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DISEASE MANAGEMENT: CULTURAL PRACTICES

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25.1 Introduction

The term cultural control describes the activities of humans aimed at controlling disease through the cultural manipulation of plants. At present, cultural control practices find their greatest value in large area and low unit value crops such as temperate cereals and forests. For some crops, such control practices may be the only economically viable methods available. Many cultural practices were features of 'traditional' farming and have been replaced as cropping has become more intensive. High labour costs in modern agriculture may prohibit the use of many of these practices. Cultural control practices could be considered a form of biological control and tend to be preventative and indirect in their actions against pathogens. The success of cultural control practices ultimately depends on understanding the biology of the pathogen and the response of the host to infection. Such knowledge facilitates management decisions which 'attack' parasites at vulnerable stages of their life cycles. It may be difficult to assess their effectiveness because the farming operations are often performed well in advance of expected pathogen attacks.

In some cases, disease can be avoided altogether by planting a crop in different sites or regions or at different altitudes from those in which it normally grows. For example, vegetatively propagated crops such as cassava, potatoes, yams, sugar cane and sweet potatoes grown at lower elevations in the tropics often become heavily infected with pathogens, especially viruses. Crops grown to produce planting material for the next crop may be grown at higher altitudes where there are fewer insects to transmit viruses and conditions do not favour disease development. Colombian farmers traditionally obtained their seed potatoes from high altitude areas where there were few aphids and transmission of virus diseases was minimal. Diseases of stored products have been avoided traditionally by storing produce at high altitudes to make use of the effect of low temperatures in slowing the spoiling process. In choosing a site for a crop, it is wise to check the previous cropping history of the land to ensure that pathogens that may be present from a previous crop will not infect the crop to be planted. For example, chickpeas should not be planted on land on which lucerne was previously grown as Phytophthora root rot affects both crops.

To prevent or control disease outbreaks, growers can either reduce the initial levels of inoculum or reduce the rate of spread of established pathogens. This chapter discusses cultural practices which attempt to destroy inoculum or inhibit the spread of plant pathogens.

25.2 Cultural practices which reduce initial levels of inoculum

Historical evidence indicates that where pathogens have been introduced into previously clean sites, disease epidemics usually follow. The spread of disease to new areas, new plants or new plant products can be prevented or reduced by practising quarantine and sanitation (crop hygiene or ways of maintaining plant health) which are discussed more fully in Chapter 23 together with methods for disinfesting soil, potting media and irrigation water so they do not carry inoculum.

Selection and preparation of planting materials

A critical decision in crop production is the selection of the cultivar(s) to be grown. Some cultivars are resistant to particular pathogens and are inherently less damaged than other genetically related plants growing in the same location. **Resistant cultivars** (Chapter 26) have provided one of the most successful approaches to the control of pathogens of many crops, especially those which cannot be controlled by other means. However, continuous plant breeding programs are often necessary to overcome the effects of the development of new races of pathogens and 'breakdown' of host resistance. Growers therefore need to be aware of the availability of new cultivars and be able to evaluate their potential in relation to other agronomic characteristics.

In natural plant communities, the diversity of species results in the spatial separation of individual plants of a particular species (see Chapters 26 and 32). Discontinuous distributions tend to reduce the spread of pathogens from one susceptible host to another. Many agricultural production systems, however, emphasise the growing of crops as dense populations with genetic homogeneity (monocultures). Such practices facilitate the spread of pathogens because all plants may be susceptible to attack. In an attempt to correct this situation, a number of **mixed cultivars** and **multiline cultivars** have been released incorporating a range of resistances (Chapter 26).

All of the major plant pathogens can be transmitted by seed or propagating material. Materials which have been certified free from disease following field inspection or laboratory testing provide a useful safeguard to growers (Chapter 23). The value of **certified seed** is further enhanced if the parent crops have been grown in areas where particular parasites are unknown. For example, commercial lettuce seed production for export can be undertaken in some areas of Australia because of the absence of lettuce mosaic virus. Alternatively, rigorous chemical control programs for selected organisms may be instituted during crop growth and storage to reduce or eliminate pathogens from planting materials. If these procedures are not followed, growers may have to treat seed (Chapter 22) or other propagating structures prior to sowing. Efficient seed-cleaning procedures also contribute to the control of some diseases such as earcockle of wheat caused by the nematode *Anguina tritici* by removing infected seeds and leaving only uninfected material.

