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Crop Diversification Affects Biological Pest Control

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Abstract

Crop monocultures encourage the multiplication and spread of pest insects on massive and uniform crop. Numerous studies have evaluated the impact of plant diversification on pests and beneficial arthropods population dynamics in agricultural ecosystems and provided some evidence that habitat manipulation techniques like intercropping can significantly influence pest control. This paper describes various potential options of habitat management and design that enhance ecological role of biodiversity in agroecosystems. The focus of this review is the application and mechanisms of biodiversity in agricultural systems to enhance pest management.

Key words: crop diversity, herbivores, natural enemies, plant-insect interactions

Introduction

To avoid environmental pollution, health problems and species loss caused by the over resilience on synthetic insecticides, exploration of multi-function agricultural biodiversity that enhance pest management is necessary in sustainable agricultural system (Gurr et al., 2003). The main reason for this lies in the fact that modern agriculture achieved significant advances in terms of agroecosystem productivity that come at the price of sustainability (Hazell & Wood 2008; Lichtfouse et al., 2009). This is because modern growing systems imply the simplification of the structure of the environment over large areas of land, replacing natural plant diversity with only a limited number of cultivated plants in monocultures (Vandermeer et al., 1998; Sachs, 2009). In addition to the loss of diversity of cultivated plants numerous benefits provided by biodiversity within agroecosystems related to biological control were brought in question (Hillel & Rosenzweig, 2005; Bianchi et al., 2006). Therefore it is important to understand the mechanisms by which diversification of habitat may favor pest management (Gurr et al., 2003).

Increasing crop species diversity via intercropping is a simple and effective measure that offers advantages at reducing pest densities (Smith & McSorley, 2000). Intercropping or mixing different crops as a traditional agricultural technique is used for preventing pest infestation in different world geographical areas (Ma et al., 2006). The plant components of intercropping system do not necessarily have to be sown at the same time, but they should be grown simultaneously for a substantial part of their growth periods (Andrews & Kassan, 1976). There are several different crop arrangements in intercropping like mixed intercropping, row intercropping, strip intercropping and relay intercropping.

Intercropping influence pest control

The advantages of intercropping over monoculture in terms of reduced pest incidence have been demonstrated in many studies (Andow, 1991). An important advantage of intercropping systems is their ability to reduce the incidence of pests due to increased botanical diversity (Risch, 1983). Compared with a monoculture, adding more plant species to a cropping system can affect herbivores in two ways. Firstly, neighbouring plants and microclimatic conditions is altered and secondly the host plant quality e.g. morphology and chemical content, is also altered (Langer et al., 2007). Plants in intercropping system may sustain lower herbivore populations because herbivores have difficulty finding them, leave them more quickly, or have difficulty relocating them after leaving (Andow, 1991). Review of 150 published studies by Risch et al. (1983) showed that specialized herbivores were less numerous in more diverse growing systems. Analyzing the 287 studies Helenius (1998) came to the conclusion that monophagous insects are much more sensitive to the increased diversity of cultivated plants then polyphagous insects. Another review by Andow (1991) identified 53% of the 287 herbivore species examined to be less abundant in diversified systems then in monocultures.

Components of intercropping system suffer significantly less damage from insects compared to their cultivation as a sole crops (Altieri & Letourneau, 1999) which has positive impact on yield (Sarker et al., 2007). Significantly lower population of insects was observed on the cowpea – *Vigna unguiculata* (L.) Walp. intercropped with maize then on cowpea as a sole crop (Olufemi et al., 2001). Maize cultivated with cassava – *Manihot esculenta* Crantz had significantly lower infestations by insects (*Sesamia calamistis* Hampson, *Eldana saccharina* Walker, and *Mussidia nigrivenella* Ragonot) up to 80% (Schulthess et al., 2004). Rice – *Oryza sativa* L. intercropped with peanut – *Arachis hypogaea* L. had lower infestations by green stink bug – *Nezara viridula* L. and stem borer – *Chilo zacconius* Blez. compared to rice monoculture (Epidi et al., 2008). The oviposition of turnip root fly – *Delia floralis* Fall. was lower in cabbage-clover intercrop then on cabbage monoculture. Disruption in the oviposition behavior of *D. floralis* by presence of clover caused reduction in the number of their pupae (Björkman et al., 2010). Maize intercropped with the non-host molasses grass, *Melinis minutiflora*, had significantly decreased levels of infestation by stem-borers *Chilo partellus* Swinhoe (from 39.2% to 4.6%) and also increased larval parasitism of stem-borers by *Cotesia sesamiae* (Khan et al., 1997). The cotton (*Gossypium barbadense* L.) intercropped with basil (*Ocimum basilicum* L.), suffered significantly less pest infestation and led to a 50% reduction in abundance of the pink bollworm, *Pectinophora gossypiella* Saunders (Schader et al., 2005). Significantly higher level of infestation by stemborers was found in maize fields without intercrop plants than in the fields with an intercrop (Khan *et al.,* 2001). Sugar bean grown between the sugarcane rows reduced nematode infestation compared with a standard aldicarb (nematicide) monocrop treatment and an untreated control (Berry et al., 2009). Root exudates from neighbouring plants can produce defensive compounds that are effective against soil born insects (Dakora, 2003).

