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Effects of Soil and Plant Management on Crop Pests and Diseases

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An ecosystem perspective on crop and soil management underscores the importance of understanding the multiple interactions among the various flora and fauna that inhabit soil systems and affect the success of any particular cropping system. By definition, pests and pathogens have impacts on crops and other plants. However, conversely, soil and crop management practices, together with the management of nutrients, water and other plants, have demonstrable effects on the many populations of organisms that have parasitic, toxic, or other impacts of significance to farmers.

In this chapter, we consider evidence on this reciprocal relationship, on how soil and crop management practices that capitalize on certain biological dynamics can have desirable and cost-effective impacts on the control of various floral and faunal bio-aggressors. This is or should be part of what has come to be known as integrated pest management (IPM). As a new paradigm for agriculture, IPM shares many principles with the biologically-based systems presented in this book, especially the direct seeding through permanent soil cover (DSPSC) cropping systems discussed in Chapters 22 and 23.

These systems are location-specific and knowledge-intensive with the pros and cons of any particular practice needing to be considered and balanced to achieve the greatest possible net favorable impact on pests and on production. These strategies require a

dynamic perspective, taking into account the temporal dimension because some time is invariably required for new biological equilibria to get established after a change is made in cultural practices.

Both time dimension and location-specificity are central themes of emerging biologically-driven agricultural practices. We will report particularly on experience that is being gained in Madagascar, where CIRAD scientists are working with national and local partners to reduce the negative environmental impacts of shifting cultivation of upland rice. We draw also on the experience of CIRAD researchers in other countries and on scientific literature more generally. Because we have most direct experience with the changes associated with DSPSC innovations presented in Chapter 22, we consider especially what has been learned about the impacts on pests and disease from curtailing tillage and from keeping soil surfaces covered.

An example of the importance of location-specificity is our finding that when DSPSC methods were introduced and evaluated in the highlands of Madagascar, attacks by white grubs and black beetles on upland rice were demonstrably reduced after just a few years of this new management (Michellon et al., 1998, 2001; Ramanantsialonina, 1999). This was very encouraging. However, when the same practices were undertaken at lower elevations, the beneficial effects were not observed (Charpentier et al., 2001). These particular pests remain one of the main obstacles to broader success with rainfed rice production and to the adoption of DSPSC.

To develop diagnostic strategies and interventions for dealing with pests and diseases, one needs to appreciate the complexity of interacting factors, both biotic and abiotic, that shape crop production outcomes. Pest control methods should be conceived and developed concomitantly with other crop and soil management techniques, to achieve the best compromises among effectiveness in pest control, cost-efficiency, and environmental impact, recognizing that what constitute optimal combinations of practices may need to change over time.

41.1 Assessing the Effects of Tillage and Its Cessation

Direct seeding in place of conventional tillage makes significant changes in the environment in which plants grow, particularly in the top layer of soil and on the soil surface by not disturbing them. Cessation of tillage has definite impacts on pests and diseases, although not always the same effect nor always desired ones.

When plowing is done, insect pest species that live or pupate in the soil and/or those that live or shelter in crop debris or in weeds before a new crop is planted may be killed or buried to a depth from where they cannot emerge. Others die of the temporary drought created in the upper soil layers, or they get exposed on the surface where they are desiccated or consumed by predators. Hence, the most immediate effect of reducing tillage is to diminish the level of pest control that is achieved through mechanical means. This is particularly important for some general soil pests such as cutworms, wireworms, and slugs (Leake, 2001). For instance, plowing considerably reduces the larval and pupal populations of white grubs, as seen in the case of *Heteronychus* spp. (Walker, 1968), and *Hoplochelus marginalis* (Vercambre, 1993).

However, some reverse effects can also be observed, because plowing can have adverse impacts on the larval or pupal stages of important predators of pests, ones that help to keep these pests in check. For instance, parasitoids of the cabbage stem weevil (*Ceutorhynchus pallidactylus*) and pollen beetle (*Meligethes aeneus*) were found to be damaged more severely by stubble cultivation with subsequent plowing than by direct

seeding (Wamhoff et al., 1999). So cultivation can reduce the predator pressure on pests, thereby contributing to pest prevalence.

