Session I

EPIDEMIOLOGY, SPREAD AND CONTROL OF *PHYTOPHTHORA MEGASPERMA* VAR. *SOJAE* AND *CEPHALOSPORIUM GREGATUM* IN SOYBEAN

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Phytophthora root and stem rot, caused by *P. megasperma* var. *sojae*, a soil-borne fungus first reported in Ohio in 1951, causes a lesion on the outside of the root and lower stem, progresses upward inducing internal browning, followed by wilting, which may lead to eventual death of the host. *Lupinus* spp. are susceptible. Susceptible soybeans are vulnerable at any age. There are at least two races of the pathogen. Resistant varieties serve as control with resistance related to quantity rather than quality of phytoalexin produced. Greenhouse and field studies showed that *P. megasperma* var. *sojae* influences plant growth by lateral root pruning. In a specially designed system, it was shown for the first time that soybean roots produce phytoalexin. Brown stem rot, caused by *C. gregatum*, has been detected in increasing numbers of U.S. soybean fields since 1944. The soil-borne fungus invades the vascular system, then the pith, and eventually causes a brown discoloration throughout the stem. Mung bean (*Phaseolus aureus*) and red clover (*Trifolium pratense*) are susceptible. Disease development is favoured by an air temperature of 15 °C, and is inhibited at 21 °C or above. Optimum temperature for *in vitro* growth is 22–24 °C, and for spore production 15–20 °C. There are no commercial resistant varieties and a 5-year corn-soybean crop rotation proves to be an effective control measure.

We proposed a three-class system for field surveys to determine prevalence of brown stem rot. Greenhouse experiments suggest that certain systemic fungicides show promise for control.

PHYTOPHTHORA ROOT AND STEM ROT

Phytophthora root and stem rot of soybean (*Glycine max* (L.) Merr.), caused by *Phytophthora megasperma* Drechs, var. *sojae* A. A. Hildeb (*Pms*) was first reported in Ohio, in 1951 (Allington and Chamberlain 1948), and has spread throughout most of the soybean growing areas of the United States (Bernard *et al.* 1957; Herr 1957; Hildebrand 1959; Kaufmann and Gerdemann 1958; Suhovecky 1955). This soil-borne fungus causes a lesion on the outside of the root and lower stem, progresses upward, induces internal and external stem browning, followed by wilting and eventual death of the plant (Hildebrand 1959; Kaufmann and Gerdemann 1958; Morgan 1963). *Lupinus* spp., alfalfa, and sweetclover seedlings are susceptible (Johnson and Keeling 1969;

Kaufmann and Gerdemann 1958; Scotland 1955). Susceptible soybeans are vulnerable at any age (Kaufmann and Gerdemann 1958; Morgan 1963; Morgan and Hartwig 1965; Schmitthenner 1958; Scotland 1955; Suhovecky and Schmitthenner 1955). There are at least two races of the fungus (Morgan and Hartwig 1965). Resistant varieties serve as control with resistance related to quantity rather than quality of phytoalexin production (Klarman and Gerdemann 1963). Meyer *et al.* (1971) showed that soybean roots, as well as stems, are capable of producing phytoalexin.

Hildebrand (1959) observed that susceptible plants may be stunted and unthrifty without formation of cankers and stem discoloration. Schmitthenner (1958) referred to this as 'hidden damage' and suggested that yields might be reduced. Our field observations (unpublished) noted height differences between *Pms*-resistant and -susceptible plants with resistant lines being consistently taller than susceptible. Susceptible plants otherwise appeared healthy and differed from the resistant only by one gene.

Meyer and Sinclair (unpublished) found that *Pms* may cause damage to the root system of either susceptible or resistant soybeans in the absence of stem canker or browning symptoms. Root pruning by *Pms* on susceptible varieties reduced plant height and yield significantly below that of *Pms*-resistant varieties. There was a tendency for a lesser effect on root and plant dry weights with an increase in depth (1, 4 or 9 cm) of inoculum placement in the soil. More stem lesions developed when inoculum was placed just below the soil line (1 cm) than when placed at 9 cm. Young (10-day-old) plants were more severely affected than 20-day-old plants.

