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Plant Disease Management Practices of Traditional Farmers

The science of plant pathology has an important role in the future success of programs and policies designed to increase and sustain food production. If plant pathologists are to be effective in addressing the problems of food production in developing countries, the agricultural systems of traditional farmers in those countries must be thoroughly understood. Then, researchers can appropriately address problems in the context of the farmers' systems and efficient, proven techniques can be disseminated to other farmers. Traditional knowledge can be overvalued or romanticized, but it is a mistake to despise or ignore it. Far too many giant development projects in developing countries have failed dismally, often with serious ecological consequences, because sufficient understanding of traditional agriculture was lacking. Today there are many concerns about modern agriculture because it is highly energy-intensive and has a narrow genetic base and because attainment of increasingly higher yields and greater efficiency may lead to monoculture and overproduction. Sometimes destructive erosion (Fig. 1), pollution, and excessive pesticide residues result. It is time to reexamine the potential for traditional agriculture to contribute to an improved, sustainable system for production agriculture.

Small farms constitute a most important element in the agriculture of developing countries. Although figures vary somewhat, the following are typical: In 1970, holdings of less than 1 ha of land constituted 33% of all holdings in developing countries (13). The average size of agricultural holdings in those developing countries was 6.6 ha. According to the National Research Council (24), "Half of the world's population is engaged in agriculture, the vast majority in the tropics and subtropics." Small farmers till 65% of the world's arable land (17), and 70% of the world's poor live in rural areas and engage primarily in subsistence agriculture (30). Poverty and socioeconomic insecurity characterize the lives of many rural people and are exacerbated among the vast number of small or traditional farmers who often have few resources beyond the labor of their families.

Traditional agriculture usually is associated with primitive agricultural systems or preindustrial peasant agriculture. Traditional farming usually is based on agriculture that has been practiced for many generations. Most small farms in the developing world utilize agricultural

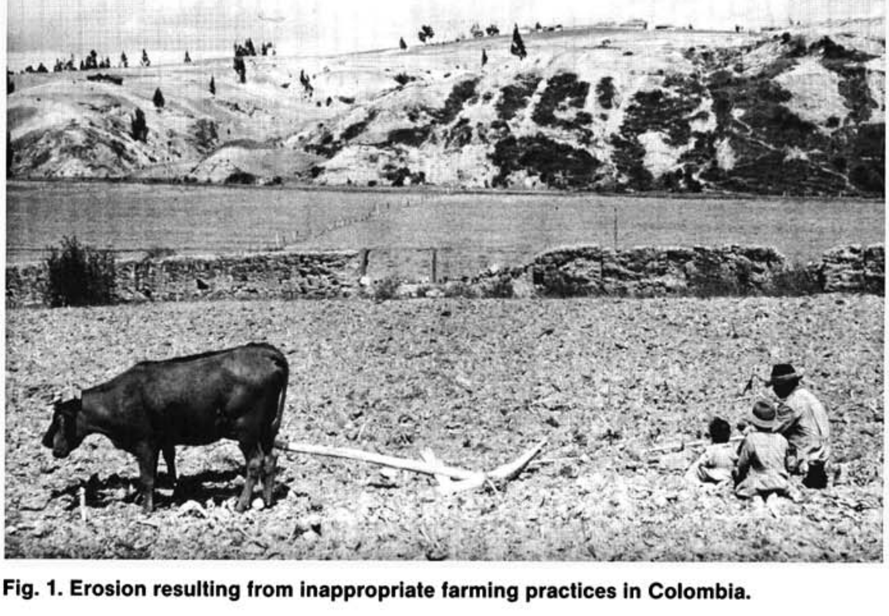

Fig. 1. Erosion resulting from inappropriate farming practices in Colombia.

practices that are to some degree traditional, but many small farmers cannot be characterized as traditional. The agricultural activities of traditional farmers are associated closely with their culture, as Schultz (28) explained:

> Among primitive and peasant societies, cultural values and attitudes, beliefs and behavior patterns often play an equal or greater role than economic considerations when deciding whether to accept or not new production practices. Kinship obligations, peer group pressure, fatalistic beliefs, negative social sanctions regarding accumulations or surplus, individuality, caste differences and constraints, and the perpetuations of common traditional values through family socialization all represent serious challenges to the foreign change agent.