Mechanisms explaining reduced pest incidence in intercropping

In order to explain reduced pest presence in intercropping system several mechanisms has been proposed.

Olfactory stimuli

Visual and olfactory signals from non host neighbors can have positive impact on focal plants by reducing their attractiveness for herbivores. Insects are known to respond to different chemical signals released from plants. Volatile chemical signals emitted by plants represent important source of information for herbivores to find host plants (Bruce et al., 2005). As the main herbivorous insects of many crops, aphids are highly sensitive and able to detect changes in small changes in plant status (Ninkovic et al., 2006). Aphids are organisms extremely sensitive to changes in the quality and physiological status of the their host plants, therefore for this purpose they considerably rely on chemical information in the process of host location and selection (Pettersson et al., 2007). The diversity of olfactory stimuli emanating from polycultures might mask the olfactory cues used by monophagous herbivores to find their host plants or otherwise confuse or repel these herbivores (Andow, 1991). Volatile compounds emitted by *Desmondium uncinatum* (Jacq.) DC. can significantly reduce the damage on maize caused by *Chilo partellus* Swinhoe (up to 99.2%) relative to the maize monocrop or maize-cowpea intercrop (Khan et al., 2006). This reseach also confirm that chemical compounds emitted by neighboring plants can have a greater significance as insect repellents than a physical barriers. Volatiles from nonhost plants may interfere with the attractiveness of focal plants, resulting in "olfactory masking" (Koschier, 2006). Female insects will spend more time searching for a suitable host plant in intercropping and so oviposit fewer eggs on the focal plants (Skovgård & Päts, 1996). Understanding the chemical interactions between plants and insects is of particular importance not only for environmentalists but also for the development of new strategies in plant protection based on the natural occuring phenomena (Agelopoulos et al., 1999).

Visual stimuli

Neighboring plant architecture may play an important role in their ability to mask, repel, confuse or disrupt focal plant herbivores (Marquis et al., 2002; Finch et al., 2003). This may be achieved by visually perceived signals from non host plants in diversified habitats. Visual signals of neighboring plants can also interrupt host finding and selectiong behavior of cabbage fly (Finch et al., 2003). Non-host plants may interfere herbivores access simply by visually blocking the focal plant and reducing the likelihood of detection (Rausher, 1981). Herbivore movement patterns, rather than natural enemies, are often more important in accounting for reduced *A. fabae* abundance on bean plants intercropped with maize (Ogenga-Latigo et al., 1993). However, periodical physical contact with neighboring plants can affect herbivores to leave such habitats. In intercropping system containing at least one nonhost plant, the number of beetles per unit host plant were significantly lower relative to the numbers of beetles on host plants in monocultures (Risch, 1981). Neighboring plants can also act as attractant for herbivores reducing their colonization and damage on focal plant (Atsatt & O'Dowd, 1976).

Volatile interaction between plants change host plant quality

Chemical interaction between plants can affect insects behavior on their host plants. Different plant species in intercropping systems often compete for available resources with consequences for plant growth (Langer, 1996), and chemical composition (Stamp et al., 2004), which in turn could affect host plant finding and acceptance by herbivores (den Belder et al., 2000). Diversity between different genotypes within same species significantly affect the plant competition in intercropping which in turn change allocation of resources and plant growth (Ninkovic, 2003). These changes, can indirectly affect the suitability of the crop plant as a food source for insect herbivores (Simpson & Raubenheimer, 1995). Adoption to future competition with neighboring plants in intercropping can increase plant resistance of focal plants to herbivores (Ninkovic et al., 2013). Laboratory experiments demonstrated that barley previously exposed to volatiles from thistle *Cirsium vulgare* L. (Glinwood et al., 2004) or couch-grass *Elytrigia repens* L. (Glinwood et al., 2003) became less acceptable for cereal aphids. Barley exposed to volatiles from the weed *Chenopodium album* had reduced aphid settling in both the laboratory and also in the field experiments (Dahlin & Ninkovic, 2013). Weeds used in these studies were not flowering during tests. Volatiles released by undamaged onion *Allium cepa* L. affected exposed potato to change volatile profile that detered olfactory response of *Myzus persicae* Sulzer (Ninkovic et al., 2013). Pettersson et al. (1999) show that volatile interaction between different barley cultivars may also reduce acceptability of exposed plants for *R. padi*. Recently, volatile interaction between plants is generaly considered as a complex process which have informative value for recaivers and can influence higher trophic levels (Glinwood et al., 2011).

