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Phytophthora Blight of Pepper and Its Control in Korea

Pepper (*Capsicum annuum* L.) is one of the most important crops in Korea based on consumption, nutritional value, and cash value to farmers. Pepper powder from the pepper fruits is used as a spice that is indispensable in the preparation of a favorite Korean dish, Kimchi. During the last decade, land planted with pepper in Korea expanded to 62,800 ha, which corresponded to almost 23% of the total cultivated area for vegetable crops (Fig. 1A and B) (35). The yield of dried pepper fruits (Fig. 1C) was 132,700 t in 1990. Consumption of pepper fruit per capita is approximately 2 kg annually.

Pepper plants have the longest growing season of all annual crops in Korea. Pepper seed is usually sown in February in seedling beds covered with polyethylene. Seedlings are transplanted to fields in May. Pepper fruits are harvested from August to October, until the first frost. Because of the lack of alternative crops that provide the same economic return to farmers, the repeated cultivation of pepper on fertile land has become unavoidable. In addition, production has been extended to marginal infertile, mountainous, sloping land unsuitable for planting other crops. The continuous monocropping of pepper plants results in various problems, including deterioration of soil physico-chemical properties, the accumulation of toxic compounds, and the increase of plant pathogens in the soil, which sometimes requires the replanting of pepper.

Phytophthora blight of pepper, which is incited by *Phytophthora capsici* Leonian, is one of the most devastating soilborne diseases of pepper in Korea (24). Phytophthora blight depends on soil as a source of initial inoculum. The repeated cultivation of pepper results in a buildup of inoculum in the soil. Disease is favored by prolonged periods of heavy rainfall accompanied by high winds from June to August in Korea. Stems of pepper plants are readily damaged by splitting, breaking, and lodging, thus accelerating development of Phytophthora blight.

The lack of effective measures to reduce soilborne inoculum of *P. capsici* helps explain why epidemics of Phytophthora blight occur frequently in pepper-growing areas of Korea. Annual disease incidence from 1985 to 1988 ranged from 8 to 25%, based on field surveys in 40 major pepper-growing areas. In the severe epidemic of 1986, one-third of the areas surveyed had disease incidence exceeding 60% (41). The severity of disease on peppers in the 1986 epidemic was due to the continuous planting of peppers in fields with a high inoculum of *P. capsici*. Consequently, the effective management of Phytophthora blight is considered of the utmost importance in sustaining acceptable production levels of pepper.

Intensive research on Phytophthora blight of pepper began in Korea during the 1980s. Studies concentrated on the biology of the pathogen, disease epidemiology, germ plasm evaluation for disease resistance, yield-loss assessment, and the testing of chemical, biological, and cultural measures of control. In this article, we present some general information about Phytophthora blight of pepper and its control status in Korea.

The Pathogen

The biology of *P. capsici* is typical of all oomycetes. The oomycetes appear to have closer affinities with algae and higher plants than with ascomycetes and basidiomycetes (6,30). *P. capsici* is heterothallic, diploid, and coenocytic, lacks chitin in the cell walls, and produces biflagellate zoospores in pedicellate sporangia (Fig. 2A), which can be dispersed with wind-driven rain (5). The fungus has two mating types, A1 and A2. Sexual structures (antheridia and oogonia) are induced only in the presence of the opposite mating type (Fig. 2B). The oospores are readily produced in diseased tissues and serve as survival structures, overwintering in infected roots or in the soil. Germination of oospores occurs when the soil is wet and temperatures are favorable, producing mycelium and sporangia. Infections of stems or roots of peppers are initiated by asexual sporangia and/or zoospores. Individuals in asexual populations most commonly survive as mycelium in infected tissues. The pathogen infects the economically important crops of pepper, tomato (*Lycopersicon esculentum* Mill.), eggplant (*Solanum melongena* L.), cucumber (*Cucumis sativus* L.), honeydew melon (*Cucumis melo* L.), pumpkin (*Cucurbita moschata* (Duchesne) Duchesne ex Poir.), watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai), and cacao (*Theobroma cacao* L.) (18,26).

