Introduction

Improvement in crop management using modern machinery equipment, fertilizers, and pesticides and progress in plant breeding within a few selected crops has led in recent decades to highly specialized agricultural practices on farms. Out of more than 300,000 plant species existing, about 7,000 crops are known to be cultivated for human or animal diet; however, 60% of the world’s energy source is based on only three crops, namely wheat, maize, and rice [1]. As a consequence, a general impoverishment of plant diversity and a high degree of genetic erosion in several important crops for human nutrition is documented since the end of World War II [2].

Simplification of the ecosystem by using one-sided crop rotations, monoculture, and crop plants of uniform genotype and the elimination of weeds with herbicides results in a strong selection for adapted pests, pathogens, and weeds leading to frequent resistance breakdown and severe weed infestations [3–5] and, importantly, a general loss of biodiversity [6].

Increasing the diversity of selection pressures acting on pests and weeds can reduce their ability to develop resistances to pesticides. Diverse crop ecosystems with adapted crops in sequential cropping including cover crops and living mulches, crop populations, and species mixtures are generally less damaged by pests, pathogens, and weeds compared to monocultures [2]. Interestingly, weeds are less abundant but weed species diversity is often higher within such diverse crop rotations. Hence, outbreaks of weed, pest, and disease epidemics and the probability of losses are reduced [4,7,8].

In this chapter, diversity by planting sequence (crop rotation), crop-border diversity, and crop-weed diversity are discussed.

Influence of Crop Rotation on Diseases, Insect Pests, and Weeds

The positive effects of a diverse crop rotation on yield and agricultural stability have been well known since ancient times. Awareness has built that much of the rotation effects lie in the plants themselves as they release considerable amounts of organic compounds into the soil in order to influence the micro-biome, the solubility of nutrients and to interact with other plants. Most pathogens and pests are weak
competitors outside their hosts and barely survive. If soil life is abundant, then it will outcompete and often directly live on the resting stages of pests and pathogens and weeds [9].

Crop rotation is most effective in the case of specialized pathogens and pests that are dependent on a host crop or have a narrow host range. For example, many soil-borne pathogens or insects survive on root or plant residues and require the cultivation of a susceptible crop for continuous survival. The length of host crop interval for insect or disease control will depend on how quickly the insect pest or pathogen can be destroyed by starvation and/or by other antagonistic effects [10,11].

With respect to weeds, important criteria for their control are variation in planting time and timing as well as techniques of seed bed preparation [12,13]. To prevent weeds from germinating simultaneously with the cash crop or at least from seed shed, the whole cropping system needs to be considered [14]. Main effects are caused by the sowing time of crops (winter or spring crops), sequence and placement of crops in the crop rotation, competitive ability of different crops against weeds, and direct weed control (herbicides and/or mechanical control) [15]. Allelopathic effects, that is, the exudation of specific compounds from the roots of certain crops may reduce germination of different weeds [15,16]. For perennial weeds, methods that deplete the weed storage organs through competition, for example, due to living mulches and perennial forage crops, and/or frequent mowing can be useful to reduce number and biomass of weeds [17–19]. These methods combined with fragmentation of weed rhizomes that can reduce the viability of storage organs have proven a high efficacy in Quackgrass (Elymus repens) control in Sweden [20]. In monoculture and pure grain rotations, weed infestation can reach a high level and weeds are more difficult to control compared to a rotation in alternation with dicotyledonous plants, for example, field beans, potatoes, or canola [21,22]. Especially the degree of infestation of problem weeds, for example, Apera spica venti, Viola tricolor arvensis, and Matricaria spp., increases considerably [23,24].

When developing a crop rotation, certain criteria should thus be considered: adequate change in tillage practices and timing, maintenance of high levels of organic matter in the soil, inclusion of crops which do not stimulate subsequent growth of the pathogen or crops that have direct negative effects on pests and pathogens (e.g., producing toxins) [11]. For example, oats and brassicas, such as various mustards, are known to exude substances that are directly suppressive to many pathogens, pests, and weeds and therefore justifying their recent popularity in rotations [25–27]. However, they are also hosts to some broad-range pathogens such as Fusarium avenaceum. Such broad host range pathogens need to be managed through the enhancement of soil suppressiveness [28,29]. To achieve this, soil protection from damaging compaction through heavy machinery, radiation, drought, and heavy rainfall by high aboveground living and dead biomass, such as occurring in minimum tillage systems, is mandatory [28,30]. In addition, this will foster the microbial activity in the topsoil layers and result, in the long term, in sustainable production systems.

