation. Lateral roots may be infected and spmetimes killed by the fungus (Fig. 5C).

This disease is most damaging to beans grown on coarse-textured soils and during drought conditions. However, when this disease occurs alone on plants growing in heavy-textured soil it does not reduce seedlings establishment or result in death of plants. The disease, however, is often found in association with other diseases of beans and thus is involved in disease complexes. In New York, this disease often occurs with Pythium rot resulting in a synergistic adverse effect on stand establishment and yield of beans.

Fusarium rot was first recognized and reported from New York in 1919, and is caused by the fungus *Fusarium solani* f. sp. *phaseoli.* The fungus is widespread among bean field soils in New York and survives for a long time in the form of thick-walled spores called chlamydospores (Fig. 5E, F, G). It also produces thin-walled, one-cell spores (microconidia) and multi-cell spores (macroconidia) which if not converted to chlamydospores are short-lived in soil. The fungus has a very narrow host range and is essentially restricted to beans. In experimental plots, when this fungus was present alone, it did not result in yield reduction, but, it did cause considerable discoloration and rotting of superficial (cortical) tissues of the stem and roots. However, it wi ll cause damage if the plants are stressed by physical factors (soil compaction, flooding, drought) chemical factors (pesticide damage, fertilizer damage, unfavorable soil pH), or biological factors such as infection of plants by other pathogens.

Pratylenchus Rot (Fig. 6, A-D)—This is the only significant nematode induced disease on snap beans in New York. Infected plants exhibit no characteristic symptoms. Severely infected plants may show general chlorosis and stunting as well as reduced root systems (Fig. 6A). Depending on the variety, small brown lesions may be visible on the fibrous roots and lower stem area.

The main diagnostic proof of damage by this nematode requires the extraction of the larvae and adult stages from roots and soil around the roots. Also, the nematode can be observed directly inside roots by using a compound microscope (Fig. 6B). The nematode is mainly restricted to the outside (cortical) tissues of the root. The nematode moves through and between the root cells causing cell breakdown and necrosis. The breakdown of cell walls results, inpart, from the mechanical action of the nematodes' spear (stylets) and the pressure of their body movements in

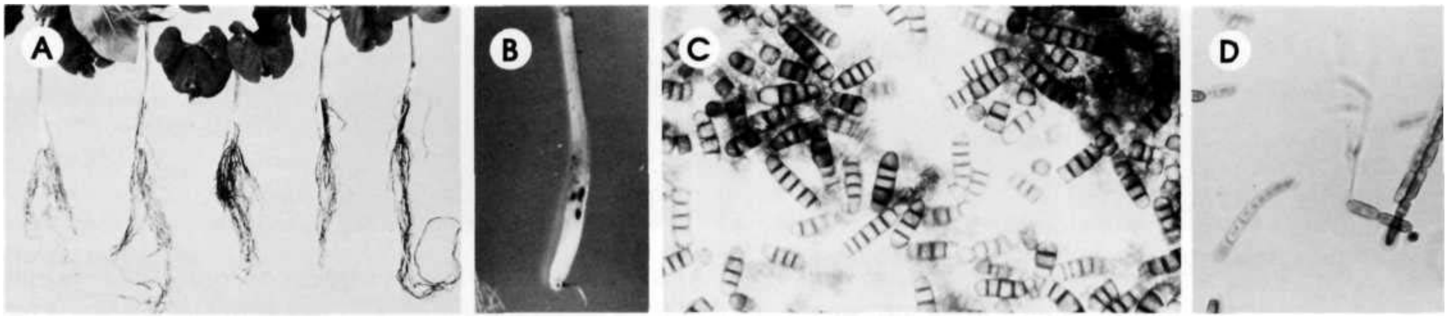

Figure 4. Thielaviopsis rot symptoms and pathogen. A) Black discoloration of stem and root tissues. B) Individual streaks as they appear early. C) Thick-walled spores, chlamydospores. D) Thin-walled spores, endoconidia produced in chains.

The disease is caused by lesion nematodes, principally *Pratylenchus penetrans* (Fig. 6C). This nematode has a very wide host range, including agronomic and weed plants. The nematode survives as eggs (Fig. 6D) or larvae and adult stages either in host plant roots or in soil. The nematode was found in soils of all bean fields examined in New York. However, the population density among fields involved in a recent study varied considerably and ranged from 3 to 168 nematodes per 100 grams of soil. The average of all fields was 59, and count of individual samples ranged from 0 to 420 nematodes per 100 grams of soil. In an earlier study the greatest density of this nematode was 1,680 per 100 grams of soil and 470,600 nematodes per 100 grams of roots. In field tests, nematicide applications on heavily infested soils have resulted in significant increases in bean yields and fewer nematodes in the roots. In field microplot tests, when this nematode was present alone it did not adversely affect vigorously growing snap bean plants. This corresponds with other reports that indicate the lesion nematode predisposes plants to damage by physical soil stresses and other soil pathogens.