Pepper plants can be infected by *P. capsici* in all stages of growth when environmental conditions are favorable. The infection hyphae of *P. capsici* grow intercellularly in infected tissues of roots and stems. The vascular tissues are not markedly disorganized even when heavily infected. Intercellularly growing hyphae penetrate host cells by forming haustorial-like bodies (14). Fungal hyphae colonize the cortical parenchyma cells and the vascular bundle in both roots and stems, and the pith parenchyma cells in stems (27). At the penetration sites of *P. capsici* in pepper stems, cell wall apposition and cytoplasmic aggregation occur distinctly below those host cell walls intimately in contact with the fungal cells (13).

Symptoms and Epidemiology

Infection of pepper plants by *P. capsici* is characterized by a sudden wilt of entire plants (Fig. 2C), which is caused by rotting of the stems near the soil surface.

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P. capsici infection occurs in the aerial parts of pepper plants when zoospores splash from the soil surface during rainfall. Leaves, petioles, fruits, stems, and branches become locally rotted, starting with small, water-soaked lesions. Leaf lesions expand rapidly to form round or irregularly shaped, dark green, water-soaked areas that later dry and turn light tan. Eventually, infected leaves abscise from the plants. The light brownish lesions at the stem base also extend rapidly into the upper part of the stem and branches (Fig. 2D) or the roots (Fig. 2E). The lower taproots and root hairs become brown and rotten. Whitish gray molds with abundant zoosporangia often develop on the surface of infected stems under suitable moisture conditions (Fig. 2F). On the pepper fruits, small, water-soaked, spherical lesions enlarge to cause severe rotting of the fruits, which later become mummified (Fig. 2F). Whitish gray molds are produced on the infected fruits under humid conditions. Blight symptoms also develop on harvested fruits after they reach market.

Epidemics of Phytophthora blight occur frequently in pepper-growing fields in Korea because of several components of the biotic and abiotic environment that favor disease, such as the monocropping of pepper plants in poorly drained clay-loam soils during long rainy seasons with low temperatures. In Korea, pepper plants are cultivated on plastic-mulched ridges (Fig. 1A). Because pepper plants are shallow-rooted, seedlings are usually transplanted deep on the ridges so as not to lodge later. Alternatively, basal stems are mounded with additional soils, thus providing optimal conditions for crown infection by inocula of *P. capsici* in the soil. Phytophthora blight begins to appear on pepper plants in early June, 10–20 days after the transplanting of seedlings into the field. In Korea, the disease spreads very rapidly, especially during prolonged periods of rainy weather from June to August. Initial infections are caused by the germination of oospores overwintering in the soil or crop residues, followed by subsequent spread through zoospores dispersed into the soil water around infected plants. The pathogen causes foliar and stem blight and crown rot. Phytophthora blight incidence in the pepper-growing areas varies annually, with a range of 15–30%, depending mainly on how long the rainy weather lasts (23).

Changes in soil water potential have significant impact on the development of Phytophthora blight and on pathogen population densities in soil (3,8). A survey conducted in 1986 of three major

Environmental factors in Korea that predispose peppers to Phytophthora blight epidemics

1. Long monocropping
2. Poorly drained clay-loam soils
3. No organic fertilization
4. Cultivation of pepper in acidic soils
5. Cultivation during long rainy seasons and low temperature
6. Low efficacy of fungicide application
7. Lack of highly resistant pepper cultivars

Fig. 1. (A) Pepper plants cultivated in soils mulched with polyethylene. (B) Ripened red fruits on pepper plants in the field. (C) Drying of red pepper fruits in sunshine.