Why Should Plant Pathologists Study Traditional Agriculture?

Anthropologists, archaeologists, ethnobotanists, and geographers—and, to a lesser degree, ecologists, economists, and sociologists—try to understand traditional agriculture. Unfortunately, plant pathologists and others in the "hard agricultural sciences" seldom take courses in these disciplines or read much of their literature, with the occasional exception of ecology and economics. Likewise, professionals in nonagricultural disciplines do not often read agricultural literature or take courses in production sciences. Consequently, each discipline develops a separate language that is often unintelligible to outsiders.

Today the rhetoric in agriculture centers on "sustainability," LISA (low-input sustainable agriculture), and biotechnology. Although these terms are vague and all-encompassing, they strongly affect current funding and research directions. There is debate among economists, some strongly advocating continual growth in the world's economy and others, more ecologically minded, believing that sustainable development should be the goal of mankind. For example, Brown and Shaw (4) stated:

> In a world where the economy's environment support systems are deteriorating, supply-side economics—with its overriding emphasis on production and near blind faith in market forces—will lead to serious problems.

Rapid economic growth rarely can be achieved without jeopardizing ecological sustainability. Some economists, such as Daly (10), argue for a steady-state economy rather than an expanding one.

Schultz (29), in his classic study, *Transforming Traditional Agriculture*, suggested that a country dependent on traditional agriculture is inevitably poor. More recently, Ruttan (27), commented:

> Traditional agricultural systems that have met the test of sustainability have not been able to respond to modern rates of growth in demand for agricultural commodities. A meaningful definition of sustainability must include enhancement of agricultural productivity. At present the concept of sustainability is more adequate as a guide to research than to farming practice.

Do such conclusions by eminent economists suggest that nothing is to be gained by a study of traditional agriculture? I think not, and I doubt if such a conclusion is intended. If modern scientific agriculture is to help alleviate world hunger and starvation, caused in part by population pressure that results in environmental degradation, sustainable agricultural practices of traditional farmers in developing countries must be thoroughly understood and compared with alternative, new practices. If changes in traditional systems are necessary or needed, a thorough understanding of these systems is imperative as a first step before changes are initiated.

Often, traditional farming practices provide effective and sustainable means of disease control. Traditional practices and cultivars (landraces) have had a profound effect on modern agriculture, and most of our present practices and cultivars evolved from these ancient techniques and plant materials. The agricultural systems of traditional farmers, including their disease control practices, are in danger of being lost as agriculture modernizes. Those practices should be studied carefully and conserved before they disappear.

Wilken (34) suggested several additional reasons to study agricultural activities of traditional farmers. First, some traditional farming systems have excellent records in resource management and conservation. Systems that have lasted for thousands of years surely justify serious study, although practices and systems developed by traditional farmers are not always successful. Eckholm (12) wrote: "The littered ruins and barren landscapes left by dozens of former civilizations remind us that humans have been undercutting their own welfare for thousands of years." Perhaps we can learn from their mistakes. The study of successful systems is especially important as petroleum, water, and other resources become scarce.

Second, although many traditional practices are labor-intensive, this aspect may be important and attractive in societies having an abundance of labor and chronic unemployment. Although traditional technology may be of little interest to scientists and Western businessmen, it represents the labor of millions of humans and the management of millions of hectares, and even small improvements would be significant for the world as a whole. For planners in developing countries, traditional methods have some advantages over modern agricultural techniques. For example, capital and technological skill requirements of traditional technologies are generally low, and adoptions often require little restructuring of traditional societies.

Finally, Wilken (34) suggested that because modern agriculture has developed primarily in temperate regions, these practices may have unexpected and undesirable impacts in developing countries, especially those found in the tropics.

Traditional Farmers' Knowledge

The knowledge of traditional farmers is often impressively broad and comprehensive. A few examples illustrate this point. The agricultural knowledge of the Hanunóo, a mountain tribe of Mindoro in the Philippines, is amazingly wide, accurate, and practical (9). They distinguish 10 basic and 30 derivative soil and mineral categories and understand the suitability of each for various crops, as well as the effects of erosion, exposure, and overfarming. Their more than 1,500 useful plant types include 430 cultigens, and they distinguish minute differences in vegetative structure.

