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Management of Plant Diseases without Using Pesticides in Sustainable Agriculture

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Abstract

In solving growers' new plant disease problems during the past three decades, various control methods without using any pesticide have been discovered. Through the systematic exclusion of each possible causal factor, and the confirmation of the working hypothesis by experimentation, several kinds of disorders were found to be due to nutrient deficiency and were controlled by application of appropriate nutrients. These include boron deficiency as the cause of latex secretion and deformity of papaya fruit, deficiency in calcium and boron as the cause of heart rot of banana tissue culture plantlets, and deficiency in nitrogen and phosphorous as the cause of ohia forest decline. The same approach was applied to discover hydrogen fluoride emitted from brick factories as the cause of marginal scorch of banana. The discovery forced the closing of several brick factories and the construction of new factories emitting insignificant amounts of hydrogen fluoride. Investigation of inhibition mechanism revealed that a soil suppressive to *Pythium splendens* was due to its high calcium content and high microbial population. Damping-off of cucumber was, therefore, controlled by mixing soil in planting holes with lime to increase calcium content and alfalfa meal to increase microbial population. Greenhouse tests confirmed the field observation that only young seedling roots are susceptible to *Phytophthora palmiuora*. The papaya replant problem caused by *P. palmiuora* was subsequently solved by replanting seeds in small quantities of pathogen-free virgin soil placed in the planting holes. All banana cultivars are susceptible to fusarium wilt caused by *Furarium oxysporum* f. sp. *cubense*. By screening tissue culture plantlets for resistance to the disease and selection for favorable traits from resistant clones, a resistant variety was released for commercial planting within 6 years. Among the extracts from various edible plants tested, sunflower oil was found to be very effective in controlling powdery mildews on several vegetable crops in the field.

From Pesticides to No Pesticides

The most commonly known method of controlling plant diseases in the field and in the greenhouse is through the use of synthetic chemical compounds.

The widespread use of such pesticides, however, has raised many concerns about the safty of foods, drinking water and farm workers, and their adverse effects on the environment. It is, therefore, imperative to find alternative control methods. In soluing new plant disease problems during the pest three decades, intentionally or not, we have discovered various control methods without using any pesticides.

Control Methods Resulted from Studying the Cause of Each Disease

Deformed-fruit disease of papaya

In the early 1970s, it was noticed in southern Taiwan that many papaya (*Carica papaya* L.) fruit were suffering from latex secretion and deformity. The disease, which is called "Ki-rui" locally, affects all commercial cultivars, and is most serious in sandy areas and during the dry winter. The percentage of unmarketable papaya fruit some times reached as high as 100% in some areas.

No insects were found to be associated with the deformed-fruit disease of papaya. Neither was a disease-spreading pattern observed in the fields. Its frequent occurrence in sandy soils and prevalence during the dry winter indicated that deficiency of nutrients might be a possible cause of the disease. Tissue analyses showed that the boron content in the leaf samples of diseased trees was much lower than that in the healthy trees. Tomato and lettuce grown in soils collected from the diseased field exhibited typical boron deficiency symptoms. These suggested that the deformed-fruit disease of papaya is caused by boron deficiency. This assumption was confirmed by the field tests which demonstrated that the application of borax or boric acid to diseased trees prevented the fruits from developing deformity (Wang and Ko,1975). Since then, the deformed-fruit disease has been under control by foliar or ground application of borax to papaya trees grown in sandy soils.

Heart rot of banana tissue culture plantlets

The propagation material of bananas (*Musa acuminata* Colla, genotype AAA) has been changed from conventional suckers to tissue culture plantlets by most growers in Taiwan in recent years (Ko et al, 1997). Yellowing and death of banana plantlets of unknown cause were observed from time to time before or after transplanting to the fields. Some growers suffered a 50 to 90% loss of banana plantlets in the fields in 1996. The symptoms consist of yellowing and necrosis of leaves, and degeneration of roots. The disease is commonly called heart rot because the affected seedlings also develop black cavity on apical meristem of the corm.

Insect larvae or eggs were not found in the corm during the early stage of cavity development. Plantlets planted in fresh soil which was mixed with pot soil containing plantlets with heart rot symptoms, in large pots did not develop the disease indicating that the disease is not infectious. When plantlets showing initial symptoms of heart rot were sprayed with calcium sulfate or sodium borate, new main roots and root hairs were produced, and the disease ceased to progress,

indicating that the disease is probably caused by mineral deficiency. The disease did not occur when plantlets were planted in soil amended with calcium and boron in small pots or in non-amended soil in large pots. Results show that heart rot of banana plantlets is caused by calcium and boron deficiencies, and that the problem can be solved by amending soil with calcium and boron or by using large size pots (Ko et al., 1997).