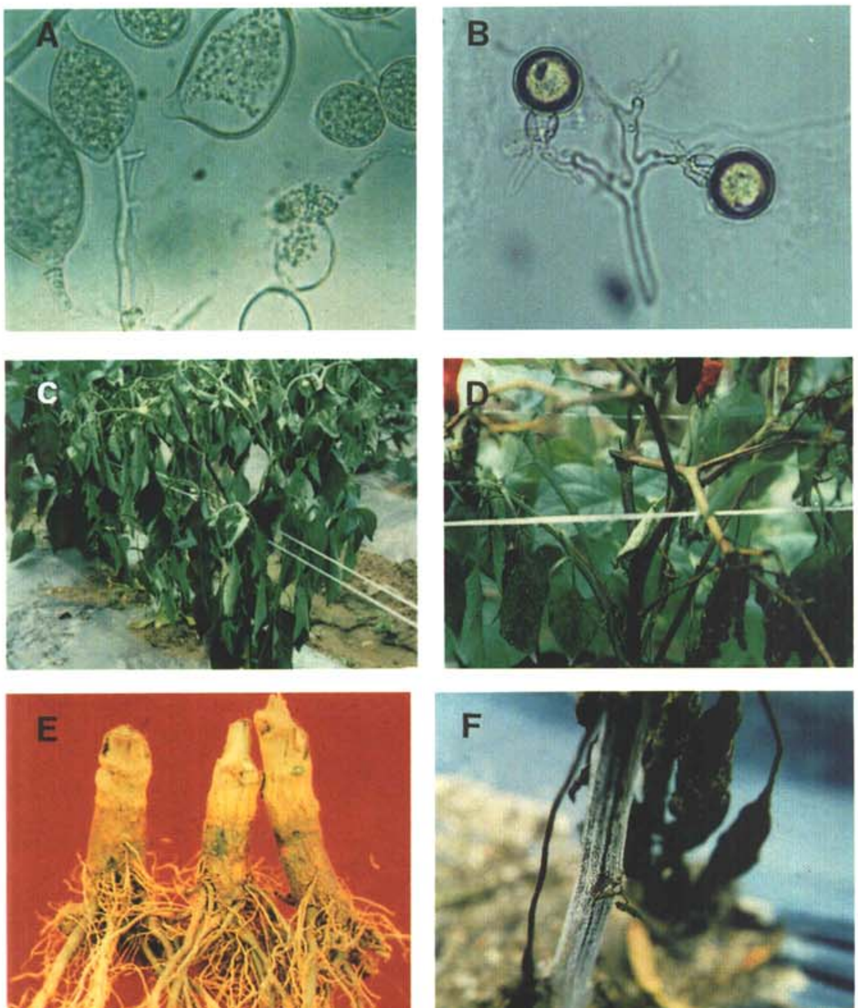

Fig. 2. (A) Zoosporangia of *Phytophthora capsici* and zoospores released from sporangia. (B) Oospores with antheridia. (C) A sudden wilt of entire pepper plants infected by *P. capsici*. (D) Brownish lesions of pepper stems and branches. (E) Light brownish lesions on the subterranean roots of pepper plants. (F) Whitish gray molds with abundant zoosporangia of *P. capsici* on the surface of heavily infected stems.

pepper-growing areas revealed that peppers with severe disease came from fields composed mostly of clay-loam soil (Fig. 3) (41). In contrast, plants from fields with loam-sand soils had only mild damage, suggesting that the pathogen spreads less actively in the loam-sand soils with good drainage. Similarly, a strong relationship between soil water content and disease incidence was found in a greenhouse study. A low level of soil water (less than 80% of maximum water holding capacity) greatly suppressed the development of Phytophthora blight (23).

Irrigation and rainfall have significant effects on Phytophthora blight in pepper-growing fields and on pathogen spread (5,23,38). Disease onset was earlier and the final incidence of disease was higher in plots drip-irrigated more frequently rather than less frequently when rainfall was low (38). With high rainfall, the total influenced the rate of disease development, amount of disease spread, and subsequent yield of peppers (15,38). In 1988, much less rainfall was recorded in mid-July and August, and the disease incidence was only one-fourth of that found in July of 1987, when rainfall was high (23).

Control Strategies

Fungicides. Effective control of Phytophthora blight depends mainly on the application of fungicides. Several fungicides such as metalaxyl, oxadixyl, propamocarb, copper oxychloride, chlorothalonil, and dithianon have been labeled for Phytophthora blight in Korea. Among the fungicides, the mixtures of metalaxyl-copper oxychloride, metalaxyl-dithianon, and oxadixyl-chlorothalonil have been most frequently employed in pepper production (40). To control Phytophthora blight effectively, six foliar sprays, which are applied at 10-day intervals, are currently recommended to farmers. However, fungicide applications are often ineffective for control of the disease (33).

Applying fungicides as a drench around the stems of pepper plants was more effective than using foliar sprays. In a 1982 field trial, three soil drenches of metalaxyl suppressed final incidence of Phytophthora blight to below 3%, compared to 20 and 31% for foliar sprays and the untreated control, respectively (25). However, fungicide drenches have not been widely practiced by farmers, since they are relatively expensive. Timing of fungicide applications seems to be important for effective control of Phytophthora blight. Fungicide sprays just before rainfall led to much greater control efficacy than sprays immediately after rainfall (25).

