

Productive and Ecological Aspects of Mixed Cropping System

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Mixed cropping, also known as inter-cropping, polyculture, or co-cultivation, is a type of plant production system that involves planting two or more species (or cultivars) simultaneously in the same field in a variable order (row or rowless). Mixed cropping plays an important role in sustainable agriculture by adding value to crop rotations and agroecosystems. Various species provide complimentary use of environmental resources in a mixture in contrast to pure stands. The recent findings confirmed the benefits of intercropping, such as increased nitrogen uptake by cereals cultivated in a mixture with legumes [1–3], and more efficient use of water and nutrients in soil profile [4]. Different species in the mixtures also use field space more effectively [5], i.e., in weather conditions unfavorable for the growth of one species, the companion crop usually grows better [6,7]. Mixed systems are characterized by higher yields than pure stands [3,5,7,8]. Crop mixtures provide several agroecosystem services, e.g., increase biodiversity and support the diversity of beneficial insects, as well as reduce the outbreak of pests, which, among other things, is linked to decreased availability of food sources [9].

Mixed cultivation fully supports the various arguments presented in its favor. The latest research shows that, in the cropping of maize with common beans or garden nasturtium *Tropaeolum majus*, yields of dry matter were obtained in comparable quantities and qualities to those resulting from the cultivation of maize alone. This study showed that the intercropping of maize in Central Europe with flowering partners could be a suitable alternative to growing maize alone and can increase field biodiversity [7].

Scientific investigations on environmentally friendly mixed cropping should be supported by studies on the direct costs and long-term benefits that are most relevant to farmers. Mixed cropping plays an important role in sustainable and organic agriculture by increasing biodiversity in the crop rotation and agroecosystem, particularly in organic farming in mountainous areas. Spring cereals' intercropping increases the land equivalent ratio (LER) compared to the integrated farming [5]. The profits of grain yield in spring cereal mixtures with barley exceeded the other spring cereal species, such as oats and triticale, in their mixed and mono-crop cultures [5].

While utilizing polyculture systems, the farmers can keep their fields under continuous production and enhance the productivity of the farmland. In the sub-Saharan region of Africa, the *Brachiaria* grass is an important source of fodder and constitutes a prominent use in pest management strategies. *Brachiaria* genotypes are used as a “pull” component for cereal pests in the climate-adapted push-pull technology (PPT), a habitat management strategy developed to manage the lepidopterous stem borers and spider mites [6]. A reduction in the pest population can be accomplished by recognizing and identifying their feeding preferences—the more pronounced the feeding preferences, the greater the reduction in the population [9].

Consequently, the damage to host plants grown in mixed sowing systems is considerably reduced. Monophagous insects are specific in this regard. The slight alteration of a host plant's canopy renders monophagous insects unable to locate an adequate food



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supply and establish a suitable breeding base. A significant reduction in the population of oligophagous insects (insects whose host spectrum is in the botanical family) is expected to occur in mixtures of adequately spaced botanical taxa. For example, cereal plants' damage can be reduced by introducing the cereal leaf beetle to cereal–legume mixtures [9]. Ecological aspects of mixed related to the limitation of herbivores favor a green deal in Europe.

A mixture of two or more plants could be introduced to increase domestic protein sources in feed and reduce the protein sources of GM feed. Yellow lupine is an alternative for GM soybean, and its use in forage will depend on the direction of economic activity. Strip intercropping with yellow lupine, a crop of low competitiveness and high sensitivity to other crops' proximity, proved to be the best solution, along with growing triticale as a companion crop with a path separating both species [3]. A proper selection of species for the inter-cropping is a key factor for their optimal development and yield. For example, in the temperate climate of Germany, some species, i.e., alfalfa, sweet yellow clover, and common vetch, proved to be unsuitable for row-intercropping with maize due to difficulties in weed control or allelopathic effects [7]. Components used for interspecies mixtures should have attributes such as uniformity of growth rate and time to mature so that the harvest date may be at the same time.

Moreover, none of the species should be too aggressive, especially when mixed with a more valuable protein plant. In the case of well-established mixtures, e.g., oats–common vetch, where cereal component is more competitive toward the legume one, a proper selection of oat cultivars may also significantly affect the quantity and quality of the mixture's yield, i.e., protein content [1]. The oats–common vetch mixtures develop higher LAI and give a higher seed yield in the conventional farming system; however, the share of vetch seeds in the mixtures is higher in the organic system than in the conventional one [2].

The water content in the soil is a factor that intensifies the inter-species competition, as was shown for barley, undersown with rye-grass, which further weakens the phosphorus uptake by both barley and rye-grass [4]. Water deficit in the soil resulted in barley being a stronger competitor, with rye-grass for phosphorus. The barley competition proved to be a stronger factor hindering phosphorus accumulation in the stems and leaves than water deficit. The strongest competition was noted at the most intense stages of barley development, i.e., during the stem elongation and heading.

The grain quality of spring cereal mixtures was also raised in [8], who found higher protein yields in mixtures of barley (hulled or naked grains) with wheat and the highest yields of net metabolic energy in a mixture of naked barley with wheat. Productive and ecological aspects of mixed cropping systems should be considered when recommending these cultures in climate-smart agriculture [4].

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