Influence of Decoy and Trap Crops on Pests

Decoy crops are non-host crops that are sown to stimulate the activation of dormant propagules of the pathogen in the absence of the host. In this way, the soil-borne pathogens waste their inoculum potential. For example, Lolium spec., Papaver rhoeas, and Reseda odorata can act as decoy crops for the pathogen Plasmodiophora brassicae in Brassica [31]. In the case of trap crops, the crop is host to the pathogen often nematodes. The trap crop attracts nematodes to infect, but the crop is harvested or destroyed before the nematode can complete its life cycle. A famous, still effective method had been developed by Julius Kühn in the 1840s in Germany when certain crucifers are sown and plowed before the beet cyst nematode (Heterodera schachtii) can fully develop its life cycle [26]. Recent breeding efforts resulted in H. schachtii-resistant oilseed radish varieties that are used as winter cover crops prior to growing sugar beets. Root exudates of resistant varieties induce hatching of young nematode larvae from eggs and cysts with subsequent penetration of the radish roots. However, due to the resistance mechanism, H. schachtii juveniles are not capable of building large feeding sites within the radish roots, which prevents the forming of new cysts [32].
**Influence of Weed and Border Diversity on Pests and Diseases**

Weeds not only compete with crops; they may also be intermediate hosts for diseases and parasites while at the same time offering food and refuge to beneficial insects within the agricultural ecosystem. Within monocropped fields, weeds are important sources of biodiversity and may be useful to improve the stability of the agricultural ecosystem. They play an important ecological role by supporting a complex of beneficial arthropods that aid in suppressing pest populations and thus the pest damage [33–36]. Strip management with weeds or flowering crops is by now standard in many sustainable perennial cropping systems such as orchards (e.g., [37–39]). Weed strips or living mulches, such as grasses or clover species, sown between winter cereals increase ground beetle densities and the number of species considerably by providing these beneficial arthropods with better food supplies and more suitable overwintering sites, from which they can colonize cereals in spring [40].

The abundance and diversity of entomophagous insects within a field are closely related to the character of the surrounding vegetation but also to the field size [6, 41]. There are many examples that indicate that crops cultivated near hedgerows, grassy margins, or uncultivated fields with flowering weeds sustain less damage by insect pests than crops cultivated in the absence of such flowering vegetation [33–36]. Nevertheless, it is important to consider the complete life cycle and feeding habit of pathogens and insect pests. Certain weeds and structure elements will serve as alternate hosts to crop pathogens. Carrot flies (*Psila rosae*) need hedges nearby to protect themselves from heat and many aphids overwinter in woody plants. There, adequate distances to fields or the inclusion of specific border strips as trap crops need to be considered [7]. In most cases, field margins, consisting of hedges, sown grasses, and flower strips, for example, provide more beneficial effects through natural enemies regulating pest populations than detrimental effects through pest habitat provision [42].

**Future Concerns**

Diversity provides an essential key to reduce the risk of losing crop yield to pest damage. Of immediate concern are the effects of climate vagaries and change that will lead to the permanent change and invasions of new pests to new areas [43]. Many pesticides may disappear from the market in the near future due to their detrimental effects. Thus, massive insecticide use in combination with increasing field sizes and simplified cropping sequences were made responsible for the drastic insect decline in the past decades [44], while glyphosate and other herbicides are antibiotics and suspected of being responsible for the development of multi-resistance with direct implications on human health [45–48] including in bee decline [46]. The realization of greater crop diversity by crop rotation and trap crops and surrounding vegetation to stabilize overall crop yields will be of even greater importance in the face of climate change and the need to reduce pesticide use. The most effective way to increase general biodiversity is to simply reduce overall field sizes, though [6]. The implementation of concepts based on crop diversity will preserve long-term stability and productivity of agricultural land and minimize environmental problems caused by intensive agriculture, for example, biodiversity loss, soil erosion, groundwater and air pollution with nutrients and pesticides.

See also Intercropping for Pest Management.

**References**