Pathogens can be transmitted to healthy material by contaminated knives and secateurs during the preparation of **vegetatively propagated material** for planting. In such situations, growers need to practise proper hygiene procedures to prevent transmission of pathogens (Chapter 23). For vegetatively propagated crops such as carnations and chrysanthemums, tissue culture techniques may be necessary to obtain disease-free planting stocks. For example, viruses and vascular wilt fungi such as *Fusarium* and *Verticillium* do not reach the apical meristems of their hosts until late in the development of the disease. Pathogen-free meristems can be tissue-cultured and used as the basis of a vegetative propagation program.

Even if planting materials are apparently free from parasites, infection may occur if they are damaged during **planting operations**. Common causes of damage include incorrect adjustment of mechanical planting devices and seedling injury during transplanting. Seedling tobacco plants can also be infected with tobacco mosaic virus via workers' hands during transplanting operations. In such situations, growers need to practise proper hygiene procedures to prevent transmission of pathogens.

Destruction of crop residues

Crop residues provide suitable substrates for many pathogens. Burying, burning and removal of postharvest crop residues are important cultural control practices performed during intercrop periods. The effect of destroying crop residues on particular pathogens depends on the type of crop (annual, perennial or harvested product), the extent of the cropping area and the survival mechanisms and host ranges of the target pathogens.

If crop residues are **buried**, some potential pathogens may be either killed or inhibited in their development. Deeply inverted surface trash assists in the control of groundnut (peanut) blight because the causal fungus (*Sclerotium rolfsii*) requires a food source near the surface of the soil. Plants with shallow root systems may also escape infection if debris from the previous crop is ploughed in deeply. This practice has been relatively successful in controlling verticillium wilt of mint (*Mentha* spp.). Fungal pathogens such as *Sclerotinia* and *Claviceps* which produce sclerotia can be controlled to some extent by burying surface soil. While burying crop residues can effectively reduce inoculum, if the form of tillage redistributes pathogens horizontally rather than vertically in the soil, it may promote, rather than reduce, future crop damage. Crop residues and other organic matter can also be composted before reuse. Heat generated during the composting process kills pathogens, provided the material is turned regularly during composting so that all of the organic matter has a turn at being in the hottest part of the compost pile.

Burning the stubble of harvested cereal crops has been a common practice throughout the world. Rice stubble is burned in many areas of Asia to reduce the inoculum of *Sclerotium oryzae* (stem rot), *Curvularia lunata* (black mould) and *Corticium sasaki* (sheath blight). In Australia, fire has been reported to control *Septoria* spp. and flag smut (*Urocystis agropyri*) on wheat, *Septoria avenae* on oats and *Pyrenophora teres* and *Rhyncosporium secalis* on barley. For example, the incidence of flag smut in wheat was significantly reduced in crops in which the previous years stubble had been burnt (Table 25.1). Good control of *Cephalosporium gramineum* and *Pseudocercosporella* spp. in cereal crops has been obtained following stubble burning in other countries.

Table 25.1 The effect of stubble burning on the incidence of flag smut in a commercial crop of a susceptible (cv. Gamut) and a resistant (cv. Timgalen) cultivar of wheat in the North Star area of northern New South Wales in 1968.* (Unpublished data of P. B. Metcalfe and J. F. Brown.)

Treatment	Percentage of infected plants*	
	Gamut	Timgalen
Unburnt	44.0	1.5
Burnt	1.3	Trace

* The areas assessed were sown to the cultivar Gamut in the previous season (1967) in which 12% of plants were diseased.

Burning crop debris is not restricted to cereal crops. Burning potato leaves after harvest reduces inoculum of *Alternaria solani* (early blight) for the next season. It also helps control weeds in the potato crop. In the slash and burn method of agriculture practised in some tropical countries, burning a 10 cm layer of litter on the soil surface destroys nematodes to a depth of 9 cm. In many areas of the world, sugar cane crops are routinely burned to facilitate harvesting operations. Many pathogens are eliminated by the intense heat produced. Where this practice does not occur, postharvest burning of trash may be employed as a disease control practice.

