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Introductory Chapter: Plant Competition in Multiple Cropping Systems beyond Conceptual Knowledge

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1. Introduction

In the coming years, farmers will face difficult challenges throughout the world in the context of climate change, water scarcity and environmental issues caused by conventional agricultural technologies. An effective management of natural resources can be encouraged by orienting the common agricultural practices towards the *functional biodiversity* concept in designing and implementing sustainable and eco-friendly cropping systems. It is well established that the enhancement of biodiversity facilitates and ameliorates the natural regulatory mechanisms of pests, insects and weeds [1].

The cropping practices that amplify the functional diversity and sustainability of an agroecosystem are as follows: diversification of farms, crop rotation, landscaping and polycrops (cultivation of various plants' associations). The polycrops are usually considered in low-input farming systems for weed control and optimization of the inputs, thus minimizing costs and the use of herbicides. Comparing with soled crop, multiple cropping systems provide faster propagation of canopy soil cover, improvement of absorbed photosynthetically active radiation (PAR), better competition with weeds and enhanced capture of available resources (light, water, nutrients). However, polycrops need to maintain at least the financial yield, crop quality and labour efficiency of the soled crops. Multiple cropping systems can be included in a scheme of relay crops. Therefore, the use of successive crops and intercrops provides an intensified use of land leading to better yields, optimized scheduling of harvests, assortment diversification and additional incomes.

Indeed, polycrops have shown a number of experimentally demonstrated advantages:

- Widen the productivity capacity of the arable land by maximizing the exploitation possibilities in time and space [2].

- Provide suppression of weeds through niche preemption and interspecific competition for resources [3, 4].
- Support the complementarity of resource consumption from physiological, temporal and morphological point of view for the associated species [5].
- Ensure superior yields due to the efficient utilization of available resources, canopy space and the mutual interactions between heterogeneous canopy components [6].
- Repel insects and diminish pests' proliferation [7, 8].

The compatibility index of species that form the phytosociological associations relies on the degree of proto-cooperation within the interspecific competition, which influences the *net biological efficiency* of each species in the mixed canopy. The *net biological efficiency* (economic efficiency) is a fraction of the biological efficiency, and the ratio between them is known as the *harvest index*. The biological efficiency represents the total dry matter accumulation of the canopy, including the aerial and root biomass, starting from the emergence to the crop harvesting. Canopy architecture plays a strategic role in the association of species and must advantage the cash crop to capture PAR. Interspecific competition for light is an instantaneous process of resource capture, and the process efficiency is closely related to the light interception and light use characteristics of each species [6]. Height and leaf area distribution of both species are crucial for the canopy growth and development. Canopy structure and species growth are closely related because the structure results from the growth of individual plants within the canopy, thus affecting the rate of resource capture in the polycrop [5, 9]. Several factors related to the genetic traits of each species and to the technological factors influence the biological efficiency of species in the mixed canopy [10].

Two or more crops that are simultaneously grown on the same field must have adequate space to maximize their proto-cooperation and minimize the interspecific competition. Four basic elements need to be considered when designing polycrops [4]: spatial arrangement, density of plants, maturity period of the component species and the canopy architecture (**Figure 1**).

Most of the practical systems are variations of four basic spatial arrangements, such as row intercropping, strip intercropping, mixed intercropping and relay intercropping (**Figure 2**). A successful polycrop relies on (1) a detailed planning of the system, (2) sowing/planting in the optimal period for each associated species, (3) proper fertilization scheme, (4) integrated control of pests and insects and (5) efficient harvesting of each component species. The use of polycrops in the vegetable production systems (cover crops, intercrops, 'trap' crops, successive crops) brings benefits in terms of crop productivity and yield stability [11, 12]. Cereal-legume intercrops are among the most frequently used and most productive [13]. Although intercropping is less frequently used in high-input agricultural systems, mixtures of cereals (such as barley, wheat or oat) with forage legumes (such as white clover, red clover or alfalfa) are common in mechanized temperate farming systems providing the suppression of perennial weeds.

In the framework of polycrop science, the present book provides basic fundamentals and several case studies of polycrop utilization in various regions of the world as a method of functional biodiversity amplification through species association that maximizes the productivity per unit of land area, suppresses the growth and development of weeds and reduces the populations of harmful pests and insects. Furthermore, the utilization of polycrops is a prospective instrument in evaluating arable land utilization options and in designing new

