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Can We Make Crops More Attractive to the Natural Enemies of Herbivores?

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Under certain circumstances plants can form alliances with the natural enemies of herbivores (predators and parasitoids) to reduce herbivory. Plants can provide these natural enemies with food (i.e., nectar and/or pollen) and shelter that increase their survival, longevity, and fecundity [1]. They may also provide natural enemies with cues to help them find their host or prey [1]. Indeed, when damaged by herbivores, plants release a species-specific blend of volatile compounds that attract the natural enemies of herbivores [2].

In many instances, however, crops lack one or more of the traits that help natural enemies become abundant and effective biological control agents of agricultural pests. For instance, monocultures often lack the proper food supplies and/or shelter for natural enemies. This can be fixed by diversifying agricultural crops. For example, growing flowering plants in the form of companion plants, intercropping, or cover crops may provide natural enemies with adequate nutritional requirements such as sugars (nectar) and protein (pollen), as well as potentially providing predators with alternative prey [3]. In addition, by breeding for high yielding crops and not necessarily for traits that increase natural enemy efficiency, crops may have unintentionally lost the volatile cues that attract natural enemies to damaged plants. In fact, crop domestication can result in plants with lower emissions of inducible volatiles, which in turn can reduce natural enemy recruitment by herbivore-injured plants [4,5]. Furthermore, it is important for herbivores to remain inconspicuous to their own enemies. For this, certain herbivores such as those with sucking mouthparts (e.g. aphids, whiteflies) either do not induce volatile emissions or reduce the emission of volatiles triggered by chewing herbivores (e.g. caterpillars) because they activate different, and often conflicting, plant defensive pathways [6]. Consequently, to aid natural enemies during host searching, plants could be bred for increased volatile emissions or, even better, primed for an increased induced volatile response after herbivore attack. Thus, provision of food and shelter, and enhancement of host-finding cues are ways to conserve and augment natural enemies in agricultural crops.

The concept of manipulating natural enemies to improve biological control is not new – it has been around for more than 30 years [7-10]. It has, however, received renewed attention lately because many chemical control approaches are becoming ineffective due to the onset of resistant pest populations. There are also more restrictions on the use of broad-spectrum conventional insecticides because of their negative effects on humans and the environment. As a result, farmer recognition of the need for sustainable agriculture, and in particular conservation of biological control agents, is crucial for future management of insect pests.

Clearly the concepts outlined above have recently motivated exciting research among scientists but the question still remains on whether farmers will adopt these ideas. A sign of encouragement comes from studies in Africa showing that infestation of stem borers in maize is reduced when intercropped with other plants such as molasses grass [11]. Reduced crop injury is achieved by a multitude of mechanisms termed collectively a "push-pull" approach, where plants attractive to the stem borers are used as "trap" crops (pull component), whereas repellent plants are used to "push" the pest away from maize, the valuable crop [11]. Intercropping not only alters the pest's behaviors but also increases larval parasitism by emitting volatiles that attract the borers' parasitoids [12]. This technology has now been adopted by thousands of farmers in East Africa for the control of stem borers in maize. Also encouraging are our recent advances in molecular techniques which will facilitate the development of genetically-modified plants that are "more inducible" for volatile emissions. For example, (*E*)-β-caryophyllene is a volatile emitted from maize roots that attract entomopathogenic nematodes to protect them against the western corn rootworm [13]. Yet, North American varieties lack the ability to emit this compound [14]. A recent study demonstrated that maize lines can be transformed to enhance the emissions of (*E*)-β-caryophyllene from roots [15].

In conclusion, manipulation of natural enemies in agro-ecosystems might soon become a common tool used globally for sustainable pest management. Still, in order to enhance (and avoid disruption of) biological control, more studies are needed to better understand the conditions under which natural enemies can be manipulated. Identifying the nutritional needs and cues used by natural enemies of herbivores during foraging is an important step towards this goal.

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