The efficacy of fungicide applications is greatly affected by the level of resistance of pepper cultivars to Phytophthora blight. There is also evidence that the systemic fungicide metalaxyl acts against Phytophthora blight by increasing the capacity of pepper plants to produce phytoalexin capsidiol (10,16). In a 1990 field experiment, six metalaxyl applications to a susceptible cultivar resulted in only 11% control (43). The comparable six fungicide applications on both intermediate and resistant cultivars showed 48 and 56% control, respectively, which corresponded to four to five times greater than that of the susceptible cultivars (Table 1). Furthermore, three fungicide applications failed to reduce Phytophthora blight on both the susceptible and intermediate cultivars, but did reduce it effectively on the resistant cultivar. Disease development on the susceptible cultivar receiving six metalaxyl applications was generally equivalent to that of the resistant cultivar without fungicide application. These data indicate that the planting of resistant cultivars could greatly increase the efficacy of fungicide applications, thereby reducing the number of fungicide sprays and very likely the risk of developing metalaxyl resistance.

Despite the excellent fungicidal activity of metalaxyl, the development of resistance to metalaxyl by some members of Peronosporales has caused considerable difficulties in the continuous use of this fungicide. In particular, failures of metalaxyl to control naturally occurring metalaxyl-resistant isolates of *P. capsici*

Table 1. Effects of cultivar resistance and fungicide application for control of Phytophthora blight in pepper plants in the 1990 field test at Jungwon, Korea

Cultivar	Metalaxyl applications (no.)	Disease incidence (%)[a]	Control (%)
Chungyang (susceptible)	0	100	0
	3	96	4
	6	89	11
Dabok (intermediate)	0	95	0
	3	96	0
	6	49	48
Mankang (resistant)	0	37	0
	3	14	62
	6	16	56

[a]Calculated as the percentage of diseased pepper plants among the total 60 plants within a plot (18 m^2) of three replicates per treatment.

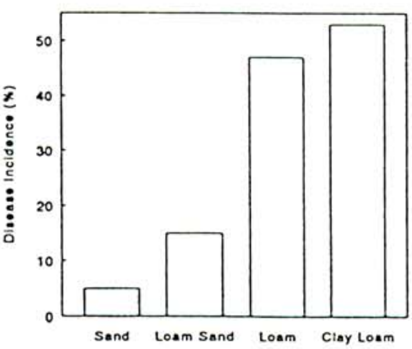

Fig. 3. Development of Phytophthora blight in pepper plants grown in different soil types.

Fig. 4. A naturally occurring epidemic of Phytophthora blight on pepper cultivars Oryun (left) and Mankang (right) that are susceptible and resistant, respectively.

has been reported in Korea (9,34). Therefore, the mixtures of metalaxyl with copper oxychloride or dithianon are being used extensively to prevent the development of resistance to metalaxyl in pepper-growing areas Korea (40).

Genetic resistance. Resistance of pepper to *P. capsici* was first identified in 1960 in certain pepper genotypes by Kimble and Grogan (29). This resistance was later reported to be governed by two distinct dominant genes that act independently without additive effects (37,39) or by a single dominant gene with modifiers (2). However, prolonged incubation period or very high inoculum concentration of *P. capsici* could occasionally overcome resistance and result in symptoms on resistant plants. Many studies have sought to identify a stable and durable source of resistance to *P. capsici* for use in breeding programs (2,29,36,39). Resistance has failed to control Phytophthora blight effectively, especially during prolonged periods of rainy weather (42), because there may be virulent isolates in the *P. capsici* population able to attack the resistant pepper cultivars. Recently it has been suggested that age-related resistance, which is distinctly expressed as pepper plants mature, may be effective in reducing damage from this disease (28). Because the disease causes severe damage in pepper plants only at later growth stages in the field, the age-related resistance must be considered in breeding resistant pepper cultivars. In our earlier studies, a sesquiterpenoid phytoalexin, capsidiol, present in infected stems, roots, and fruits of pepper plants, accumulated to high levels as plants matured (10,15). In comparable infected organs, the resistant cultivar Kingkun always contained more capsidiol than did the susceptible cultivar Hanbyul. Capsidiol production appears to have a role in increasing the resistance of pepper plants with aging. In further studies, it has also been suggested that the expression of age-related resistance of pepper plants to *P. capsici* may be due to the metabolic and nutritional changes in tissues of pepper stems during aging, i.e., changes in the activity of some enzymes, the pronounced increase in proportion of dry matter, the significant decrease in amounts of mineral nutrients such as nitrogen, phosphorus, potassium, calcium, and magnesium, and the decrease in fructose, glucose, and sucrose in the stem tissues (17,20).