The success of burning in destroying inoculum is determined by the intensity of the burn which is, in turn, influenced by the amount, moisture content and quality of the plant debris, the wind velocity and the duration and temperature of the burn. However, any advantage in disease control has to be weighed against the adverse effects of burning. These include loss of nutrients, contamination of the environment with smoke, addition of carbon dioxide to the atmosphere contributing to warming of the earth and increased soil erosion following the removal of protective vegetation.

Experience with yellow spot (*Pyrenophora tritici-repentis*) of wheat has shown that stubble burning can be used to reduce the level of inoculum of a fungus without contributing to soil erosion. Inoculum of *P. tritici-repentis* survives between crops in wheat and triticale stubble and while stubble burning soon after harvest was practised, the disease was of minor importance. Unfortunately, stubble burning left the soils exposed to loss of water through evaporation and severe erosion by run-off following high intensity summer storms. Farmers stopped burning their stubble and yellow spot increased in importance, reducing yields. To prevent erosion and improve water infiltration, stubble now is left on the soil surface over the summer months and ploughed in, burnt or grazed shortly before sowing the next season's crop in autumn or early winter. This practice has resulted in considerable yield increases under conditions suited to the development of severe yellow spot.

Because burning can totally destroy a source of inoculum, it is widely used in eradication campaigns to remove inoculum of newly introduced pathogens and prevent an epidemic developing. A notable example is the removal and burning of citrus trees infected with citrus canker (*Xanthomonas citri*) in many countries.

In Australia, sheep or cattle are widely used to remove crop stubble after harvesting. Sheep are also used to remove fallen fruit in apple orchards.

Elimination of living plants that carry pathogens

Crop plants remaining from previous seasons and **volunteer host plants** that establish in fallowed land or around cropping areas when climatic conditions are suitable during intercrop periods may provide sources of inoculum for succeeding crops. Unwanted crop plants should be destroyed by either cultivation or the application of herbicides.

Weeds or wild plants may act as **alternative hosts** of plant parasites allowing the pathogen to survive between seasons and providing a source of inoculum in the new growing season. For example, grasses such as *Hordeum leporinum* are hosts of the wheat take-all fungus *Gaeumannomyces graminis*, many dicotyledonous weeds contain *Meloidogyne* spp. and other nematodes and certain leguminous green manure crops maintain the halo blight organism, *Pseudomonas syringe* pv. *phaseolicola*. Removing the overseasoning host eliminates or reduces inoculum for the following season. However, the relationships between weeds and crop parasites are often obscure and many weeds are symptomless carriers of various viruses. In other situations, it may not be practicable to eliminate alternative hosts because they can be commercially valuable crops. Only cooperative action by growers to delete crops, rearrange crop rotation sequences or undertake concerted efforts to destroy virus vectors can overcome these problems.

Other important inoculum sources are the **alternate hosts** of many destructive rust fungi. Some rusts cannot complete their life cycles in the absence of alternate hosts, which also provide the opportunity for the rust fungus to undergo sexual recombination, possibly producing new races of the fungus. However, the influence of an alternate host on a rust disease can be highly variable and the effectiveness of campaigns to eradicate alternate hosts can be unpredictable.

Two important macrocyclic cereal rusts, *Puccinia graminis* and *P. coronata* require alternate hosts (*Berberis* spp. and *Rhamnus* spp., respectively) to complete their life cycles. In the absence of their alternate hosts, both rusts survive on susceptible hosts (mainly volunteer plants) via urediniospore infections. This is the way wheat stem rust oversummers in Australia. In colder climates, such as North America, where urediniospores cannot survive the severe winters, the alternate host may play a greater role in providing primary inoculum in a growing season. There has been a concerted effort to eradicate *Berberis* spp. in the United States. However, infections in wheat crops still arise from urediniospores carried by air currents from the warmer southern states or from Mexico. For these rusts, removal of the alternate host tends to postpone a disease outbreak by eliminating a primary source of inoculum. It also prevents sexual reproduction reducing the probability of producing recombinant genotypes.