CONTROL OF BEAN ROOT ROTS

Effective and practical commercial management of bean root rot in New York using a single control measure has been and probably will continue to be difficult. Seed or soil treatments with selective pesticides, crop rotations, cover crops, seedbed preparations, and other measures have at times improved yield or reduced root rot severity. However, none of these measures have been consistently economical or effective. Progress has been made in identifying sources for tolerance to individual pathogens but commercial snap bean cultivars with a high level of tolerance to all pathogens are not yet available. In fact, it is probably impossible in the near future to develop commercial varieties that have a high level of tolerance to all of the bean root rot pathogens.

The difficulties in controlling bean root rot in New York are not surprising considering that any combination of five distinct pathogens can be involved in the root rot complex. There is a need to combine the most effective and practical measures available to combat the entire root rot complex. Such a program is now being developed at the Experiment Station in Geneva.

The following is a brief summary of the information that is available on bean root rot control. GROWERS SHOULD CONSIDER USING AS MANY PRACTICAL

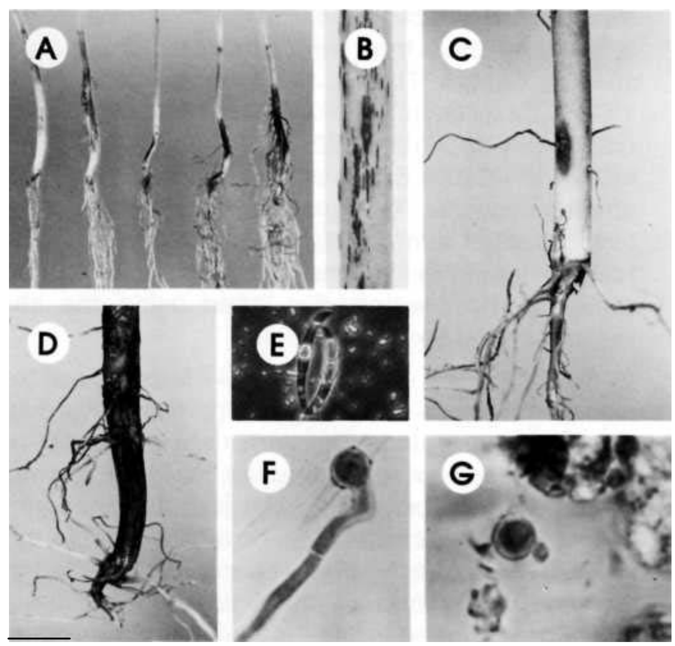

Figure 5. Fusarium rot symptoms and pathogen. A) Symptoms of infection showing different degrees of discoloration. B) Individual streaks on stems. C) Infection proceeding from a branch root to stem. D) Complete discoloration of the superficial (cortical) stem area. E) Two multi-celled spores (macroconidia) (one with a chlamydospore) and small one-celled spores (microconidia). F) Germinating thick-walled spore (chlamydospore). G) Chlamydospore in soil.

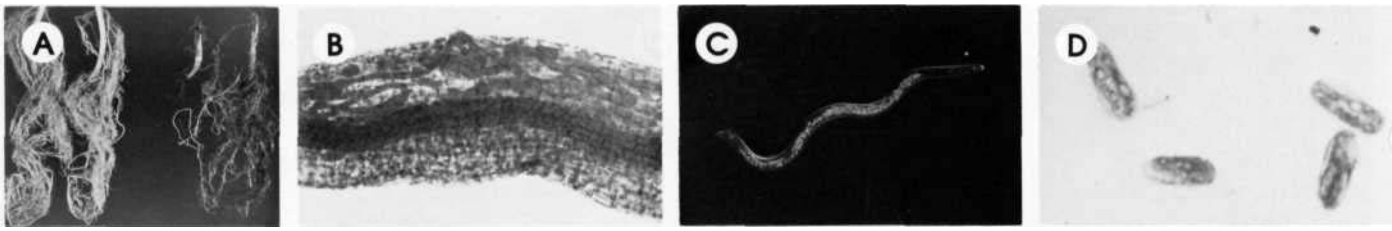

Figure6. Pratylenchus rot symptoms and pathogen. A) General discoloration and reduced roots. B) Large number of nematodes inside a small root segment. C) Mature lesion nematode. D) Eggs with second-stage larvae.

MEASURES AS POSSIBLE ON FIELDS WITH AND WITHOUT A PREVIOUS HISTORY OF SEVERE INCIDENCE OF BEAN ROOT ROT. IT IS MUCH EASIER TO PREVENTTHE DEVELOPMENT OF SEVERE ROOT ROT INCIDENCE IN A RELATIVELY CLEAN FIELD THAN TO REDUCE ROOT ROT IN A HEAVILY INFESTED FIELD.