Presence of natural enemies

Presence of natural enemies play important role in suppresion of herbivores in agroecosystems. Specific crop habitats are considered to play important role in survival of natural enemies of hervivores (Bianchi et al., 2006). It is known that increased plant species diversity support diversity and abundance of natural enemies as well as their activity (Haddad et al., 2001). Intercropping provide additional resources such as food and shelter that enhance abundance and effectiveness of natural enemies (Mensah, 1999). Survival and reproduction of general and special list of beneficial insects requires provision of additional resources such as pollen and nectar that are scarce in monoculture (Isaacs et al., 2008). Recent studies on the effect of plant diversity on generalist natural enemies have shown their increased abundance in more diverse growing systems (Denno et al., 2005). Mixing of different plant genotypes within same species may influence ladybird habitat preference (Ninkovic et al., 2011). It has been shown that ladybird positively respond to increased botanical diversity (Elliott et al., 2002). Reduced pest incidence in intercroping system was attributed to increased population of natural enemies (Kyamanywa & Tukahirwa, 1988). The foraging behaviour of *C. septempunctata* is also influenced by habitat characteristics, including the identity and diversity of plants (Pettersson et al., 2008). In growing systems where intercrop provides a permanent vegetation cover, the interaction between pests and its natural enemies can more easily come into equilibrium. For this reason, biological control is more successful in perennial crops than in annual crops (Trenbath, 1993). In a field study, the frequency of adult *C. septempunctata* was higher in barley plots containing high densities of the common weeds *Cirsium arvense* (L.) Scop. and *Elytrigia repens* (L.) Nevski. than in control plots with barley as sole crop (Pettersson et al., 2008). Performance of natural enemies is enhanced in mixed cropping systems, because these systems provide a variety of microhabitats and alternative prey (Root, 1973). However, parasitoids benefited from more diversified systems since the flower resources provide them additional source of food (Lavandero et al., 2005). In review of 42 different studies that compared parasitiod density and parasitism rates Coll (1998) reported that in two third of studies were more abundant and attacked more herbivores in intercropping system then in monoculture.

Conclusion

This review has summarized diversified cropping systems in which insect pest impact has been regularly reduced. Intercropping has proven to be simple and efficient ecological approach that modifies local environment and favor reduced pest pressure and enhanced activity of natural enemies. Studies reported here provide evidence that crop diversification can play important ecological role in pest management. The findings presented above illustrate how naturally occurring processes in intercropping such as competition for resources, chemical interactions between plants can affect herbivores and reduces their performance. It is obvious that modification of single practices such as cultivar choice in diversified cropping system can significantly impact herbivores and their natural enemies. Crop diversification correctly assembled in time and space performs important ecological role supporting naturally occurring plant insect interactions that support crop protection. Since the plant-plant interactions constantly occur in intercropping future challenge for modern agriculture will be to choose appropriate combination of crops to create a cropping system able to manage insect population to certain level. Furthermore, there is a need for long-term studies on effects on natural enemy populations in diverse agroecosystems are essential for the development of diverse systems for optimal pest reduction. However, crop diversification also promote the application of infochemical signals in intercropping system as an effective biological control agent and thus contribute to reduce the use of insecticides.

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Diverzifikacija useva utiče na biološku kontrolu insekata

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Sažetak

Gajenjem biljaka u monokulturi stvaraju se povoljni uslovi za širenje herbivornih insekata. Brojna istraživanja koja su proučavala uticaj povećanja diverziteta gajenih biljaka na herbivorne insekte i njihove prirodne neprijatelje pokazla su da različite tehnike upravljanja staništem kao što je interkropingimaju značajan uticaj na kontrolu insekta. Ovaj rad ima za cilj da prikaže različite načine upravljanja staništem kao i njegovom uticaju na ekološku ulogu biodiverziteta u agroekosistemima. Fokus ovog rada je pregled mehanizama kojim povećanje diverziteta gajenih biljaka utiče na smanjeno prisustvo herbivornih insekata u u ovakvim sistemima gajenja biljaka.

Ključne reči: povećanje diverziteta gajenih biljaka, herbivori, prirodni neprijatelji, interakcije između biljaka i insekata

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