There is so far no evidence for pathogenic races of *P. capsici,* but several reports indicate varying degrees of virulence of isolates on different hosts. Polach and Webster (37) defined 14 pathogenic strains of *P. capsici* based on pathogenicity to different hosts but not to different pepper cultivars. In this study, recombination for pathogenicity and mating type occurred, based on 391 single-oospore progenies from crosses of A1 and A2 types. The ability of *P. capsici* to overcome the resistance of pepper plants was controlled by at least two genes. In earlier studies, we examined the pathogenic variation on Korean pepper cultivars of *P. capsici* isolates from diverse geographic origins (26,42). However, the Korean pepper genotypes did not differentiate any pathotypes from the *P. capsici* isolates used. The great genetic variation observed in these same isolates from Korea, Europe, and New Mexico for restriction fragment length polymorphisms of mitochondrial DNA (12) suggests the possible existence of variation in virulence of naturally occurring *P. capsici* isolates. Recently, Bowers and Mitchell (4) also demonstrated that oospore progenies from pairings of pathogenic isolates of *P. capsici* differed in their ability to cause disease in pepper plants.

One of the main reasons for frequent epidemics of Phytophthora blight in pepper production in Korea seems to be a low level of resistance in Korean pepper cultivars. At present, approximately 140 pepper cultivars have been released, but less than 20 are being planted intensively. Most of these are F1 hybrids. Of 15 major commercial cultivars in 1988 field trials, none show a high level of resistance to isolates of *P. capsici* (42). Disease incidence on the tested cultivars ranged from 23 to 65%, depending on the *P. capsici* isolates. In 1990, some resistant cultivars such as Mankang and Kingkun exhibited low levels of disease incidence, compared to 94–100% disease incidence of other susceptible cultivars (Fig. 4) (43). Further reduction of *P. capsici* infection on such resistant cultivars could be achieved by the use of fungicide applications, as described above. Farmers who recognize the importance of using resistant cultivars in severely Phytophthora-affected areas willingly grow such cultivars in their fields. In contrast, some farmers are reluctant to grow resistant pepper cultivars because of some defects in fruit quality and lower yields. For these reasons, the use of resistant cultivars is limited to pepper-growing areas where alternative control measures cannot be used against severe epidemics of Phytophthora blight. Breeding of resistant pepper cultivars with desirable agronomic characters is, therefore, considered the most urgent issue, and this goal is being pursued in both private seed companies and national experiment stations in Korea.

Biological control. In recent years, research on the biological control of Phytophthora blight in peppers has been expanded in response to growing concerns about the side effects of fungicides as environmental pollutants. Various actinomycetes, bacteria, and fungi antagonistic to *P. capsici* exist in soils where pepper is grown (1,19,21). In particular, some antagonistic microorganisms such as *Streptomyces violaceoniger* (11), *Pseudomonas cepacia* (19), *Pseudomonas aeruginosa* (21), and *Trichoderma harzianum* (19) were very effective against Phytophthora blight on pepper plants under laboratory and greenhouse conditions. *S. violaceoniger* strain A 50 produces the nucleoside antibiotic tubercidin, which is strongly inhibitory to mycelial growth of *P. capsici* (11). Some antibiotic substances highly active against *P. capsici* also are produced by *Pseudomonas aeruginosa* strain B 5 (22). The antagonists *Pseudomonas cepacia* and *T. harzianum* can be formulated into alginate granules for field applications, incorporated into soil medium for seedbeds, or absorbed into peats for soil-drench by suspending them in water. In greenhouse tests (19), levels of suppression of Phytophthora blight ranged from 0 to 86%, depending on application method, antagonist concentration, and the amount of pathogen inoculum. Disease suppression by the antagonist remains highly effective 3 weeks after application and gradually decreases thereafter. Soil drenches and dipping of seedling roots with the antagonist suspensions are more effective in disease suppression than the coating and dipping of pepper seeds. Minimum concentrations of antagonists required for disease suppression are approximately 10^5 and 10^7 cfu/g of soil for *T. harzianum* and *Pseudomonas cepacia,* respectively (19). Antagonist population in soil increased for 2–3 weeks after application but decreased gradually to below the initial levels.

