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Point of view

Introducing the term 'Biocontrol Plants' for integrated pest management

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ABSTRACT: Studies of interactions between crops, additional plants, pests and beneficial organisms already exist as well as studies of natural enemy preference, dispersal, and abundance. However, these studies focus on tri-trophic interactions from an “arthropod” point of view. We think that in order to optimize crop protection methods we need to understand the effects that plant structures have on the various arthropods and on subsequent tri-trophic interactions. Although studies and reviews describing the role of secondary plants in Integrated Pest Management (IPM) exist, to date a general term which encompasses all plants added to a cropping system with the aim of enhancing IPM strategies has yet to be formulated. Therefore, we suggest a new term, “biocontrol plants”, which we define as plants that are intentionally added to a crop system with the aim of enhancing crop productivity through pest attraction and/or pest regulation; a term that will promote the use of biocontrol services, and can ultimately lead to an increase in the sustainability of cropping systems.

Introduction

In two recent studies, Parolin et al. (2012a, b) reviewed the secondary plants used in crops or surrounding habitats and highlighted their most important functional characteristics that enhance pest management. The addition of such plants may act as efficient biocontrol tools. In this study, we propose the introduction of a new term to deal with those secondary plants that are specifically suited to enhancing biological control in Integrated Pest Management (IPM; Van Lenteren, 1988), that we name “biocontrol plants”, because there is a need for simplification and categorization. We hope that the use of this term will make it easier to implement the concept of integrating different types of secondary plants into cropping systems, and increase the search for the best-suited biocontrol plant species, especially those that can be found within the local flora.

The increasing need for higher crop yields both in the field and in greenhouses brings with it problems linked to large monocultures and pest attacks. Chemical pest control has to be reduced owing to its unwanted effects on non-targeted organisms (Biondi et al., 2012a, 2012b; Desneux et al., 2007; Han et al., 2010) and pest resistance (Liang et al., 2012; Shad et al., 2012). Thus, alternative and sustainable long-lasting pest control methods are urgently needed to enhance the activity of beneficial organisms (Jonsson et al., 2008; Wratten et al., 2012).

IPM is a promising alternative, but currently, knowledge of this subject is more focused on the biology and interactions at high trophic levels, i.e. between pests and beneficial organisms, than on the first trophic level, the plants. Plants can be indirectly used as biocontrol agents as well. Indeed, adding plants to a crop system in order to enhance biological control and – indirectly – reduce pest-related yield losses is not new to agricultural systems (Ripper, 1944).

When a plant provides shelter or food for biocontrol agents that influence the interactions and the potential equilibrium between phytophagous arthropods, biocontrol arthropods and culture plants, the addition of plants to a crop plant system can ideally have direct positive effects on the crop plants or beneficial organisms, or indirect negative effects on pests (Osborne et al., 1998; Figure 1). This arrangement can result in secondary plants having positive effects on the productivity of crop plants and enhancing the effectiveness of biological pest management (Parolin et al., 2012a, b). Only recently have clear definitions and delimitations of terms regarding additional plants been reviewed and the synonyms organized (Parolin et al., 2012a).

The reasons why certain plant species are chosen as biocontrol plants are barely evident, leaving many questions open as to how and why these plants influence present pest and/or beneficial organisms (Andow and Prokrym, 1990; Cortesero et al., 2000). In a recent study, we described which plant characteristics and morphoanatomical traits can enhance crop productivity by assisting in pest control, i.e. by inhibiting pest organisms or giving shelter/food to beneficial organisms (Parolin et al., 2012b). Beneficial species have different requirements with regard to diet breadth, dispersal ability, and intrinsic rates of increase (Frank, 2010). Morphological, physiological or phenological characteristics of the biocontrol plants which host them are, therefore, manifold.

We need more detailed knowledge of the mechanisms of beneficial plant-predator-pest interactions to optimize the application of biocontrol plants in IPM. Only with a detailed knowledge of the effect of biocontrol plants on beneficials' behavior, preference, dispersal, birth rate, and death rate can we establish optimal biocontrol plant systems for different agronomic situations. Thus, this study aims to help optimize the choice of plant species to be used as additional organisms in biological control systems.