Ohia forest decline

Thousands of acres of native ohia [*Metrosideros collina* (Forst.) Gray subsp. *polymorpha* (Gaug.) Rock] forests on the island of Hawaii are declining. It is seen as a gradual thinning and unthrifty appearance of the crowns of trees followed by defoliation and death. The decline is of great concern because recent surveys have indicated an intensification of the deterioration of ohia forests. The ohia tree is important because it is a pioneer species on new lava flows and provides valuable watershed protection. Loss of ohia would mean the loss of forest cover.

The decline was not associated with the presence of any plant pathogens or with insect infestation. However, it was observed that ohia trees started showing the decline symptoms at a much younger age on massive lava than on small porous lava. This suggested the possibility of nutrient deficiency as the cause of ohia decline. To test this hypothesis, fertilizers were applied to the declining ohia trees. Declining trees treated with a complete fertilizer (NPK plus micronutrients) responded by producing numerous new leaf buds on branches and trunks. The trees also responded to a mixture of NPK without micronutrients. Application of N, P, and K individually or a mixture of micronutrients were not effective. Declining trees responded to a combination of NP, but not to combinations of NK and PK. Results indicated that ohia trees are declining because of deficiency in nitrogen and phosphorous.

Marginal scorch of banana

During the 1960s, a mysterious disease of banana called marginal scorch was noticed in several orchards in southern Taiwan. Water-soaked, irregular lesions started from the margins of affected leaves and, as the disease progressed, coalesced and turned dark green or dark brown, with waves of new lesions appearing behind the old ones. Fruit produced by affected plants were greatly reduced in size and not suitable for export. Because of the seriousness of the problem, the government allocated funds for plant pathologists in Taiwan to study this disease and also sought advice from foreign experts.

In the mid-1970s, I was invited to inspect the diseased orchards and develop methods to tackle the problem. Experiments performed under my supervision revealed the disease to be noninfectious. When diseased plants from the affected area were planted among healthy plants in a nonaffected area, the disease did not spread to healthy plants and, furthermore, diseased plants became healthy. In addition, the disease was found to be originated from the air and not from the soil. Healthy plants planted in soil transported from the affected area to a nonaffected area did not become diseased, but healthy plants

transported to the affected area all developed marginal scorch. The causal agent finally was found to be hydrogen fluoride emitted from nearby brick factories (Su et al., 1978 ; Sun, 1994). Analysis of leaf tissues showed that the concentration of fluoride was about 10 times higher in diseased leaves than in healthy leaves. Healthy leaves fumigated with hydrogen fluoride vapor developed symptoms of marginal scorch indistinguishable from those occurring in nature, and fluoride content increased more than sixfold in diseased tissues (Su et al., 1978).

After the revelation of the cause of marginal scorch, a lawsuit was brought by some banana growers, forcing the closing of several brick factories. When new factories were constructed to save energy and reduce labor costs the kiln design was changed from the conventional dome-shaped downdraft type to a modern tunnel type that utilizes residual heat for drying and preheating clay blocks. When hydrogen fluoride released from the clay blocks in the brick-forming chamber(>1,000 C) passed through the tunnel, about 98% was reabsorbed by the clay blocks drying in the tunnel. The kiln modifications, therefore, unintentionally solved the banana marginal scorch problem (Sun, 1994).

Control Method Discovered During the Study of the Inhibition Mechanism of Suppressive Soil

Damping-off of cucumber

Suppressive soils occurring naturally in fields are usually recognized by consistent observation of lower incidence of disease in a certain area in comparison with that in the nearby area. The suppressive fields involved are relatively large and the number of such suppressive soils which have been reported so far is very limited. Since both microorganisms and nonbiological components in soils are very diverse and their distribution is not uniform, it was considered possible that suppressive soil may exist as islands, small in area, in proportion to the total area of a conducive field.

A method was, therefore, developed for screening soils for suppression of sporangial germination. With this method soil from a small pasture in the South Kohala district on the island of Hawaii was found to be highly suppressive to germination of *Pythium splendens* and to the damping-off of cucumber caused by the pathogen (Ko and Ho, 1983). Suppression of *Py. spendens* in this soil was found to be due to a combination of high microbial population and high calcium content (Kao and Ko.1983; 1986a). Subsequently cucumber damping-off caused by *Py. spendens* was successfully controlled in the field by mixing soil in planting holes with alfalfa meal to increase the microbial population and lime to increase the concentration of available calcium (Kao and Ko, 1986b).