Brown Stem Rot

Brown stem rot, caused by *Cephalosporium gregatum* Allington and Chamberlain (1948), was reported from several areas where soybeans (*Glycine max* (L.) Merr.) are grown in North America (Allington 1946; Allington and Chamberlain 1948; Dunleavy 1966; Gray *et al.* 1970; Hildebrand 1948; Murgand and Dunleavy 1966; Ross and Smith 1963). Potential yield losses are not known. Gray *et al.* (1970) proposed a three-point rating system for determining soybean yield reduction by *C. gregatum* and showed that only plants with stem browning extending to 6 in. or above in the stem showed a significant reduction in yield.

The soil-borne fungus invades the vascular system through the roots, then enters the pith, and eventually causes a brown discoloration throughout the stem (Allington 1946; Allington and Chamberlain 1948; Chamberlain 1956 1961). Mung bean (*Phaseolus aureus*), red clover (*Trifolium pratense*) and lucerne (*Medicago* spp.) are susceptible (Dunleavy 1967). Schneider (1971) found that *C. gregatum* entered the roots of soybean and moved to the top nodes of plants in the early pod-filling stage within 2 days after adding a

water suspension of the fungus to the plant growth medium. The fungus was isolated from the tops of similar plants within 1 day after dipping the cut hypocotyls into a spore suspension of the fungus.

There is a lack of agreement on the influence of air temperature on brown stem rot development. Chamberlain and co-workers (1948, 1954) reported that internal browning occurred within 3 weeks at 15 °C in inoculated plants, while plants grown at 21 and 27 °C showed little or no symptom development. These results are somewhat correlated with the behaviour of the organism in culture (Allington and Chamberlain 1948; Chamberlain and Allington 1948). Phillips (1970), however, observed the most extensive symptom development at 27 °C and was not completely inhibited at 32 °C. Schneider (1971) concluded that there was a direct relation between exposure time of infected plants to cool temperatures and the extent of internal browning. Plants grown for 12 weeks at 25–42 °C showed on 35 per cent browning of the stem, while plants exposed to 18–24 °C for 10 or 12 weeks showed 65 and 54 per cent, respectively.

The effects of physiological plant age on disease development also have been disputed. Chamberlain and McAlister (1954) stated that internal browning progressed more rapidly in plants beyond the pod-filling stage than in younger plants irrespective of temperature. Dunleavy (1969), however, found that the percentage of plants infected in each of eight varieties of different maturity groups was not related to time of bloom or plant maturity. Schneider (1971) showed that there was an inverse relation between the percentage of the stem showing internal browning and age of plant at the time of inoculation. Development of internal stem browning in plants grown in the greenhouse was 65 per cent in plants inoculated at 6 weeks, 61 per cent at 8 weeks, and 35 per cent at 10 weeks. Controls showed no browning. It was not ascertained whether incubation period was an additional factor involved.

There is a high positive correlation between disease incidence and acreages devoted to soybean production, but very little between percentage of fields showing diseased soybeans and precipitation during the growing season (Chamberlain and McAlister 1954). A 5-year corn-soybean rotation proved to be an effective control measure (Dunleavy and Weber 1967). There are no commercial resistant varieties. Gray and Sinclair (1971) showed TBZ (thiabendazole) used as a soil drench in clay pots (25 ml of 200 mg/l in 750 g of soil), reduced the development of internal browning in soybeans which were wound-inoculated with *C. gregatum* when plants were 8 weeks old. They could not reisolate the fungus from treated plants. Thapliyal (1970) showed that benomyl (duPont's Benlate 65 WP), when used as a seed dressing or as a soil drench, significantly reduced internal browning caused by *C. gregatum*.

References

Allington, W. B. (1946). Brown stem rot of soybeans caused by an unidentified fungus. *Phytopathology*, **36**, 394.

Allington, W. B., and Chamberlain, D. W. (1948). Brown stem rot of soybean. *Phytopathology*, **38**, 793–802.

Bernard, R. L., Smith, P. E., Kaufmann, M. J., and Schmittenner, A. F. (1957). Inheritance of resistance to Phytophthora root and stem rot in the soybean. *Agron. J.*, **49**, 391.

Chamberlain, D. W. (1956). Effect of a by-product of *Cephalosporium gregatum* on water flow in soybean stems. *Phytopathology*, **46**, 6 (abstr.).

———— (1961). Reduction in water flow in soybean stems by a metabolite of *Cephalosporium gregatum*. *Phytopathology*, **51**, 863–865.

Chamberlain, D. W., and Allington, W. B. (1948). Effect of temperature on brown stem rot of soybeans. *Phytopathology*, **38**, 4 (abstr.).