In tests conducted in polyethylene filmhouses, granules or peat formulations with some antagonists effectively reduced *Phytophthora* incidence by 64–73% compared to the untreated control (31). The disease reduction seems to be due mostly to the delay of initial infection by *P. capsici,* because initial infections were delayed 40–79 days by the antagonist treatment. In field trials in different pepper-growing areas, performance of the antagonists varied greatly with year and place, resulting in inconsistency in the control of Phytophthora blight. In most field trials, however, antagonists did not suppress disease incidence below levels obtained by fungicide treatment. Poor performance of the antagonists in field trials may be due to failure of successful colonization. The antagonist populations in field soils decreased rapidly below the threshold level of antagonistic activity within a month after application, unless they were applied frequently. More understanding of antagonist behavior in soil is required for successful biological control of Phytophthora blight. Much effort has been made in Korea to improve root colonization of the antagonists associated with various inherent or environmental factors including soil physico-chemical and biological properties.

Cultural control. Rotation with nonhost crops has long been known as an effective control measure for soilborne diseases. However, crop rotation has not been employed systematically for pepper cultivation in Korea because of lack of alternative crops with comparable economic value to farmers. Sesame and peanut production are recommended as high-value cash crops, but farmers still favor continuous monocropping of pepper.

Intercropping of pepper with either sesame (*Sesamum indicum* L.) or peanut (*Arachis hypogaea* L.) was found to be very effective in suppressing Phytophthora blight (Fig. 5) (23). Nevertheless, the intercropping system has not been widely used by farmers because of difficulties in cultural management of the two crops in a field. In the peanut-pepper cropping sequence, the number of fungi and actinomycetes increased compared to pepper monocropping. Extracts of peanut- or sesame-cultivated soils and root exudates and extracts of either crop inhibited mycelial growth, sporangium formation, and zoospore release of *P. capsici* (32,33). The incidence of Phytophthora blight greatly declined in soil amended with such extracts. Other nonhost crops such as onion (*Allium cepa* L.), Welsh onion (*Allium fistulosum* L.), ginger (*Zingiber officinale* Roscoe), and green pea (*Pisum sativum* L.) also have similar inhibitory effects on *P. capsici* (32,33).

In severely *P. capsici*-infested fields, rotation of peanut or sesame with pepper reduced Phytophthora blight incidence by 39 and 11%, respectively (32). Precropping of Welsh onion and green pea before pepper also limited disease to 31 and 19%, respectively (33). Pepper yields increased 16–47% as a result of rotation or precropping compared to pepper monocropping.

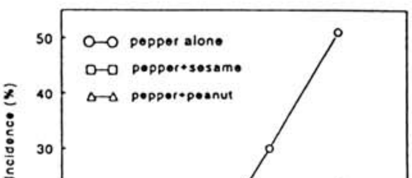

Fig. 5. Inhibitory effects of intercropping with sesame or peanut on the incidence of Phytophthora blight in pepper plants (cv. Oryun) in the fields during the 1988 growing season in Eusung, Korea. Disease incidences on 252 pepper plants within a plot (60 m^2) were rated at different time intervals after transplanting on 2 June 1988.

In greenhouse tests, mixed cropping of green pea, sesame, Welsh onion, peanut, spinach (*Spinacia oleracea* L.), and garlic (*Allium sativum* L.) appreciably reduced Phytophthora blight incidence (32,33). However, the reduction effect is not pronounced in the field. The combination of mixed cropping using peanut with reduced fungicide applications gave slightly better control of Phytophthora blight in the field but was not as economical as monocropping of pepper with regular fungicide applications (33).