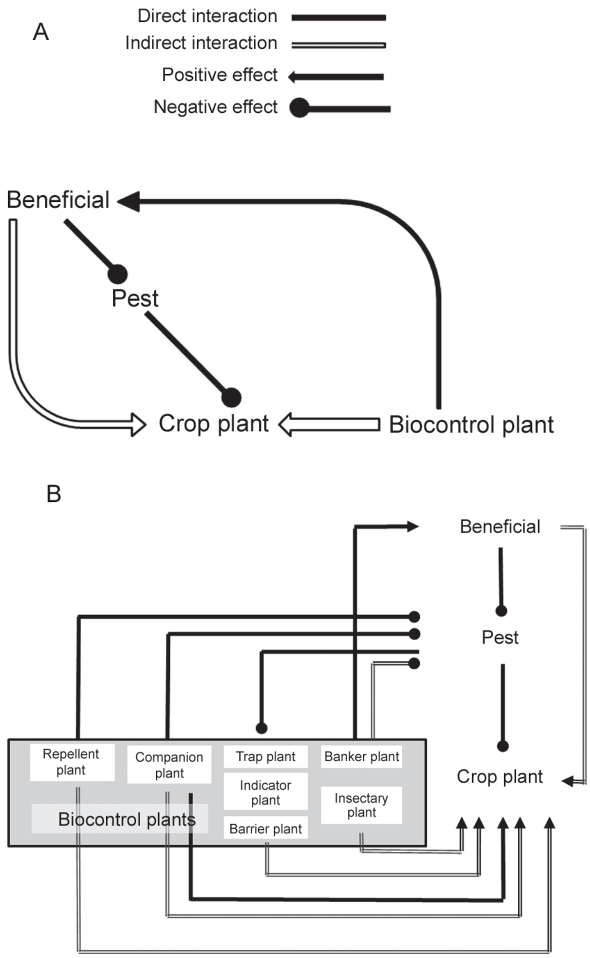

Figure 1 – Biocontrol plants and possible interactions with pests, beneficials and crop plants. The processes of multitrophic interactions are non-exclusive (adapted from Parolin et al., 2012 b). A) simplified and B) with details of kinds of biocontrol plants.

Additional plants used in crop raising systems

To date, in the literature, we find several categories of plants added to crop systems, e.g. companion plants, trap plants, banker plants, indicator plants. Many descriptions of systems with additional plants are found in "grey literature" or in non-published reports. Many studies which analyze the employment of plants to sustain a reproducing population of natural enemies within a crop that provides long-term pest suppression have an entomological perspective (e.g. Berlinger et al., 1996; Bottrell et al., 1998; Caballero-Lopez et al., 2012; Huang et al., 2011; Lundgren et al., 2009; Wäckers et al., 2005).

We suggest a new head term which to date is completely lacking when dealing with additional non-crop plants added to a crop system: "Biocontrol plants". This new term encompasses all kinds of "side-plants" that, by intention, are added to a crop system (Figure 1).

We are aware of the fact that some of the plant categories may not be purely "biocontrol plants", e.g. plants which act as catalysators in trophic interactions, such as for predator establishment. In the strict sense of the term we can define only trap plants and banker plants as "biocontrol plants" which provide an environment which is favorable for biocontrol agents such as predator arthropods. Indeed, indicator, companion, or repellent plants do not interact with biocontrol animals but, nevertheless, can act as biocontrol plants in a crop system (Parolin et al., 2012a).

Definition of the new term "biocontrol plant"

We suggest the term "biocontrol plants" as a generic term, since to date, no term exists that encompasses the aforementioned secondary plants, which are intentionally added to a crop system in order to improve its protection and productivity. We define this term as follows: **"A biocontrol plant is a plant that is intentionally added to a crop system with the aim of enhancing crop productivity by mutual benefit, pest attraction and/or pest regulation and thereby contribute to an increase in the efficiency of biological control systems, subsequently leading to increased crop productivity"**.