In contrast, *Gymnosporangium sabinae* (the causal agent of cluster cup rust of pears in North America) always requires the presence of its alternate host, Juniper, to complete its life cycle. Removal of juniper plants in the vicinity of a pear orchard prevents establishment of the disease. Sometimes the alternate host of a rust has greater economic importance than the primary host. *Cronartium ribicola* is a widespread rust of *Ribes* spp. and its alternate hosts are various five-leaved *Pinus* spp. Attempts to control the devastating pandemic of this pathogen in North America have largely concentrated on the eradication of *Ribes* spp. near forests containing more valuable *Pinus* spp.

Removing diseased plants or plant parts to eliminate sources of inoculum is carried out routinely in many nurseries, greenhouses and high-value crops. Strawberry leaves infected by various leaf-spotting fungi are removed early in the season. Diseased parts of larger plants such as tree crops are often removed by pruning. Infected branches are removed in cases of fireblight of pome fruit (*Erwinia amylovora*), apple canker (*Nectria galligena*), powdery mildew of apples (*Podosphaera leucotricha*) and silver leaf of plums (*Chondrostereum purpureum*). Mummified fruit as well as diseased twigs should be removed from pome and stone fruits to reduce the inoculum of *Sclerotinia* spp. Subsequent sanitation measures usually involve burning pruned material and treating cut surfaces with suitable fungicides. Pruning inevitably influences the microclimate within the tree canopy indirectly affecting any subsequent disease development. In mixed farming enterprises, livestock can be used to 'graze off' crop residues.

Crop rotation

Crop rotation, the successive planting of different crops in the same area, is one of the oldest and most widespread cultural practices. It may also include a fallow period in which land is 'rested' from cultivation. Crop rotation improves soil fertility, moisture and texture and assists in weed and pathogen control. The most successful rotations employ intervals between susceptible crops which are longer than the known survival period of pathogens. Rotations are most likely to be effective in controlling pathogens such as *Gaeumannomyces graminis*, *Pyrenophora tritici-repentis*, various *Colletotrichum* and *Phoma* spp. and some pathogenic bacteria which only survive in the presence of a specific host (or its residues) or as resistant propagules. They are less likely to be effective in controlling damping-off and root-rot fungi such as *Pythium* and *Aphanomyces*, *Fusarium* spp. including the vascular wilt pathogens, *Sclerotinia* spp, *Macrophomina phaseoli* and *Plasmodiophora brassicae* which can survive for long periods in the soil as saprophytes.

Probably the most widely used rotations are for the control of soil-borne pathogens of cereals. These often include either a non-host leguminous crop which can improve soil fertility as well as reducing inoculum or a fallow period during which alternative weed hosts and volunteer plants are removed or destroyed. Take-all (*G. graminis*), foot-rot (*Pseudocercosporella herpotrichoides*), *Ascochyta* sp. and some other pathogens of wheat have been controlled in some regions by removing grass hosts, especially during fallow periods. Long term (long course) rotations are required to control pathogens such as *Streptomyces scabies*, *Phymatotrichopsis omnivora* and *Rhizoctonia solani* which survive in the soil as resistant spores or as sclerotia. In some European countries, yields from sugar beet crops may become uneconomic due to infection by the nematode *Heterodera schachtii*. When non-host crops are grown or the land is fallowed, populations of the nematode fall to about half their initial level. This trend must continue until a 'safe' population level is attained before another sugar beet crop can be grown. The composition and length of rotations to be grown on 'beet-sick' soils is controlled by legislation. Regular cultivation of fallow land during dry seasons can destroy pathogens such as the bacterium *Ralstonia solanacearum* because crop debris is repeatedly brought to the surface of the soil and exposed to the drying effects of the atmosphere. However, extended fallow periods are of dubious value because the land is unproductive.

Some rotations may include a crop which inhibits the development of a specific pathogen. High levels of root knot nematodes (*Meloidogyne* spp.) occur in soils following crops such as maize, sweet corn and capsicum. However, other crops such as forage sorghum, pinto peanut, watermelon, Rhodes grass, green panic and cowpea host few nematodes. Crops of susceptible plants following these crops show little sign of nematode damage. Legumes such as *Crotalaria* and *Stylosanthes* spp. have also been used to reduce populations of the nematode *Pratylenchus* spp. in soils. Similarly, *Tagetes* spp. (marigolds) inhibit the development of a range of nematode species. Many brassica crops produce glucosinolates that break down to produce isothiocyanates which are active against several soil-borne pathogens.