Mayan Indians in Mexico have their own comprehensive plant classification system. Berlin et al (2), describing the Mayan (Tzeltal) taxonomic system, stated that 471 mutually exclusive generic taxa were established as legitimate Tzeltal plant groupings.

Much of the literature on traditional agriculture is anecdotal rather than experimental, to the distress of scientists who believe that only information obtained by scientific methods is of real value. Also, traditional agriculture often includes a mixture of superstitious, religious, and magical beliefs. Some beliefs are of no practical value, but others are linked to sound agricultural practices. Ayamara Indians near Lake Titicaca in Peru were interviewed regarding their knowledge of plant diseases (19). They believe that plant diseases are caused by halos around the sun, certain phases of the moon, drought, hail, lightning, excessive humidity, fog, frost, dew, and the use of horse or cattle manure. Entrance into a field of animals in heat, pregnant or menstruating women, drunk men, or people or animals when dew is on the ground also is thought to cause disease. The Ayamara dust their crops with ashes, spray them with fish water, place branches of muña (*Minthostachys* sp., a traditional insect repellent) between plants, and rogue diseased plants. To control diseases they practice careful seed selection and crop rotation and do not plant when the moon is full or the sun has a halo. Several of these practices would reduce disease incidence and severity, but clearly such activities are a mixture of the useful and the useless.

Traditional Farmers' Practices for Managing Plant Diseases

Archeologists believe that humans began crop production perhaps 10,000 years ago. Some ancient farmers developed sustainable agricultural practices that allowed them to produce food and fiber for thousands of years with few outside inputs, but other traditional systems were not so successful. Many of the successful practices have been forgotten or abandoned in developed countries but are still used by many traditional or subsistence farmers modernizing their agriculture in developing countries. Although considerable evidence shows that traditional farmers experiment and innovate, most useful traditional methods of agriculture probably were developed empirically through millennia of trial and error, natural selection, and keen observation. These practices often conserve energy and maintain natural resources. Traditional farming systems, especially in the tropics, frequently resemble natural ecosystems that, with their high level of diversity, appear to be stable, resilient, and efficient. Traditional farmers are not always interested in the highest yields but are concerned more with attaining stable, reliable yields. They minimize risks and seldom take chances that may lead to hunger, starvation, or loss of their land.

Most practices of traditional farmers for disease management in developing countries consist of cultural controls, yet little information on such practices is available in an easily accessible or understandable form. Palti's *Cultural Practices and Infectious Crop Diseases* (25) is an excellent source of information on cultural practices for managing plant diseases, although it emphasizes primarily modern agriculture. Some practices of traditional farmers are: altering plant and crop architecture, biological control, burning, adjusting crop density or depth or time of planting, planting diverse crops, fallowing, flooding, mulching, multiple cropping, planting without tillage, using organic amendments, planting in raised beds, rotation, sanitation, manipulating shade, and tillage. Most, but not all, of these practices are sustainable. The disease resistance of traditional cultivars selected for millennia also is highly important.

Pesticides are used by traditional farmers in very small amounts, but their expectations for pesticides are often unrealistically high. For example, 59 farmers were interviewed in Tabasco, Mexico, about their control methods for web blight of beans. Although they used several cultural methods of control, all expected a chemical solution to the problem (26).

Examples of Cultural Practices for Managing Plant Diseases

Mulching (*tapado*) for web blight of beans. Web blight of common beans (*Phaseolus vulgaris* L.) is caused by the fungus *Thanatephorus cucumeris* (Frank) Donk (anamorph: *Rhizoctonia solani* Kühn). In the warm and humid lowlands of the tropics, web blight is possibly the single most destructive disease of beans and can cause rapid defoliation and sometimes complete crop failure. An epidemic of web blight in the Guanacaste region in northern Costa Rica resulted in a 90% reduction in bean yields in 1980. This loss occurred in beans planted using clean cultivation.

