Biological Control of Seedling Root Rot of Papaya Caused by Phytophthora palmivora

Wen-hsiung Ko

Assistant Professor, Department of Plant Pathology, University of Hawaii, Hawaii Agricultural Experiment Station, Hilo 96720.

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ABSTRACT

Greenhouse tests confirmed the field observation that resistance of papaya roots to *Phytophthora palmivora* was directly correlated with the age of the plant. Excellent control of seedling root rot of papaya caused by this fungus was obtained by planting seeds in small quantities of pathogen-free virgin soil placed in infested fields. Phytopathology 61: 780-782.

Additional key words: unspecialized parasites, *Carica papaya.*

In Hawaii, most papaya (*Carica papaya* L.) is grown on approximately 1,000 acres of lava rock land on the island of Hawaii. Within 3-4 years after planting by direct seeding, replanting is necessary because of decline in yields and difficulties in managing tall trees. Replanting usually is not possible because of root rot caused by a *Phytophthora* sp. previously referred to as *Phytophthora parasitica* Dast. (3, 9). The papaya pathogen was recently reclassified as *P. palmivora* Butler (8). Although there are currently more than 4,000 acres of abandoned papaya fields in Hawaii, production has not been interrupted because virgin land has been continuously opened for new plantings. However, supply of such land is nearly exhausted.

In virgin-field plantings, initial infections of papaya by *P. palmivora* occur on fruits and the upper portion of the trunk during rainy periods. Diseased fruits, covered with numerous sporangia and chlamydospores, fall to the ground and serve as an important source of inoculum in soil. This fungus persists in soil and causes root rot and death of seedlings when papaya seeds are subsequently replanted in the same field. No resistant cultivar has yet been developed. Because of the extremely rocky and porous nature of the lava land, it is not possible to fumigate soil. Attempts to control *P. palmivora* in replant fields with fungicides and fumigants applied as soil drenches have not been successful (J. E. Hunter, *personal communication*). This paper reports the successful biological control of *P. palmivora* in the papaya replant fields.

Materials and Methods.—*Greenhouse tests.*—Effects of seedling age on susceptibility of papaya roots to *P. palmivora* were studied in a greenhouse. The greenhouse temperature was the same as the outdoor temperature. Five seedlings were established in soil of stony sandy loam in a 10-liter plastic container at 1-month intervals for 5 months. Sporangia of *P. palmivora* were obtained by growing the fungus under fluorescent light for 7 days at 24 C on V-8 juice agar (1). One hundred ml of sporangial suspension (ca. 10×10^4) was evenly distributed over the soil surface in each container. Three containers were used for plants at each age. The experiment was repeated once.

Field tests.—Papayas were grown in virgin soil placed in planting holes in fields previously planted to papaya to determine if seedlings started under these conditions would remain healthy after their roots extended into infested soil. Planting holes with diam and depths of 30×10 cm and 30×20 cm were filled with virgin soil to about 3 cm above the ground level. Planting holes (30×10 cm) without virgin soil were used as controls. The control is identical to the regular practice of the papaya growers. Each treatment consisted of 10 planting holes which were spaced 2.4×3 m, and replicated 6 times. Twenty seeds were planted in each hole. Seedlings were thinned to three/hole after 2 months, and further reduced to one hermaphroditic tree at 5-6 months of age after flowers were produced. The test was repeated twice in papaya replant fields on the island of Hawaii. Experiments I and II were done at Opihikao in November 1969 and May 1970, respectively. Experiment III was done at Malama-Ki in June 1970. The percentage of seedlings killed by *P. palmivora* was determined 3 months after planting. Isolation of *P. palmivora* from diseased roots was done routinely with a selective medium (7).

Virgin soils used in these experiments were sandy loam and silt loam. Before use, they were tested for the presence of other soil-borne papaya pathogens, such as *Pythium* spp., by transplanting five 3-week-old papaya seedlings into a 2-liter pot containing randomly collected soil samples. Twenty seeds were also planted in the same pot. Three pots were used for each virgin soil. Papaya roots were slightly injured during transplanting, and the soil was saturated with water at least twice a day to accelerate disease development. After 1 month, seedlings were examined for disease symptoms. Only those virgin soils free from papaya pathogens were used.

Results.—*Greenhouse tests.*—Two weeks after inoculation, percentages of 1- and 2-month-old plants killed by *P. palmivora* were 94 and 47%, respectively

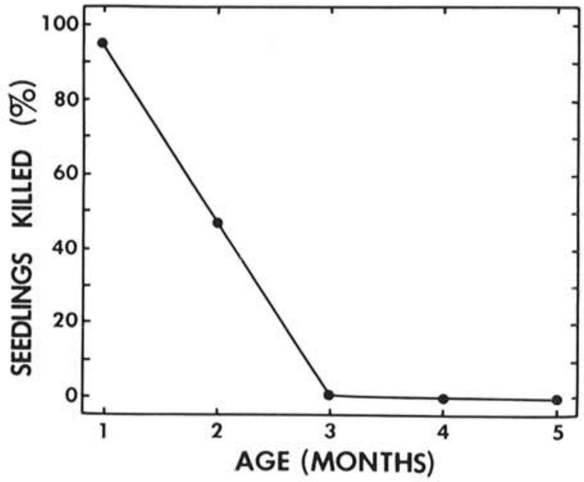

Fig. 1. Relationship between age of papaya seedlings and their susceptibility to *Phytophthora palmivora*.

(Fig. 1). However, all plants 3 months or older at the time of inoculation survived. Most of the tap roots and part of the lateral roots of the 1- and 2-month-old plants that survived were found to be completely rotted, whereas only small brown lesions occurred on the lateral roots and lower portion of the tap roots of older plants. *Phytophthora palmivora* was not isolated from the upper portion of the tap roots of older plants, indicating that mature root tissues of papaya plants are resistant to infection.