Plowing does not necessarily help control pathogens in the soil either. True, it generally buries pathogenic inoculum present on the soil surface and on the stubble of the previous crop. Pathogens that would otherwise attack crops at the base of their stems are removed from their usual entry point, and the new crop can more readily escape infection by fungi, such as *Rhizoctonia* or *Sclerotium* (Davet, 1996). However, such temporary dislocation of sclerotes does not necessarily affect their viability, and the next plowing can bring back to the surface a very active inoculum that infects the next crop. In addition, since many fungi have the capacity of penetrating any part of the root system, plowing can result in a more extensive, subsurface distribution of the inoculum by tillage implements (Davet, 1996). The survival of *Sclerotinia sclerotiorum* has been found to be enhanced when the inoculum was buried deeply by plowing (Wamhoff et al., 1999). Thus, tillage may give only short-term control of this pathogen.

While plowing can give mechanical control of some weed species, it can have the reverse effect for some major plant pests. When the tubers of *Cyperus rotundus* are cut and disseminated by plowing during rainy periods, repeated plowing increases the volume of infested soil, and it contributes to a wider distribution of *Striga asiatica* seeds (Andrianaivo et al., 1998). Compared to DSPSC, plowing also increases distribution of *Striga* seeds via wind and rain water (Andrianaivo et al., 1998). So, it is not necessarily true that tillage reduces pest and disease incidence. The beneficial effects are often short-lived or even subsequently negated.

41.2 Effects of Mulching

41.2.1 Direct Physical Effects

Crop residue left on the soil surface directly supports survival of certain residue-borne pathogens by providing substrates for their growth and by positioning the pathogens at the soil surface where spore release can occur (Kuprinsky et al., 2002). However, the incidence of foliar diseases can be reduced by having a cover-crop mulch, primarily because this prevents the dispersal of pathogen propagules through rain splashing and/or wind-borne processes (Teasdale et al., 2004). Mulches can also suppress the establishment of soil-inhabiting herbivores, such as Colorado potato beetles, by disrupting their emergence and migration behavior (Teasdale et al., 2004).

There are other documented instances and ways in which mulch reduces crop vulnerability to pest or disease loss. When sorghum is directly seeded after wheat, it is much less prone to attacks by *Fusarium moniliforme*, an opportunistic fungus that is favored by water stress and high temperatures (Dounnik and Boosalis, 1980); both of these conditions are minimized by the mulch component of DSPSC. Zero-tillage with its resultant rice-stubble mulch reduces populations of the leafhopper *Amrarasca bigutulla* and the bean fly *Ophiomyia phaseoli*, because these insects have a strong preference for landing on bare soil. The mulch and stubble left on zero-tillage treatments appear to obstruct long-wavelength radiation that these insect pests rely on (Litsinger and Ruhendi, 1984).

In Brazil, DSPSC methods, planting cotton on dead sorghum mulch, have made it possible to reclaim fields so infested with *C. rotundus* weeds that they could not be controlled with conventional farming procedures (Séguy et al., 1999a). The control

mechanisms introduced by DSPSC include the shading and physical obstruction caused by mulch, as well as competition and allelopathy, plus better water and mineral nutrition of crops which makes them better able to compete (see section 41.4). Similarly, in Cameroon, *Brachiaria* mulch has been observed to have positive effects on the main sorghum crop, notably by lowering soil temperature which results in lower *S. hermonthica* incidence (Naudin, 2002). Net effects of plowing are not always predictable, so an empirical frame of mind is needed, with careful attention to effects on predators and beneficials as well as pests.

41.2.2 Indirect Effects through Increased Fauna Abundance and Diversity

Dead plant cover from previous crops left on top of the soil serves as a refuge for an enormous number of invertebrates. While some can be economically important crop pests, many species are beneficial organisms, including nutrient recyclers, pest predators, and parasitoids (Pruett and Guaman, 2003). Certainly, slugs, crickets, plant bugs, leafhoppers, and spittlebugs may be significant pests of alfalfa seedlings in conservation-tillage systems that depend upon the existing cover of vegetation (Grant et al., 1982; Byers et al., 1983). Also, in the regions of Madagascar around Lake Alaotra and Manakara, dramatic damage by black beetles (*Heteronychus* spp.) has been observed on rice that is cropped on mulch at the beginning of the season, with a significant impact on yield, with damage correlated with mulch thickness (Charpentier et al., 2001). This is a common effect with many mulch-based systems that must be reckoned with.