25.3 Cultural practices which reduce the rate of spread of disease

In many cases, cultural practices are directed at improving the growing conditions of plants by providing proper nutrition, moisture, light and lack of competition from other plants. They may also be aimed at creating conditions unfavourable for the development of pathogens. A grower's ability to manipulate the environment is somewhat limited in the field but in greenhouses or storage facilities, high levels of control over environmental parameters can be achieved.

In simple greenhouses, proper spacing of plants and the provision of good ventilation reduces humidity and inhibits infection by pathogens such as *Botrytis*. In more sophisticated greenhouses, growers frequently lower the relative humidity, especially at night, to dry the surfaces of plants and discourage the spread of pathogens such as *Botrytis* spp. and *Diplocarpon rosae*. In the field, more rapid drying of plant surfaces can be achieved by improving air movement through the crop by sowing or planting at lower densities, orienting rows in the direction of the prevailing wind and by irrigating in the morning so plants can dry off during the day. Crops on northern facing slopes (in the southern hemisphere) dry more quickly than crops on other aspects. Pruning or training procedures that open the canopies of fruit trees to allow light penetration also improve ventilation of the canopy and reduce the incidence of disease. Conversely, practices which allow plants to stay moist for long periods favour disease development. Thus windbreaks or other structures that interfere with airflow or irrigating late in the day so plants remain wet all night encourage disease development.

Other aspects of the environment can be manipulated to reduce disease development. To control the spread of fungi that require ultraviolet or near-ultraviolet light for sporulation, growers may cover plants with films that block out radiation in these wavelengths to stop the fungi sporing. In storage facilities, proper aeration hastens drying of a product's surface and inhibits germination and infection by bacterial or fungal pathogens. Rapid cooling after harvesting and storage under conditions of low temperature and appropriate levels of carbon dioxide not only prolongs the life of fresh produce, but also inhibits disease development.

The remainder of this section discusses ways of improving plant growth and creating environments in the field that discourage spread of pathogens from one host to another.

Tillage practices

Tillage incorporates various types of organic matter including crop residues, manure, green manure, volunteer crop plants and weeds into the soil. Tillage practices tend to have indirect effects on the spread of plant pathogens, although some forms of inoculum can be widely dispersed by implements. Tillage reduces populations of weeds and volunteer crop plants that harbour pathogens between crops. It also buries plant pathogens from the top soil into deeper layers of the soil where they cause less or no disease. Practices involved in the preparation of seed beds can greatly modify physical properties of soils such as moisture characteristics, bulk density, aeration and temperature profiles which in turn influence the incidence of disease. Forming the soil into hills, ridges or raised beds provides better drainage and irrigation. Tillage may also influence nutrient release mechanisms and the total effect is often expressed as increased crop vigour. Healthy plants may be more resistant to some pathogens but the more humid microclimate within the crop can be conducive to the spread of other pathogens. Successive tillage operations can reduce inoculum levels of some pathogens through exposure of the inoculum to desiccation by the sun.

Modern agriculture has moved away from regular cultivation of soil between crops towards a system of minimum tillage, or even no-tillage. Minimum tillage is a method of planting crops that involves no seed bed preparation other than opening the soil to place the seed at the intended depth. Usually the soil is not cultivated during crop production and chemicals are used for weed control. Minimum tillage reduces injury to the roots of crop plants caused by mechanical tillage or hand weeding, reducing the opportunities for opportunistic pathogens to infect. It also reduces the spread of pathogens by tillage practices. However, it may favour the development of some diseases such as those that can be controlled by burying inoculum too deep for infection of plant roots to occur. In no-tillage systems, crop residues are left on the surface of the soil. The residues may become a food source for pathogens or alter the physical environment occupied by both the host and its pathogens.