Chemical Control Measures

1. Use fungicide-treated seeds—Application of fungicides as slurry treatments are most effective in controlling seed decay and damping-off diseases of beans. In New York, a combination of fungicides is needed and is more effective than the use of only one fungicide such as Captan, Thiram, Lesan, Apron, or Demosan. THE COMBINATION OF CAPTAN + APRON + DEMOSAN AS A SLURRY SEED TREATMENT WAS FOUND MOST EFFECTIVE. Apron and Demosan are highly effective against *Pythium* and *Rhizoctonia,* respectively. Captan is moderately effective against all bean root rot fungal pathogens. Growers should consider reducing the seeding rate when using the above recommended seed treatment.

2. Soil treatment with pesticides—Preplant soil treatments with broad-spectrum, fumigants such as methyl bromide, chloropicrin and Vorlex are very effective in controlling all root rot pathogens. However, the use of these pesticides on beans is not practical or economically feasible. Demosan or Terraclor applied as an in-furrow spray using dual-row nozzles directed onto the seeds and backward on the covering soil is registered for use on beans and is effective where Rhizoctonia rot is a problem. There are a number of promising new fungicides and nematicides that might be adapted for use on beans in future.

Cultural Practices As Control Measures

1. Crop rotation—Continuous cropping of a field to beans or other crops susceptible to the root pathogens (beets, cabbage, melons, peas, potatoes, etc.) will result in high populations of root rot organisms, and increased disease severity. Rotation with a grain crop (barley, corn, oats, or wheat) will reduce the pathogen population. Crop rotations should be practiced in relatively clean fields as well as in fields with severe root rot, but, there should be a minimum of two years and longer if possible. More detailed information on cropping sequences in relation to bean root rot will be available soon.

2. Cover crops and other soil amendments—Plowing under cover crops or adding crop residues will generally reduce root rot severity if enough time is allowed for decomposition before planting. The effect may be due to the increased activities of beneficial soil microorganisms and/or the influence on soil structure. Specific recommendations on cover crop use in relation to root rot severity are being formulated and will be made available soon.

3. Plowing and seedbed preparation—Reducing soil compaction and improving soil tilth will reduce root rot damage. Root rot organisms are most abundant in the top six inches of the soil. Subsoiling or breaking the soil with chisels to a depth below the plowed layer will promote deeper and greater root formation, and thus more tolerance to root rot. Deep plowing and turning under of infected crop residues will reduce rot organisms, especially *Rhizoctonia.* Growing beans on raised ridges or beds will be beneficial during wet and cool weather patterns as it will increase aeration and soil temperature as well as decrease soil moisture. Pythium rot severity is especially reduced on raised ridges.

4. Adjusting planting time and depth of planting— Whenever possible, fields with a history of severe root rot should be planted late and seeded shallow.

5. Planting density—Root rot increases with increasing plant densities within the row in affected fields. The seeding rate should be reduced when the recommended seed treatment is used. Close row spacing and high plant canopy will increase root rots (especially *Pythium* and *Thielaviopsis* rots) as they maintain high soil moisture by reducing air drainage especially later in the growing season.

6. Cultivation—Bean plantings with severe root rot should not be cultivated or should receive only a shallow cultivation not too close to the rows. Severely infected plants produce a large number of adventitious roots above the infected stem areas and close to the soil surface. If enough moisture is maintained throughout the season, these roots can maintain the plants and produce a crop although it may be reduced. Normal cultivation will break most of these roots and further stress the plants.

7. Effects of fertilizers and herbicides in use—Fertil izers and herbicides have been reported to cause both increases and decreases in root rot severity. Evalua tions of Eptam, Treflan, and Dinitro at recommended rates as well as soil incorporated Dinitro at 6 pounds active per acre in commercial New York fields with root rot had no measurable effect on rot severity or bean yield. Similarly, none of the fertilizers used by bean growers in New York had a significant effect on rot severity. However, well fertilized and vigorously grow ing plants are known to be more tolerant to activities and damage inflicted by rot organisms, especially *Fusarium* and *Pratylenchus.*

8. If possible, avoid planting beans in fields heavily infested with root rot organisms—A soil indexing procedurethat effectively differentiates relatively clean fields from those with severe rot problem is available and its use should be considered. Results of this test can aid growers, whenever practical and feasible, in avoiding a problem field and thus possibly avert a loss. The test involves growing beans in representative soil samples from the fields in question. The test plants should be maintained for five weeks in conditions favorable for root rot development (wet and cool during at least the first two weeks). Extension county agents should be consulted for further information on soil sampling procedures and conducting the test yourself or by others.

CONTROL BY PLANT RESISTANCE

Sources of resistance to individual root rot pathogens have been identified and progress is being made to incorporate them into commercial cultivars. However, none of the commercial snap bean cultivars available have shown any significant advantage with regard to resistance to the bean root rot complex in New York. It is hoped that resistance to one or more pathogens will be utilized in adapted and productive cultivars for the conditions in New York. The lack of resistance to the other components of the root rot complex will be managed by chemical or cultural means.