The main sources of inoculum in the hot, humid tropics of Costa Rica are mycelial fragments and sclerotia in the soil (15). Inoculation of beans occurs when splashing raindrops contain infested soil. Traditional farmers in many areas use a system called *frijol tapado*, meaning "covered beans." Bean seeds are broadcast into carefully selected weeds, and then the weeds are cut or chopped with a machete so the bean seeds are covered with a mulch of weeds. Fields selected for *tapado* generally are occupied by broadleaf weeds and certain grasses that will not regrow after they are cut. A semideterminate type of bean, between a bush and a climbing bean, is used. The beans grow through the mulch (Fig. 2A) and eventually cover it (Fig 2B). This combination of mulch and bean plants effectively prevents weed growth and appears to conserve soil moisture. In addition, the mulch prevents soil splashing, which was found in a Costa Rican study (16) to be the most important means of dissemination of inoculum causing web blight.

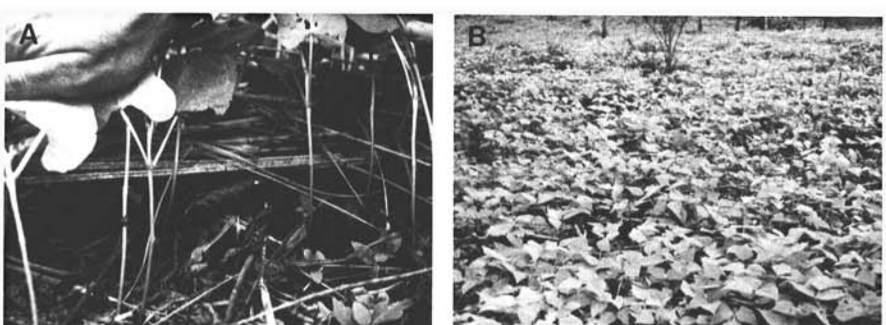

Fig. 2. (A) Bean plants grow through *frijol tapado* mulch and (B) eventually cover it, preventing weed growth and conserving soil moisture.

In the absence of web blight, yields in fields under the *frijol tapado* system are generally lower than those in fields planted in drilled rows with clean cultivation. For this reason, some in Central America oppose continuation of the *frijol tapado* system. On small farms in Costa Rica, however, most of the beans currently produced are grown in this system. Small farmers use it because the risk is low, investment in labor is small (primarily to cut weeds), and a crop is assured even when prolonged periods of rain allow *T. cucumeris* to destroy bean yields under the clean-cultivation system. Covered beans can be planted on steep hillsides without erosion problems. Furthermore, *tapado* fields require little if any maintenance, so farmers may safely leave a planting while they harvest coffee or engage in off-farm activities. *Tapado* fields require less labor and, although yields per land unit are low, labor returns per workday are higher than for clean-cultivated beans.

Raised fields, raised beds, ridges, and mounds. Raised fields, raised beds, ridges, and mounds were used widely for millennia by traditional farmers in geographically separated areas of tropical America, Asia, and Africa. Raised bed systems of agriculture with striking similarities evolved in these widely separated areas. Drainage, fertilization, frost control, and irrigation were among important considerations, but planting in soil raised above the surrounding area was also a significant disease management practice, especially for soilborne pathogens. Specialized traditional raised bed systems such as *chinampas* in Mexico, *tablones* in Guatemala, and *waru waru* in Peru are in use today. How much the management of plant diseases and other pests entered into the evolution of these systems is unknown. Raised beds are used extensively today in Asia, often after a rice crop. Flooding for rice culture destroys many soilborne pathogens, and vegetables and other crops can be grown subsequently on raised beds, with fewer disease problems. Similar practices are used widely in tropical Africa after rice. Most vegetables in Asia are grown on raised beds. Mounds, ridges, and raised beds are used worldwide today by indigenous farmers for root and tuber crops, and their use often reduces root rot problems. The widespread use of raised beds in both modern and traditional agriculture today testifies to their value.