The effect of tillage practices on the soil microflora is often overlooked. Many of these organisms are competitors or antagonists of soil-borne pathogens. Minimum tillage practices are thought to promote greater microbial antagonism in the vicinity of cereal roots than normal cultivation practices. However, little is known about the influence of cultivation on these activities although incorporation of organic matter (e.g. green manure crops) is known to reduce the incidence of some diseases. Plant residues intensify the microbial activity of the soil which may result in the formation of fungitoxic or even phytotoxic compounds.

Sowing and harvesting practices

Many crop plants tend to be more susceptible to attacks by various parasites at certain stages of their development. Changing the usual **sowing time** of a crop can exploit weather conditions which are unfavourable for the spread of pathogens or their vectors and reduce crop losses. These practices often necessitate introductions of new cultivars which are adapted to the selected growing period. However, the introduction of a 'new' cultivar with different growth characteristics may also create other disease problems. In temperate climates, the crop growing season is largely influenced by the prevailing temperature regime, providing that rainfall is adequate or irrigation is possible. Other strategies may be applied in tropical climates so that a susceptible growth phase occurs in relatively dry periods. Greatest variation in sowing times is possible in greenhouses where considerable manipulation of crop microclimates is practicable.

Methods of sowing vary considerably between crops and even with the same crop in different regions. It is therefore difficult to generalise about the effect of sowing methods on the spread of diseases. Farmers aim to optimise germination and early growth at densities which give maximum yields in the particular environment. **Depth of sowing** is usually determined by seed size and the moisture status of the soil. Deeper sowing may promote germination but it also lengthens the (usually) susceptible pre-emergence seedling phase. Smuts and seedling diseases caused by *Fusarium* spp. and *Rhizoctonia* spp. are more serious if seeds are planted deeply. Similarly potato seed pieces are more readily attacked by *Rhizoctonia* if planted too deeply.

Crop density can influence disease development. Generally as the density of a crop increases, the incidence of disease also increases. For example, in the 1950s, due to an increased demand for seedlings, nurseries expanded in size and increased the density of seedlings in their nursery beds. This practice lead to crowding of the seedlings and serious epidemics of damping-off caused by fungi such as *Pythium*, *Fusarium*, *Rhizoctonia* and *Cylindrocladium*. There are a number of reasons why high plant densities increase disease incidence. Most are associated with the ease of transferring inoculum from one plant to another when the plants are close together. For example, the distance pathogens or their vectors have to travel from one host to the next is reduced, splash dispersal of inoculum is easier and there is also increased contact between the leaves or roots of neighbouring plants. In addition, with denser plantings, more plants may be wounded during cultivation creating more opportunities for weak pathogens to infect. Finally, the micro-environment within the crop is altered. Temperatures are more uniform, the relative humidity increases and leaves stay wet longer after rain or dew. All these conditions favour the development of disease.

Sometimes, dense stands may reduce disease incidence and increase yields. In Africa, the aphid vector of the groundnut rosette virus is attracted to broken ground cover rather than continuous ground cover so dense planting inhibits the landing response of the vector. In this case, weeding actually increases disease incidence because it leaves breaks in the ground cover.

Farmers can manipulate plant densities by varying sowing or planting rates and may use increased rates to compensate for expected crop losses from pathogens. Crop density can also be manipulated by pruning, thinning, trellising, fertilisation, water management, staking and harvesting plants or plant parts, depending on the types of crop. All these practices are designed to prevent foliage or root contact.

The **direction of sowing** in some row crops may influence disease incidence. Reports from northern Australia suggest that blue mould of tobacco (*Peronospora hyoscyami*) can increase in severity if rows are aligned in an east-west direction because plants are less exposed to the drying effects of sunlight than in rows oriented north-south.

Germination and early seedling growth can be promoted by **modifying the soil environment** around the seed. Practices such as lime pelleting may either directly inhibit some infection processes or indirectly reduce disease via greater seedling vigour. Soil-borne pathogens such as *Phytophthora*, *Pythium* and *Aphanomyces* are favoured by high soil moisture so improving soil drainage or sowing or transplanting into raised beds, ridges, mounds or hills reduces the incidence of disease.

Intercropping

Intercropping, the growing of a crop or crops between the rows of another crop, is more common on smaller farms and is very popular in China. Labour requirements increase as the number of crops increases, but total production is