On the other hand, results from Queensland, Australia, have indicated that long-term reduced or zero-tillage need not lead to increased problems with soil insect pests. Zero-tillage was seen to have the greatest diversity of macrofauna species, while there was no change in the population density of soil herbivores, particularly the three major agricultural pests for emerging seedlings: earwig (*Nala lividipes*), wireworm (*Agrypnus variabilis*), and false wireworm (*Cestrinus trivialis*) (Wilson-Rummenie et al., 1999). The more diverse and continuous availability of food sources that mulch provided in this case improved the survival and activity of predators so that pests could not predominate.

Many farmer fears that mulch will magnify their pest problems are not well-founded. These effects are specific to locations and crops, as well as to kinds of mulch, necessitating *in situ* evaluation. That mulch and zero-tillage generally produce higher crop yields suggests that their net effect is likely to be positive and that pest problems are not exacerbated.

41.3 Effects of Rotations and Crop Associations

One of the reasons why lower numbers of plant-feeding (phytophagous) insects are often found in complex environments such as polycultures, considered in the preceding two chapters, is because countervailing populations of predators and parasitoids can be larger and more effective in such situations, notably because of the more continuous availability of food sources and favorable microhabitats. For example, attacks on maize by the pink borer (*Sesamia calamistis*) were reduced in Reunion when the maize was undersown with birdsfoot trefoil (*Lotus uliginosus*), and when earthworms were added. The cover crop plus earthworms created conditions allowing the development of soil macrofauna that are antagonistic to the pink borer (Boyer et al., 1999).

In Vietnam, CIRAD researchers and colleagues have documented: (1) a rapid decrease in the biodiversity and density of macrofauna associated with conventional systems of rice monocropping that had bare soil compared to the preceding forest; (2) a rapid raise in the biodiversity and density of macrofauna in previously, degraded soil when it was cultivated with a permanent vegetal cover (*Brachiaria*) associated to the main crop of peanut (*Arachis*); and (3) the replacement of ants and termites by earthworms under mulch which were not present when the soil was not kept covered (Husson et al., 2003). Some examples provided below do not directly involve soil management; however, as part of DSPSC or IPM strategies, they avoid or minimize the use of synthetic chemicals for pest control that could have adverse effects on soil organisms.

Physical obstruction and visual camouflage are two explanations that can be offered as to why fewer specialized pest insects are found on host plants that grow in diverse backgrounds compared with similar plants being grown in bare soils (Finch and Collier, 2000). Phytophagous insects are more likely to find and remain on host plants growing in dense, nearly-pure stands, whereas a second plant species in the field disrupts the ability of insects to efficiently attack their intended proper host (Asman et al., 2001).

From an aboveground perspective, the more nonhost plants that are removed from a crop area, the greater is the chance that an insect will find a host plant. Bare-soil cultivation that eliminates all plants but the crop ensures that it becomes exposed to the maximum pest-insect attack possible in that particular locality (Collier et al., 2001). There is evidence indicating that in high-trash situations, apterous aphid vectors are unable to identify their host and consequently their colonization is reduced (A'Brook, 1968). Studies on the influence of crop background on aphids and other phytophagous insects on Brussels sprouts have suggested that the maintenance of some weed cover can be useful in integrated control of certain Brassica pests (Smith, 1976).

Polycultures, as a rule, support lower herbivore loads than do monocultures. One possible reason is that specialized herbivores are more likely to find and to remain on pure crop stands that provide them concentrated resources and monotonous physical conditions (Altieri, 1999). The numbers of pest insects found on crop plants can be reduced considerably when the crop is undersown with a living mulch such as clover (Finch and Collier, 2002). Attacks on geranium (*Pelargonium*) by the weevil *Cratopus humeralis* were reduced when the crop was undersown with birdsfoot trefoil in Reunion (Quilici et al., 1992; Michellon, 1996; Michellon et al., 1996a). Also, the root system of Kikuyu grass seems to reduce the damage done to geranium roots by the white grub *H. marginalis* (Michellon et al., 1996b). Intercropped plants that draw on the same nutrient pool as the desired crop can compensate for the nutrients taken up by giving protection to the crop against its pests.