In their articles and books about traditional peoples and agriculture, anthropologists occasionally mention insects but almost never mention plant diseases. An example is a study by Waddell (32), who described the "mound builders" of New Guinea—a group of traditional farmers who have worked out a sustainable system of agriculture by cultivating sweet potatoes (*Ipomoea batatas* (L.) Lam.) on mounds, producing high yields for long periods of time, with no apparent disease problems. The mounds permit continuous cultivation without fallow. Sites in the study area are known to have been in continuous cultivation since 1938 (when Europeans first made contact with these people). When a new mound is prepared, old sweet potato vines, sugarcane (*Saccharum* sp.) leaves, and other vegetation are placed in the center. When this material begins to decompose, the mound is closed with soil and subsequently planted with sweet potato cuttings. According to Waddell, the two or three harvests obtained per year total 19 tons of sweet potato roots per hectare. The only reference to disease I could find in this excellent, detailed treatise is the following:

> It [sweet potato] is also less susceptible to disease than taro (*Colocasia esculenta*), which has suffered greatly in recent years from the depredation of the taro beetle (*Papuana* spp.) and the virus *Phytophthora colocasiae* in various parts of the Pacific.

The error regarding the nature of *Phytophthora* (an oomycete, not a virus) perhaps illustrates the level of knowledge and interest that most anthropologists, archaeologists, economists, geographers, and sociologists have regarding disease problems. Diseases seldom are mentioned in their published studies of indigenous or traditional agriculture. One should not be unduly critical, however, since few plant pathologists study or reference work in the above disciplines.

Probably the best known raised-field system is the *chinampas*, or "floating gardens," of the Valley of Mexico, which the Spanish conquistadors erroneously thought floated. When, in 1521, the Spaniards entered the capital of the Aztec civilization, located on an island in Lake Texcoco, they were amazed by the immense areas in *chinampas*. The high productivity of *chinampas* has been cited as a major factor that allowed the Aztecs to grow from a small tribe to a powerful group that essentially dominated most of Mexico when the Spaniards arrived. Armillas (1) estimated that the Aztec *chinampas* may have fed 100,000 people.

Chinampas are still to be found near Mexico City at Xochimilco. Constructed in the shallow Lake Texcoco, they generally are rectangular and separated by canals (8). The surface of the *chinampas* is ideally about a meter above the water level. Two operations build up the *chinampas*. First, mud rich in nutrients from the bottom of the canals is dredged up using a hand tool and spread on the *chinampa* surface to maintain the canals and enrich the *chinampas*. In addition, aquatic weeds and animal manure (and in the time of the Aztecs, human waste) are also spread on top. A wide variety of crops were grown by the Aztecs on the *chinampas*, and many diverse crops still are seen today. Seedbeds are prepared by spreading a layer of mud over vegetation, cutting the mud into small rectangular blocks called *chapines*, and planting a seed in each *chapin*. The *chapines* are subsequently transplanted to the soil of the *chinampas*, thus giving the crops a good start. Cropping can continue year-round, even through the dry season. The *chinampa* system allows continuous cropping by sophisticated water control, multiple cropping, periodic addition of organic material and nutrients, and transplanting of healthy, selected seedlings (*chapines*) with strong root systems. The diversity of crops grown on traditional *chinampas* also may have contributed to the success of the system by inhibiting the spread of disease.

Lumsden et al (21) compared levels of damping-off caused by *Pythium* spp. on seedlings grown in soils from *chinampas* with levels on seedlings grown in soils from modern systems of cultivation near Chapingo, Mexico. Disease levels were lower in the *chinampa* soils, and when inoculum of *P. aphanidermatum* (Edson) Fitz. was introduced, the fungus was suppressed by *chinampa* soils. They concluded (21):

> In the *chinampa* agroecosystem, apparently a dynamic biological equilibrium exists in which intense management, especially of copious quantities of organic matter, maintains an elevated supply of organic nutrients and calcium, potassium and other mineral nutrients which stimulate biological activity in the soil. The elevated biological activity, especially of known antagonists such as *Trichoderma* spp., *Pseudomonas* spp., and *Fusarium* spp., can suppress the activity of *P. aphanidermatum*, other *Pythium* spp. and perhaps other soilborne plant pathogens.

Zuckerman et al (35), in a cooperative study among scientists from Mexico and the United States of suppression of plant-parasitic nematodes, found that the high organic content of the soil probably was responsible in part for the relatively few nematodes in *chinampa* soils, but they also found nine organisms that had antinematode activity.