Idea oirginated from Field Observation

Papaya replant problem

Most of Hawaii's papaya is grown on approximately 3,000 acres of lava rock land in the southeastern corner of the island of Hawaii. In new plantings on virgin land initial infections of papaya by Phytophthora palmivora occur on fruit and the upper portion of the trunk during rainy periods. If the rainy season is prolonged, some growers may be forced to abandon their fields within 2 years after planting because of heavy infection. Nearly all papaya trees in the abandoned fields may be infected shortly by the fungus. Diseased fruit covered with sporangia and chlamydospores of P. palmivora fall to the ground and serve as an important source of inoculum in the soil. The fungus persists in the soil and causes root rot and death of seedlings when papaya seeds are subsequently planted in the same field. No resistant papaya cultivar has yet been developed. Because of the extremely rocky and porous nature of lava land, it is very difficult to control P. palmivora in replant fields with fungicides and fumigants.

It was observed in abandoned papaya fields that although roots of papaya seedlings were attacked by P. palmivora , roots of larger papaya trees remained free from infection by this pathogen, indication the possibility that only young seedling roots are susceptible. Greenhouse tests confirmed the field observation, and papaya replant problem was subsequently solved by replanting seeds in small quantities of pathogen-free virgin soil placed in the planting holes. Because of nutrient deprivation imposed by microbial competition, P. palmivora spores are not able to germinate and grow in soil. Virgin soil, therefore, remains free from the pathogen in infected fields (Ko, 1971; 1982). More than 30 years after its development, the virgin soil method is still being used for planting papaya in replant fields in Hawaii.

Screening for Resistance from Somaclonal Variants: a Fast Way of Obtaining Resistant Cultivars for Commercial Planting

Fusarium wilt of banana

Fusarium wilt of Cavendish bananas caused by race 4 of *Fusarium oxysporum* f. sp. *cubense* is the most serious problem in banana production in Taiwan. All the commercial banana cultivars tested are susceptible to this disease. Due to the existence of about 3% of mutants in the plantlets derived from 'Giant Cavendish' (Hwang, 1986), a screening program was initiated in 1984 to search for mutants resistant to the disease. During the period of 1984-1997, a total of 12 resistant clones were obtained, all derived from 'Giant Cavendish' (Hwang and Ko, 1988; 1989; 1991). Six clones are highly resistant and the other six moderately resistant. All are morphologically different from the parent and carry inferior horticultural traits such as taller stature, longer growth cycle, reduced bunch weight and poor postharvest characteristics. However, after repeated selection from the tissue culture plantlets derived from these resistant clones, clones with improved agronomical and physiological traits were obtained. The improved moderately resistant clone 'GCTCV-215-1' was

released as a new cultivar 'Tai Chiao No.1' for commercial planting in 1990, only six years after the initiation of the screening program. The fruit quality of 'Tai Chiao No.1' is comparable to that of 'Giant Cavendish'. Since 1991, more than one million 'Tai Chiao No.1' plantlets were planted each year. The wilt incidence on this variety ranged from 5.1 to 6.5%, compared to 42.6 to 69.0% on 'Giant Cavendish'.

Extracts from Edible Plants for Disease Control

Powdery mildew of tomato

We have formed a research group consisting of plant pathologists, entomologists, agronomists, horticulturists, and an oriental medical doctor to test extracts from edible plants including vegetables and medicinal plants for their ability to control plant diseases and insect pests. When tomato leaves were sprayed with 0.1% emulsified canola oil, corn oil, grape seed oil, peanut oil, safflower oil, soya bean oil or sunflower oil, the severity of powdery mildew caused by *Oidium neolycopersici* was greatly reduced. Among these edible oils tested, sunflower oil was the most effective in the control of powdery mildew. When sprayed with 0.5% sunflower oil, powdery mildew on tomato leaves was reduced to a negligible level. Scanning electron microscopy showed that control of powdery mildew with sunflower oil resulted mainly from the inhibition of conidial germination and suppression of mycelial growth of the pathogen (Ko et al., 2003). Emulsified sunflower oil has been used successfully in the control of powdery mildews on tomato, cucumber, pea, eggplant and bean in the field. Extracts from several medicinal plant species have also showed strong inhibitory effects on plant pathogenic fungi. Their ability to control diseases in the field is currently being evaluated.

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