On the other hand, it is known that volunteer crop plants and weeds can be hosts and reservoirs for many crop diseases or for their insect vectors (Kuprinsky et al., 2002). Some pests sustain themselves on cover crops that thus serve as hosts and favor the build-up of infestation. In Benin, for instance, the cover plant species *Canavalia ensiformis* and *Mucuna pruriens* were found to be good alternate host species for the maize pest *Mussidia nigriovenella* (Schulthess and Setamou, 1999). So in this situation, use of these particular cover crops was disadvantageous.

In Kenya, as discussed in the preceding chapter, a "push-pull" or "stimulo-deterrent diversionary" strategy (Miller and Cowles, 1990) has been able to control stemborers affecting maize. This strategy combines the use of trap and repellent fodder plants, so that stemborers are at the same time repelled from the maize crop and attracted to the trap crop. The semiochemicals that mediate this behavior of the pests and parasitoids have been isolated, so the mechanisms are clearly identified (Khan et al., 1997a, 1997b, 2003).

A number of vegetative covers possess allelopathic potential and release chemicals into the soil that inhibit the germination and growth of certain weeds (Weston, 1996). It is reported from Côte d'Ivoire that maize infestation by *Striga* when undersown with *Pueraria phaseoloides* and *Calopogonium mucunoides* as live cover crops was drastically reduced. There was also some improvement with the sowing of *Cassia rotundifolia* (Charpentier, 1999).

Diseases can thus be avoided through crop selection and the rotation of crops to include some nonhost crops. This is most effective for pathogens that are soil- or residue-borne (Kuprinsky et al., 2002). Diverse cropping rotations contribute to better and more balanced soil fertility for supporting crops because each crop species has different nutritional requirements for optimum growth and development, and each draws on individual nutrients from the soil at different rates (Kuprinsky et al., 2002). This balance has a positive effect on crop resistance to diseases, as discussed in the next section. Although the results of many studies conducted so far highlight the difficulty of predicting exactly how the vegetational diversity introduced through undersowing of live mulches will affect pests and diseases, the general effect is positive.

41.4 Effects of Different Management Practices

Occasionally, no-till practices are associated with an increase in pest and disease severity compared to conventional tillage. However, such differences do not necessarily result in a negative impact on yield. In Mexico, for instance, Kumar and Mihm (2002) found that despite higher damage by Lepidopteran pests, maize production remained higher under no-till than in conventional tillage systems. Also, although white grub presence was reported at Chequèn, Chile, when DSPSC techniques were introduced, no noticeable damage was observed. Particularly the ability of the scarab beetle (*Bothynus* spp.) to damage plant roots was compensated for by a positive effect on greater soil macroporosity that enhanced the soil's ability to draw organic matter down into lower soil layers, which enhanced crop performance (Crovetto Lamarca, 1999).

Recent research in Brazil has distinguished among different subfamilies of Scarabaeidae. Dynastinae normally feed on organic matter and rarely on roots, while Melolonthinae feed mostly on roots and less on organic matter. Root-feeding species become predominant in soils where biodiversity has been reduced, relative to species that decompose litter and other organic matter and do little damage to roots. The total volume of the holes opened by the latter, notably *Bothynus* spp., was as much as 10 times greater in no-tillage agroecosystem than in conventional tillage (Brown and Oliveira, 2004). These saprophagous species bury large amounts of plant litter in the soil, significantly increasing P, K, and organic matter in their tunnels compared to adjacent soil. These tunnels, up to 3 cm in diameter and even more than 70 m⁻², extend from the surface to >1-m depths, putting them, along with earthworms and termites, in the category of ecosystem engineers (Chapter 11).

There is an indirect positive effect from mulching and the use of cover crops of better crop nutrition from minerals derived from the decomposition of organic matter. Balanced and adequate fertility for any crop reduces plant stress, improves physiological resistance to pest attack, and decreases risk of disease. It also results in induced resistance of plants vis-à-vis pests through nonpreference (antixenosis), tolerance, and compensation mechanisms. These mechanisms derive from the biological dimension of soil systems.