Although little has been reported on the utility of raised fields in general for control of plant diseases, this is often a benefit added to their obvious irrigation, drainage, and agronomic values.

Cultural practices in Mexico. The cultivation of maize illustrates well the knowledge of traditional farmers and the complexity of their cropping systems. Mexican farmers near Puebla have been growing maize for perhaps 7,000 years, and their accumulated experience with the crop is considerable. First, most of the maize cultivars they grow are native landraces, as they are best adapted to the area and perform better than those available from CIMMYT (International Maize and Wheat Improvement Center) or the government (6). Here, maize is grown not in a monoculture, but together with squash and climbing beans. Economic yields and nutritional benefits are often superior with this multiple cropping system. Other benefits include cultural control of the major bean diseases effected by growing beans in association with maize (31).

At harvesttime in Puebla, an observer from the temperate corn belt might not approve of the appearance of the maize fields, which are choked with weeds. Mexican scientists have observed that farmers often weed their fields for about 90 days, then let the weeds grow, because little additional yield results from further weedings. Furthermore, the weeds are used as fodder for animals in the dry season. Farmers have noted that wind and water erosion is far less when weeds are present in a field. Efraim Hernandez X. (*personal communication*) noted that about 40 of the weed species found in Mexico's cornfields are eaten as pot herbs by traditional farmers. In fact, some are allowed to go to seed in order to encourage a good seed set. Traditional farmers in Tabasco do not have a word for "weed" in their vocabulary but instead use a concept of good and bad plants (*mal y buen monte*). The same plant may be either good or bad, depending on where and when it is found (7). Thus, weeds in fields are not necessarily the result of poor farming practices.

Another practice in the maize field is to bend the ears downward (*doblando la mazorca*). Farmers have found that this protects the grain from rain and that the grain dries better on the plant in the sun than in storage, is less accessible to rats and birds, and reaches such a low moisture content that storage deterioration is greatly reduced. Montoya and Schieber (23) sampled maize in Guatemala that had been bent down and found only 1.0% of the grain damaged by fungi, compared with a mean of 14.5% of the grain damaged from similar maize plants whose ears had not been bent down.

Weatherwax (33) found references describing the agriculture of the Aztecs in Mexico using the *doblando la mazorca* practice in the 16th century. He cites Friar Sahagún, who went to Mexico in 1529 and described work for an Aztec maize farmer:

> The duties of the farmer are: to fill up the holes where maize is planted, to heap the earth around the young plants, to eradicate the grass, to thin out the plants and remove the small ears and ear suckers and tillers so that the plants will grow well, to take off the green ears at the proper time, to break over the stalks at maturity and

harvest the corn when it is dry, to husk the ears and knot the husks together or fasten the ears together in strings, to carry the harvest home and store it, to break up the stalks which have no ears and to shell the grain and clean it in the wind.

Although Mexican maize fields may look haphazard and poorly attended to observers from temperate zones, the Mexican traditional farmers have sound reasons for their practices. Perhaps agricultural scientists can learn from them.

In 1980 I visited a traditional farm near Puebla with a group of students. There I noticed a basket containing beans, and I separated out 17 different types from the basket (Fig. 3). Later I learned that the collection included common beans, lima beans (*Phaseolus lunatus* L.), and scarlet runner beans (*P. coccineus* L.), all of which the farmer grew on his 1.5 ha. When asked why he grew so many varieties, the farmer replied that some grew better in wet years and some grew better in dry years. When insects attacked, some varieties survived while others did poorly. His wife preferred certain varieties for specific cooking purposes. In common with anthropologists and geographers, he mentioned nothing about diseases. The diversity of his many varieties probably protected against various insects, diseases, other biological stresses, and the vagaries of climate.