Field tests.—Three months after planting, 37, 21, and 42% of the papaya trees were killed in control plots of Experiments I, II, and III, respectively, whereas all trees growing in small islands of virgin soil survived. Growth of surviving plants in the control plots was poor, and *P. palmivora* was consistently isolated from roots of dying plants. In Experiment II, the average heights of papaya trees grown in virgin soil and the control were 60.8 and 39.3 cm, respectively. One year after planting, all the papaya trees in the "virgin islands" in Experiment I were healthy and produced fruits, while additional loss of plants continued to occur in the control (Fig. 2). Results with the two types and amounts of virgin soils used were similar.

Papaya plants grown in virgin soil in one of the replicates of Experiment III were pulled out and examined 4 months after planting. Only about 3% of the plants showed small brown lesions on the lower portion of the tap roots. No such lesions were found on lateral roots.

Discussion.—Observations in abandoned papaya fields disclosed that mature papaya roots in direct contact with diseased fruits, covered with numerous sporangia and chlamydospores of *P. palmivora*, were not infected by this fungus. This suggested that when papaya roots mature, they become resistant to this pathogen. This assumption was confirmed by greenhouse tests which demonstrated that resistance of papaya roots was directly correlated with the age of the plant. Since papaya roots are susceptible to *P. palmivora* only

Fig. 2. Control of papaya root rot caused by *Phytophthora palmivora:* VS = papaya trees grown in small quantity of virgin soil placed in planting holes in the replant field; C = control plants grown in planting holes without virgin soil. Plants are 1 year old. Note the extremely rocky nature of the lava land.

when the plants are young, it was considered possible that the disease could be controlled simply by protecting the roots during the early stages of growth. This concept proved to be correct, and complete control of *P. palmivora* in replant fields was obtained by planting papaya seeds in small quantities of pathogen-free soil placed in the planting holes.

In the replant field, it was observed that papaya roots extended beyond the virgin soil within 1.5 months after planting, but none of the plants was killed by *P. palmivora* after 1 year. In the greenhouse test, 47% of the 2-month-old plants were killed 2 weeks after inoculation. This difference may be attributed to the excessively large quantity of inoculum used in the greenhouse test as compared to that present in replant fields, and also to retardation of papaya roots by confinement in containers which increases disease severity (W. H. Ko, *unpublished data*).

Greenhouse tests showed that only young seedlings were killed by *P. palmivora*. In some cases the tap root was destroyed, but some of the lateral roots continued to support the growth of the plant. Similar observations have been made on trees grown in replant fields. Because of the absence of a tap root to anchor them, these trees topple and die when they become tall and produce a heavy fruit load. This explains why toppling and death of papaya trees continued to occur at older stages in replant fields.

The principle involved in this biological control is to protect young seedlings by planting seeds in small quantities of pathogen-free field soil placed in the pathogen-infested fields. Due to nutrient deprivation imposed by microbial activities, natural soil causes autolysis of fungal mycelia (5) and quiescence of fungal spores (4). Therefore, most fungi do not have the ability to move in soil, and the small quantities of virgin soil will remain free from fungal pathogens in the infested fields.

If pathogen-free natural soils are difficult to obtain, fumigated soil could be used. Rapid reinfestation of the fumigated soil by pathogens in the field (6) could be prevented by exposing the soil to air after fumigation to allow saprophytic microorganisms to recolonize and deplete the available nutrients in it. The same degree of control of *P. palmivora* in papaya replant fields was obtained when recolonized fumigated soil was used as a substitute for virgin soil (W. H. Ko, *unpublished data*).

This approach may be useful for controlling other unspecialized parasites which are characterized by their destructiveness to juvenile tissues and restriction by mature host tissues (2). Unlike chemical applications, this method has the advantages of being relatively inexpensive, very effective, and nonhazardous.

LITERATURE CITED

1. Aragaki, M., & R. B. Hine. 1963. Effect of radiation on sporangial production of Phytophthora parasitica on artificial media and detached papaya fruit. Phytopathology 53:854-856.
2. Garrett, S. D. 1970. Pathogenic root-infecting fungi. Cambridge Univ. Press, London. 294 p.
3. Hunter, J. E., & I. W. Buddenhagen. 1969. Field biology and control of Phytophthora parasitica on papaya (Carica papaya) in Hawaii. Ann. Appl. Biol. 63:53-60.
4. Ko, W. H., & J. L. Lockwood. 1967. Soil fungistasis: relation to fungal spore nutrition. Phytopathology 57:894-901.
5. Ko, W. H., & J. L. Lockwood. 1970. Mechanism of lysis of fungal mycelia in soil. Phytopathology 60: 148-154.
6. Kreutzer, W. A. 1965. The reinfestation of treated soil, p. 495-508. *In* K. F. Baker & W. C. Snyder [ed.] Ecology of soil-borne plant pathogens, prelude to biological control. Univ. Calif. Press, Berkeley.
7. McCain, A. H., O. V. Holtzmann, & E. E. Trujillo. 1967. Concentration of Phytophthora cinnamomi chlamydospores by soil sieving. Phytopathology 57: 1134-1135.
8. Tokunaga, J. 1969. Fine structure and chemical composition of the cyst and hyphal walls of Phytophthora palmivora. Ph.D. Thesis, Univ. Calif., Riverside. 97 p.
9. Trujillo, E. E., & R. B. Hine. 1965. The role of papaya residues in papaya root rot caused by Pythium aphanidermatum and Phytophthora parasitica. Phytopathology 55:1293-1298.