41.4.1 Effects on Microbial Communities

Microbial community management is a key element of cultural practices, though it is sometimes underestimated given a lack of knowledge about causal relationships. For millennia, soil health has been maintained empirically, particularly through applications of organic matter, mainly as manure. Faced with possible crop losses due to parasitic attacks, the first farmers progressively adapted their cropping systems to keep risks at acceptable levels (Altieri, 1999).

Ecosystem health has been defined in terms of an ecosystem's stability and resilience in response to some disturbance or stress. It has been known for some time that certain soils are "disease-suppressive" (Corman et al., 1986). This quality can be viewed as a manifestation of ecosystem stability and health (van Bruggen and Semenov, 2000). Soils with high fertility and high levels of organic matter appear to enhance natural mechanisms for biocontrol of pathogens, as suggested by the fact that in some soils pathogens cause little or no disease, despite an apparently favorable environment for them to grow in. There are many ways in which an antagonist can operate to curb or control pathogens. There can be rapid colonization in advance of pathogen presence to pre-empt space and substrates, or subsequent competition may lead to exclusion from a given ecosystem niche. Antibiotics may be produced, or there may be mycoparasitism or lysis of the pathogen (Altieri, 1999).

In other cases, the suppressiveness is probably due to the activity of soil microbiota since suppressive soils consistently show higher populations of actinomycetes and bacteria than do soils conducive to disease. Additions of organic material increase the general level of microbial activity; and the more microbes there are in the soil, the greater are the chances that some of them will be antagonistic to pathogens (Altieri, 1999).

The rotation of diverse crops provides a heterogeneous food base for microorganisms that offers more ecological niches and encourages microbial diversity. Reduced tillage contributes to this diversity because more heterogeneous residues accumulate on the soil surface over time (Kuprinsky et al., 2002). However, high microbial biomass and activity in soils under organic and integrated farming are not always correlated with high disease suppression. Specific organic amendments, such as mulching with straw and the practice of using lucerne as a break-crop in cereal cultivation, have been seen to influence the inoculum potential of *F. culmorum* and resulting disease outbreak and suppression, for example (Knudsen et al., 1999).

Some microorganisms simply assist crop plants to grow better, so that even if a disease is present, its symptoms are masked or impeded (Altieri, 1999). A positive impact of DSPSC techniques, notably using live mulch of *Arachis pintoii*, has been a lower incidence of fungal and bacterial diseases on rainfed rice and cotton, as reported from the humid tropical zone of north-central Brazil (Séguy et al., 1999b). Possible explanations are that better and more stable regulation of water and mineral plant nutrition under DSPSC may minimize water stress and help the crop plants to resist parasitic aggression.

41.4.2 Interactions with Manure

The application of contaminated manure can have some adverse effects on soil and plant health, so such biological amendments can be counterproductive. In Mali, the frequent use of organic manure, often contaminated with the seeds of parasitic plants, is known to favor their dissemination (Hoffmann et al., 1997). *Striga* has been found to be concentrated in certain cattle grazing zones and on their itineraries where manure deposition and application sustain the weed populations (Bengaly and Defoer, 1997). In Madagascar, cattle eating *Striga* plants do not digest the seeds, and thus they contribute

to *Striga* dissemination, either directly through feces or through subsequent applications of manure (Andrianaivo et al., 1998).

Organic manure, particularly cow dung, can be a source of infestation by white grub species, particularly *Heteronychus plebejus* (Rajaonarison and Rakotoarisoa, 1994; Bourguignon, 1997). In addition, certain antagonisms that are enhanced by the addition of organic manure can work against entomopathogenic fungi (see Section 41.4.1). So the application of organic manure, depending on the conditions, can have either positive or negative effects on pests, notably white grubs and *Striga*. Some adverse effects can be solved by pretreatment of organic manure, for instance, by heating as achieved with composting (Chapter 31). No such problem is foreseen with DSPSC practices, however, since this crop and soil management system relies on organic matter derived from litter decomposition, which has positive effects through better plant nutrition.

Plants whose root systems are well developed can sustain a parasitic load higher than others with less favorable growing conditions. Application of organic matter in a soil often has positive effects on root systems' health status, an indirect effect that supports another discussed in the following section. Manure and compost have been found to reduce attacks of *Rhizoctonia solani* on radish and bean (Volland and Epstein, 1994) and of *Pyrenochaeta lycopersici* and *Phytophthora parasitica* on tomato (Workneh et al., 1993). While the reasons for this are not all certain, the effect is widely seen and often reported by farmers who rely on organic nutrient inputs.