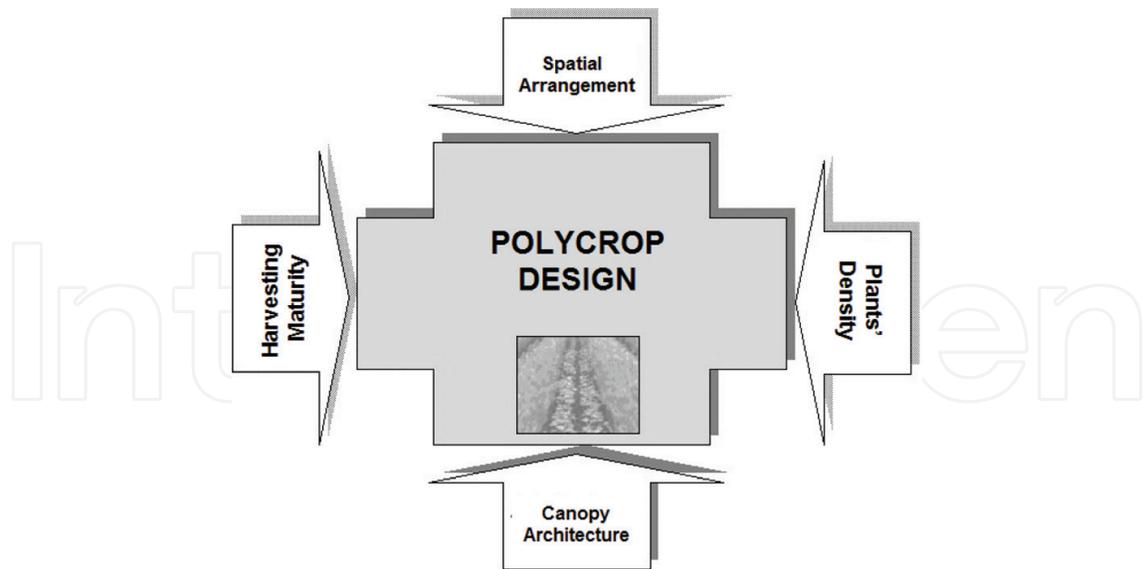


Figure 1. Criteria for designing polycrops.

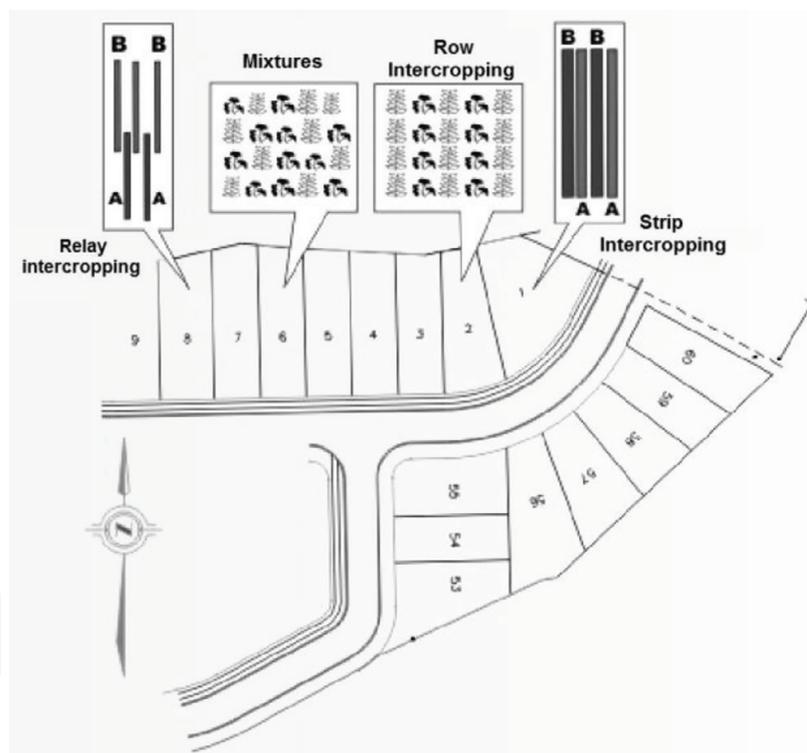


Figure 2. Spatial arrangements of polycrops.

cropping technologies, which provides sustainable cropping alternatives in the context of agroecosystem development at the ecoregional level.

The book is organized in six chapters that are divided in two sections which are as follows:

- Functional biodiversity and cropping systems: The first chapter introduces the reader to plant competition in multiple cropping systems. The second chapter provides insights regarding the ecological role of biodiversity for crop protection from pest management,

soil fertility and plant health to plant resistance. It also discusses the benefits of nanoformulation of pesticides through target-oriented nanoparticles' (NPs) syntheses and their application against crop pests and diseases because they are cost-effective, nontoxic and environmentally friendly approaches. The third chapter analyses species traits and biodiversity indices to solve problems associated with legume persistence in cropping systems providing details regarding the competition for resources.

- Multiple cropping systems and plant competition: This section contains three chapters that present rice-based multiple cropping systems from Brazil and India and cassava cropping under the teak stands in Indonesia. The inclusion of rice cultivars with greater competitive ability represents a promising tool for weed management in Brazil, since new cases of herbicide resistance are often reported, and alternative control strategies are scarce. In India, the inclusion of green manures/pulses/leguminous crops in nutrient-exhaustive rice-based cropping system saves the nitrogen fertilizer for the successive crops, increases the grain yields and profitability and improves the soil structure. In Indonesia, the pattern of land utilization under the teak stands requires the selection of suitable plants according to the temporal dynamics, namely, the season (dry or rainy) and the plants' age.

2. Final considerations

Successful polycrops provide benefits for rural development by maximizing outputs (yields) and land equivalent ratio and minimizing inputs (fertilizers, herbicides and pesticides). Pest levels are often lowered in polycrops [14]. Farmers have generally regarded multiple cropping as a technique that reduces risks in crop production; if one member of an intercrop fails, the other survives and compensates in yield to some extent, allowing the farmer an acceptable harvest [15]. To gain acceptance, such agricultural practice must provide advantages over the other available options of the farmers. Obstacles in adoption of new strategies or practices of diversification are identified at sociological and financial level, rather than technological (a difficult step from conceptual to procedural knowledge). However, further research is still needed to assess the mechanisms of competition between species, to establish suitable companion species and to conceive intensive sequences of operations and adapted mechanization. Most of the polycrops are more suitable for extensive practices on small farms, but the move towards organic farming can compensate the production losses through higher prices of the agricultural ecological products. A keen extension strategy is necessary to familiarize the farmers with successful multiple cropping systems. To introduce such systems at farm level, first steps would imply trial fields located in the rural area to show the potential benefits of multiple cropping to the farmers.

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