Rotation and fallow to manage potato cyst nematode. In Peru, before the arrival of the Spaniards, farmers of the Inca empire used fallow and rotations for potatoes (*Solanum tuberosum* L.) (11). Today, isolated communities in the Andes use long rotations (6–8 years) for potatoes. Brush (5) described a typical rotation/fallow in an isolated mountain valley of Peru:

> A third stratagem used by Uchucmarcan peasants to assure a potato harvest is to cultivate fields for only one to three years before returning them to a long fallow of eight or more years. Farmers usually sow potatoes in the first year and other Andean tubers—oca (*Oxalis tuberosa*), mashua (*Tropaeolum tuberosum*), and ullucu (*Ullucus tuberosum*)—for one or two subsequent years. The long fallow period lowers subsistence risk in two ways: by reducing the amount of erosion and soil loss and by killing disease vectors such as nematodes and fungi, which remain in the soil and depend on the continued potato planting to survive.

Brodie (3) indicated that nonhosts play an important role in management of the potato cyst nematode and stated that nematode densities in the soil decline 30–50% annually when a nonhost crop is grown. Mashua is common in rotations with potatoes and contains nematicidal compounds. Thus, the strategy of the Peruvian farmers to rotate with nonhosts of the potato cyst nematode is a sound practice.

Through centuries of trial and error, the Incas and their predecessors must have learned that long rotations and fallows gave the best potato crops. The destructive potato cyst nematodes (*Globodera pallida* (Stone) Behrens and *G. rostochiensis* (Woll.) Behrens) exist in extremely high population levels in most potato-growing areas of the Peruvian Andes, where in many areas the traditional long rotation/fallow period is not used. Studies in Rothamsted, England, demonstrated that a 7-year fallow reduces potato cyst nematode populations below the economic threshold, so that a profitable crop can be grown (20). Thus, the Inca fallow/rotation had a sound practical basis and was an effective disease management practice. To the Spaniards the Inca fallow/rotation seemed to be a senseless custom. Long fallow/rotation periods were abandoned, and serious losses caused by the potato cyst nematodes in Peru resulted.

Manipulations of plant architecture—multistory cropping in household gardens. The village gardens in West Java first were described in the 10th century (22). Small in size (often less than 0.1 ha), they nevertheless are important for feeding the dense populations of Java. Such gardens may constitute 15–50% of the land available for cultivation for each village. More than 70 plant species are grown in the gardens, including plants for food, timber, firewood, medicine, and ornament.

The striking diversity of species used (some villages reportedly use up to 250 crop species) has important implications for the significance and severity of diseases in the gardens. Pesticides seldom are used or needed. Animals of various kinds are also important constituents of the gardens, and they graze, feed, or are fenced within the garden and fed with products of the gardens. Their waste contributes to nutrient cycling in the gardens. Fish found in ponds in some gardens are fed vegetable and human waste.

Each plant receives individual care and each plant has its "place" in the garden. The gardens imitate the tropical forest ecosystems of Java. The physical arrangement (horizontally and vertically) is sophisticated, taking advantage of the available solar energy and the tolerance of individual species to shade. The upper layer, or top crop canopy, utilizes species tolerant of sunlight; as the gradient of light and humidity changes vertically, different species are grown in their proper "niches." Gardeners have reliable ecological knowledge that allows them to fit plants into sites that meet their various requirements.

The Chagga, a Bantu group living on Mount Kilimanjaro in Tanzania, are skilled traditional farmers who make use