41.4.3 Nutrient Effects

By facilitating the quick absorption of any excess nitrogen, plowing modifies plant physiology, and the absorption of other minerals is slowed down (Séguy et al., 1981, 1989). This is particularly the case with *Pyricularia grisea*, the pathogen responsible for rice blast, which is the most important disease of rainfed rice worldwide (Ou, 1985). Blast is a problem for farmers in Madagascar, and its damage is aggravated by the application of inorganic nitrogen fertilizers. This effect is probably due partly to the injurious effects of ammonium accumulation in the cells of plants treated with high N (Ou, 1985). However, also an abundance of soluble nitrogen, particularly amino acids and amines in plants, may serve as a suitable nutrient for fungus growth. Therefore, to minimize the adverse impact from rice blast infection, moderate doses are usually recommended when applying N-fertilizer. Plants receiving large amounts of nitrogen have less silication of epidermal cells and thus lower resistance to herbivores. The application of nitrogen also reduces hemicellulose and lignin in the cell wall and weakens plants' mechanical resistance to blast (Ou, 1985).

Massive nitrogen applications have multiple consequences for plant physiology and for host population structure, thus on plant receptivity to certain diseases. Agricultural practices that lead to significant discrepancies in nitrogen availability (in terms of quantity, form, and balance with other nutrients) are likely to translate into variations in the amount of disease (Primavesi et al., 1972; Séguy et al., 1981, 1989; Chaboussou, 2004).

Rice resistance to *P. oryzae* in volcanic soils may be due to the greater presence and availability of micronutrients such as Cu and Mn, while susceptibility might be linked to the high content of amino acids in plant tissues and to reducing sugars that sustain pathogen development (Chaboussou, 2004). In Cameroon, it has been found that soil type — through its effect on rice plant nutrition — was a determinant in rice plant resistance to blast (Séguy et al., 1981). In the Lake Alaotra plain of Madagascar, on peat soils recently put under cultivation, nitrogen release during the first year was so much that rice plants had abnormal growth and were destroyed by rice blast (Séguy et al., 1981). The pathways

of influence and causation in the domain of plant nutrition are multiple, and effects can be ambiguous, because of countervailing influences. However, studies are showing that many soil factors affecting plants' nutrient access and supply directly affect the damage caused by pests.

41.5 Assessing the Effects of Pesticides

DSPSC systems, in addition to minimizing the effects that mineral fertilizers can have on soil biota, reduce reliance on pesticides, particularly herbicides, to control weeds and kill them. Cover crops are used instead to form a suitable mulch that protects the soil and suppresses weed growth. In some cases, carefully selected insecticides are applied, such as seed treatments, and there can be use of herbicides in cases where the ground cover strategy is not sufficient at first. Experiments are ongoing with different crop rotations that can minimize or end the use of agrochemicals, but DSPSC is not a strictly "organic" system. It combines inputs and practices with the aim of mobilizing biological processes for farmers' benefit. Its attitude toward the use of agrochemicals is therefore empirical and pragmatic.

Herbicide applications can, in fact, increase pest damage to crops by removing weeds as alternate hosts or by driving the pests on to nearby crops. For instance, the larvae of stalk borer (*Papaipema nebris*) typically move from grassy weeds to maize when herbicides are applied, so that certain areas within maize fields become more damaged after weed removal (Stinner and House, 1990). Musick and Suttle (1973) have observed that armyworm adult moths (*Pseudaletia unipunctata*) oviposit on small grain cover crops, such as rye and wheat, in which maize was planted directly, so when herbicides kill these grasses, the larval armyworms feed on maize.

If one has to drill seed directly into a green crop or weed residues, for example, to take advantage of rain in the winter time, a synthetic pyrethrum insecticide may be applied first in a tank mix with glyphosate to prevent insect attacks on the emerging small plants (Pruett and Guaman, 2003). Because of the problems associated with specific pest species in conservation-tillage farming, considerable effort has been directed toward developing tailored insecticide control measures for these systems. In temperate climates, for example, implementation of DSPSC often results in increased slug problems during the first years. In such instances, the application of a molluscicide after crop emergence can be highly beneficial (Leake, 2001). Also, in Madagascar, in areas where black beetle attacks are greater on mulch than on plowed plots, seed treatment is mandatory for upland rice production, although its cost may reduce the attractiveness of DSPSC (Charpentier et al., 2001).