Chamberlain, D. W., and McAlister, D. F. (1954). Factors affecting the development of brown stem rot of soybean. *Phytopathology*, **44**, 4–6.

Dunleavy, J. M. (1966). Factors influencing the spread of brown stem rot in soybeans. *Phytopathology* **56**, 298–300.

———— (1967). Red clover infected by *Cephalosporium gregatum*. *Phytopathology*, **57**, 810 (abstr.).

———— (1969). Time of brown stem rot symptom expression and percentage infection of plants of eight soybean varieties infected with *Cephalosporium gregatum*. *Phytopathology*, **59**, 1024 (abstr.).

Dunleavy, J. M., and Weber, C. R. (1967). Control of brown stem rot of soybean with corn-soybean rotations. *Phytopathology*, **57**, 114–117.

Gray, L. E., Thapliyal, P. N., and Sinclair, J. B. (1970). A rating system for determining soybean yield reduction by *Cephalosporium gregatum*. *Phytopathology*, **60**, 1024.

Gray, L. E., and Sinclair, J. B. (1971). Systemicity of ^{14}C-labeled 2-(4′-Thiazolyl) benzimidazole (TBZ) in soybean. *Phytopathology*, **61** (*in press*).

Herr, L. J. (1957). Factors affecting root rot of soybean incited by *Phytophthora cactorum*. *Phytopathology*, **47**, 15–16 (abstr.).

Hildebrand, A. A. (1948). An occurrence of brown stem rot of soybeans in Ontario. *Scient. Agr.*, **28**, 261–263.

———— (1959). A root and stalk rot of soybeans caused by *Phytophthora megasperma* Ruchsler var. *sojae* var. nov. *Can. J. Bot.*, **37**, 927–956.

Johnson, H. W., and Keeling, B. L. (1969). Pathogenicity of *Phytophthora megasperma* isolated from subterranean clover roots. *Phytopathology*, **59**, 1279–1283.

Jones, J. P., and Johnson, H. W. (1969). Dupine, a new host for *Phytophthora megasperma* var. *sojae*. *Phytopathology*, **59**, 504–507.

Kaufmann, M. J., and Gerdemann, J. W. (1958). Root and stem rot of soybean caused by *Phytophthora sojae* n. sp. *Phytopathology*, **48**, 201–208.

Klarman, W. L., and Gerdemann, J. W. (1963). Resistance of soybeans to three *Phytophthora* species due to production of a phytoalexin. *Phytopathology*, **53**, 1317–1320.

Meyer, W. A., Thapliyal, P. N., Frank, J. D., and Sinclair, J. B. (1971). Detection of phytoalexin in soybean roots. *Phytopathology*, **61** (*in press*).

Morgan, F. L. (1963). Soybean leaf and stem infections by *Phytophthora megasperma* var. *sojae*. *Pl. Dis. Reptr.*, **47**, 880–882.

Morgan, F. L., and Hartwig, E. E. (1965). Physiologic specialization in *Phytophthora megasperma* var. *sojae*. *Phytopathology*, **55**, 1277–1279.

Morgan, F., and Dunleavy, J. M. (1966). Brown stem rot of soybeans in Mexico. *Pl. Dis. Reptr.*, **50**, 598–599.

Phillips, D. V. (1970). Effect of temperature on brown stem rot of soybean. *Phytopathology*, **60**, 1307–1308 (abstr.).

Ross, J. P., and Smith, T. J. (1963). Brown stem rot of soybean in North Carolina and Virginia. *Pl. Dis. Reptr.*, **47**, 329.

Schmitthenner, A. I. (1958). Root rot is still threatening the state's soybean crop. *Ohio Fm Home Res.*, **43**, 58–59, 62.

Schneider, R. W. (1971). Etiology of *Cephalosporium gregatum* in soybean. M.Sc. thesis, University of Illinois, Urbana, 25 p.

Skotland, C. B. (1955). A *Phytophthora* damping-off disease of soybean. *Pl. Dis. Reptr.*, **39**, 682–683.

Suhovecky, A. J. (1955). Phytophthora root rot of soybeans. Ph.D. thesis, Ohio State University, Columbus, 83 p.

Suhovecky, A. J., and Schmithenner, A. F. (1955). Soybeans affected by early root rot. *Ohio Fm Home Res.*, **40**, 85–86.

Thapliyal, P. N. (1970). Systemicity and fungicidal activity of three systemic fungicides in soybean. Ph.D. thesis, University of Illinois, Urbana, 51 p.