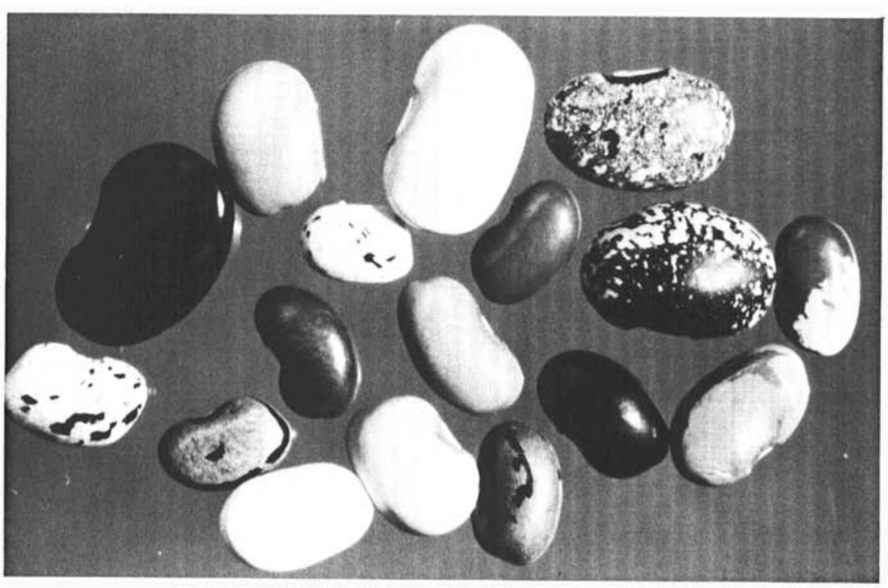

Fig. 3. Three species and 17 varieties of beans grown by a traditional farmer on 1.5 ha in Puebla, Mexico.

Fig. 4. Mixed cropping in the highlands of Ecuador. (Courtesy Roger Kirkby)

of multistory gardens to support their dense populations on about 1,200 km^2 (14). Their gardens contain both animals and food and cash crops. More than 100 different plant species have been recorded in Chagga home gardens, including 15 different types of bananas that are grown for food, brewing beer, and fodder. Vertically, five relatively distinct zones or layers can be distinguished, although there is considerable overlap. The lowest (0–1 m) contains various food crops, herbs, and grasses. The second zone (1–2.5 m) comprises coffee and various small trees and shrubs. The third zone (2.5–5 m), the "banana" zone, also includes some fruit and fodder trees. The fourth zone (or canopy of 5–20 m) consists of fuel and fodder trees. Finally, the fifth zone (15–30 m) consists of valuable timber, fuel, and fodder trees.

Although little information was given on disease occurrence in these systems, some reflection helps to explain why they can often exist for centuries without apparent major plant disease problems. They resemble in some respects the stable natural ecosystems of the region. Traditional farmers for centuries have selected landraces that can thrive under their conditions and that may be optimal for the conditions under which they are grown. The great diversity of crops (Fig. 4) provides a degree of protection, because pests are less able to build up to destructive proportions on the few isolated plants of each species found in household gardens. The use of intercropping reduces losses by most plant pathogens. The architecture of the entire system and of individual plants is manipulated by traditional farmers, especially in intercropping situations. Shade can affect humidity, dew deposition, and temperature and thereby reduce the severity of damage caused by pathogens.

Conclusions

Cultural controls are often forgotten or barely mentioned in the modern literature on plant diseases, even though many traditional farmers have adequately managed plant diseases for millennia, primarily with cultural practices. Many of these practices are sustainable, although some are highly labor-intensive. It is important to integrate traditional cultural controls into pest management systems for developing countries, especially those for control of plant diseases, to a greater degree than has been done in the past. Efforts must be made to thoroughly understand the agricultural systems and practices of traditional farmers in developing countries and to avoid the serious errors and failed projects of agricultural development efforts in recent decades. At the very least, these traditional practices are a point of departure and will contribute to the development of appropriate and acceptable improved practices.

Traditional agricultural practices deserve more respect than they receive. The knowledge of traditional farmers is often broad, detailed, and comprehensive. Although traditional farmers may not know what fungi, bacteria, or viruses are, in many cases they have effective, time-tested practices for managing pathogens. Traditional agricultural practices must be understood and conserved before they are lost with the rapid advance of modern agriculture in developing countries. Plant pathologists can learn much from traditional farmers to elucidate principles and practices useful in the future management of plant diseases.

The remarks of Haskell et al (18) summarize the complexity and challenge of traditional agriculture:

> It is now becoming recognized that any attempt to import technological change in ignorance of, even in defiance of, the socio-cultural background of small farmer practice is a recipe for disaster. The basic reason is simple; traditional peasant systems of agriculture are not primitive leftovers from the past, but are, on the contrary, systems finely tuned and adapted, both biologically and socially, to counter the pressures of what are often harsh and inimical environments, and often represent hundreds, sometimes thousands, of years of adaptive evolution in which the vagaries of climate, the availability of land and water, the basic needs of the people and their animals for food, shelter, and health, have been amalgamated in a system which has allowed society to exist and develop in the face of tremendous odds.

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