No-till cultivation systems, on the other hand, may buffer the impacts of insecticide on the arthropod assemblage, thus minimizing its effect so it has less impact than in conventional cultivation. With deltamethrin, for instance, there are significant decreases in arthropod abundance in the maize canopy compared with conventional tillage (Badji et al., 2004). On the other hand, Brust et al. (1985) found that a soil-applied organophosphate insecticide did not suppress soil arthropod predator activity any more in no-till than in conventional tillage treatments. As DSPSC increases the overall sustainability of production systems by taking advantage of natural biological processes for pest management, the evidence reported in this section underscores the importance of keeping pesticide use to a minimum and of using selective molecules so as to minimize any inhibition of biological control processes.

41.6 Discussion

Some disturbance to the environment is a necessary part of agriculture. Just like putting a field under tillage after fallow will alter pest and plant disease problems, so reduced tillage practices, like any change in cultural practices, may increase, decrease, or have no effect on these problems. What will happen depends on the soil type, location, and prevailing environment, as well as on the species of insects or pathogens, as well as plants involved (Bockus and Shroyer, 1998; Kuprinsky et al., 2002).

For instance, the extreme diversity of pedologic situations created by the different geological processes by which the highlands and medium-altitude regions of Madagascar were formed, complicated by the variations in altitude and subtropical climate and the great biodiversity and endemism found in Madagascar, has contributed to biological equilibria that can vary greatly over relatively small distances. These differences in the entomofauna spectrum may account for the apparently contradictory results reported in the introduction to this chapter.

A review of the results of earlier work has shown that the implementation of DSPSC in most situations is associated with reduced pest and disease incidence on crop plants. Evidence has been offered of a wide variety of possible mechanisms accounting for this: direct physical effects of tillage (or the lack of it) and of mulching; changes in pest behavior due to plant diversity; effects of semiochemicals; increased predation, parasitism, or antagonisms; and induced crop resistance through better nutrition.

However, when switching from plowing to no-till, it will probably not be appropriate to continue all other practices in the same way as before. Where farmers have experienced problems with no-till or with direct-drill techniques, this has usually been associated with their failing to adopt other new practices to accompany the changes (Leake, 2001). Some time may be required before new favorable equilibria are reached. Thus, the targeted use of selected chemical inputs, at least for their "starter" effect, can be compatible with the mobilization of soil biological processes underlying DSPSC. This is in line with CIRAD's flexible approach to crop protection (Ratnadass et al., 2003).

The experience of CIRAD and its partners in Madagascar (particularly FOFIFA and TAFa) to alleviating constraints on upland rice production, building on earlier work in Brazil and elsewhere on the African continent, has justified a more holistic approach to soil system management, appropriately adjusting the management of crop, water, and nutrient factors, along with soil management methods that promote more favorable biological conditions for successful crops.

Our organizations have collaborated to provide special opportunities for implementing IPM approaches, evaluating the systems being improved with a focus on the major biotic constraints (white grubs/black beetles, rice blast, and Striga). The main objectives have been: (1) to determine mechanisms involved in the reduction of these pests' adverse impacts in DSPSC; and (2) to minimize externalities of these systems, both in the final product and in the environment, in term of chemicals used for crop protection, so as to enhance production outcomes.

To meet these objectives, we are exploring the potential for using within DSPSC certain biostimulants and concentrated organic fertilizers that can speed up induced resistance, as well as plant-derived insect repellents, along the lines discussed in Chapters 32–35. Although these are assumed to be more environmentally benign than traditional chemical pesticides, we know that their potential unintended side-effects need to be studied and evaluated (Chen et al., 2002; Sonnemann et al., 2002).

This is an area of knowledge generation and practical application where the science is still young, and where there are many opportunities to make improvements. The conclusion from experience so far is that the control of pests and diseases is best pursued in conjunction with knowledge of soil-system management, to take advantage of whatever these associated practices can contribute to making agriculture more reliable and productive.

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