Efficacy of control of Phytophthora blight by cropping systems is affected largely by suppressing the level of inoculum in the soil. In the early stages of disease development prior to the production of secondary inocula, Phytophthora blight incidence is greatly inhibited by nonhost cropping. In greenhouse tests with varying levels of inocula, disease inhibition by mixed cropping was highest in the presence of the lowest inoculum levels.

Pepper plants are more adapted to inadequate rainfall than to rainy weather. Consequently, appropriate drainage with high ridges is recommended to Korean farmers for successful cultivation of pepper. However, most farmers hesitate to employ high ridges because of the cost of managing high-ridge systems with plastic film mulching. In a field experiment conducted with varying ridge heights from 0 to 45 cm (7), ridge heights of 15–30 cm greatly reduced incidence of Phytophthora blight and increased the fruit yield, when compared to the no-ridge fields (Table 2). However, the highest ridge, 45 cm, decreased the yield of pepper fruits, since the root systems of pepper plants on the high ridge could be readily affected by drought. A high-ridge system in the pepper fields may be useful when the risk of damage in pepper production from the Phytophthora disease is greater than the cost of ridge preparation in the severely infested areas.

Transplanting depth of pepper seedlings also seems to affect the severity of Phytophthora blight. The most widely used technique of transplanting is to plant seedlings with their crowns approximately 1 cm below the soil surface. In a series of experiments carried out with various transplanting depths, however, high levels of infection by *P. capsici* were observed in the seedlings transplanted with their crowns 1 cm below the soil surface and level with the soil surface (Table 3). Planting peppers with their crowns 4 cm above the soil surface reduced initial disease incidence and symptom severity.

Conclusions

To establish the most effective control strategies for Phytophthora blight of peppers, we need to know much more about the biology of *P. capsici* and the genetics and physiology of pepper-*P. capsici* interactions. Studies of the genetic variation in virulence of the *P. capsici* isolate and the pepper-*P. capsici* interaction at the molecular level are in progress in Korea. Various control measures can be utilized to reduce Phytophthora blight damage in pepper production, but they do not offer complete control. To date, no single measure has

Table 2. Effect of ridge height on the occurrence of Phytophthora blight in pepper plants (cv. Dabok) and yield of pepper fruits at the fields in Suwon, Korea, in 1988

Ridge height (cm)	Disease incidence[a] (%)	Dry fruit yield (kg/ha)
0	17.6	3,005
15	7.8	3,846
30	5.3	3,696
45	5.2	3,125

[a] Calculated as the percentage of diseased pepper plants among the total 352 plants within a plot (160 m^2) of three replicates.

Table 3. Disease incidence on pepper plants (cv. Chunghong) at different planting depths inoculated with *Phytophthora capsici* in Jinju, Korea, in 1986

Planting depth of crowns	Disease incidence[a] (%)				
	10[b]	20	30	40	50
1 cm Below soil surface	33	86	86	90	96
Soil surface	24	90	96	100	100
4 cm Above soil surface	0	76	90	96	96
15 cm Above soil surface	0	0	5	24	43

[a] Calculated as the percentage of diseased pepper plants among the total 30 plants within a plot (8 m^2) of three replicates.
[b] Days after inoculation.

been found to effectively control the disease. During the last decade, many pepper cultivars highly susceptible to Phytophthora blight have been cultivated intensively in Korea. Therefore, resistant pepper cultivars with high fruit quality should be developed by seed companies. In particular, farmers managing Phytophthora blight must understand the continued need for integrated disease management. The integrated management of Phytophthora blight can be accomplished by combining the judicious use of appropriate fungicides such as metalaxyl with resistant cultivars. Cultural controls such as appropriate drainage with high ridges, crop rotation, intercropping, and mixed cropping should also be integrated into the overall disease control program.

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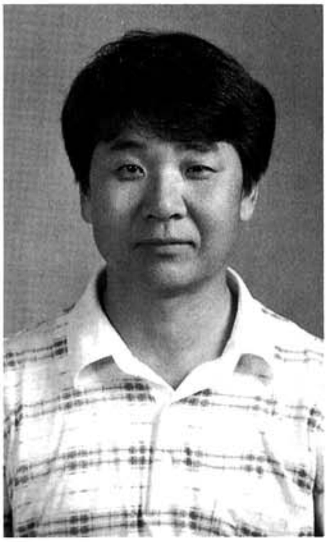

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