To date, we still have a scant understanding of why certain plant species are efficient in enhancing biocontrol, and which plant morphologies and structures enhance the desired proliferation of biocontrol arthropods (Parolin et al., 2012b). The plants known to act as biocontrol plants are typically generalists rather than specialists, which are very tolerant of suboptimal conditions, i.e. rustically resistant perennial species, which grow even under water stress and are not easily destroyed by a large number of bioaggressors which settle on them (Parolin et al., 2012c, 2013a, 2013b). Thus, they share characteristics typical of invasive species. With regard to the choice of new potential biocontrol plants, therefore, we should favor native plant species in order to prevent them becoming invasive when introduced to new territories.

Functional characteristics of interest in "biocontrol plants"

For practical solutions, plants must be grown quickly and inexpensively. They need to be compatible with the horticultural requirements, such as light and temperature, of the crop with which they are grown (Frank, 2010), and they must remain healthy under severe feeding by aphids or other herbivores (Kim et al., 2009). Thus, the main functional characteristics which are relevant to the employment of biocontrol plants are that they should be easy to cultivate and long-living, and they must be neither attractive to prejudicial pests nor competitive with the crop (light, nutrients, etc.). Moreover, their needs should be close to those of the crop to be protected (temperature, humidity, light, nutrients, etc.) (Parolin et al., 2012b).

We cannot neglect the aspect that the animals present, be they pests or beneficials, may change the morphology of the plants, e.g. gall-forming arthropods

(Kurzfeld-Zexer et al., 2009). Also in the case of plants infested with fungi the mycelium may form an ecological niche where pests such as the spider mite *Tetranychus urticae* might protect themselves against their predators. However, preliminary experiments with some potential banker plants indicated that if several plant species are present the crop system may demonstrate a certain resistance which impedes the proliferation of pests even though they may be present (Parolin et al., 2013a).

In some cases, plants may share the characteristics of more than one of the previously defined plant groups (companion, trap, banker, indicator plants, etc.; Parolin et al., 2012a), as is the case with eggplants: they act as indicator plants, trap crops (they are more attractive to white fly than *Poinsettia*) and as a 'nursery' for biological control agents. Species like these which display many traits might be especially interesting because the species can be applied on multi-purpose levels. Furthermore, in cases like these our new term "biocontrol plants" can be employed without implying contradictions.

In our concept of "biocontrol plants" we do not focus on temporal aspects which would include the preplant release of predators on the crop plants themselves.

Final remarks

We hope that the introduction of the new head term "biocontrol plants" represents a positive contribution to the ongoing discussion about the search for alternatives to potentially toxic pesticides and to the employment of secondary plants in crop systems as a means of increasing the resilience of interactions between co-occurring organisms even if there are only few as in a greenhouse crop system. Our contribution aims to increase knowledge and thus efficacy by reducing the difficulties in the employment of biocontrol plants and thereby promote further acceptance of biological control, which should also become economically more feasible. Fortunately, there is a growing awareness of the importance of biological control as an alternative to chemical control in crop production (Bompard et al., 2013; Desneux et al., 2010; Kleespies et al., 2013; Ragsdale et al., 2012; Zappalà et al., 2012).

Interest in biological control is important as many arthropod pests have developed resistance to pesticides leaving growers to search for alternative management strategies (Ali et al., 2012; Lu et al., 2012; McCaffery, 1998). Increasingly, consumers are demanding that products be grown in a sustainable manner and be free of insecticide residue (Dabbert et al., 2004). Furthermore, the acceptance of the rise in importance of the role of the first trophic layer allows perspectives for biological control with tri-trophic interactions.

In the light of climatic changes, there is a pressing need to find biocontrol plant species with broad ecological amplitudes, which, for example, are tolerant of heat and water stress, increase the diversity of the crop system and thus enhance biological control and finally indirectly crop productivity.

This contribution aimed to help in the careful choice of plant species. Multiple species that are natural enemies can improve biological control if they target the different life stages of a pest species that can be found in different parts of a given habitat (Sih et al., 1998; Straub et al., 2008). However, antagonistic interactions between natural enemy species, such as intraguild predation, can reduce biological control (Chailleux et al., 2013; Rosenheim et al., 1995; Sih et al., 1998). The same may occur in systems which are not understood in detail, where plants added could enhance the proliferation of nontargeted organisms. Therefore, thorough analyses and a real understanding of the interactions and causes are fundamental to the implementation of biocontrol systems. We hope that this review contributes to this, and that biological control may further increase through the use of biocontrol plants.

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