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Research Application Summary

The interaction between host plant resistance and biological control presents opportunities for plant breeders in Africa's integrated pest management programs

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Abstract

The concept of integrated pest management (IPM) presents a holistic approach to management of pests, optimizing actions associated with at least two pest management tactics without ecological backlash. However, efficient integration of IPM components requires interdisciplinary approach that includes entomologists, ecologists and plant breeders for sustainable plant protection solutions. For instance, there is potential to use and boost the direct and indirect defense systems of plants to enhance biological control in plant protection. If deployed in a well studied and synergistic manner, host plant resistance can give intriguing results for IPM. Host plant resistance (HPR) affects both pests and biological control agents in various ways implying that, plant traits intended for defense against phytophagous insects may affect biological control agents. This presents an opportunity for plant breeders to develop crop varieties suitable for specific biological control agents. Synergies between basal resistance and biological control remain unexplored because plant breeders, entomologists and ecologists work in isolation which limits the potential for exploitation of the benefits of the interaction between host plant resistance and biological control. The possibilities to increase the durability of crop resistance to pests by applying inherent resistance-enhancing measures in combination with biological control are interesting but have received far too little attention by IPM researchers. A collaborative research approach can provide opportunities for IPM integration in Africa. There is need to understand basic biological processes and tritrophic interactions that occur among plants, pests and beneficial species in various crop production systems. The integration of host plant resistance with biological control of arthropod pests can provide effective control against pests in Africa's cropping systems.

Key words: IPM, parasitoid, plant breeding, predator

Résumé

Le concept de lutte intégrée contre les ravageurs (IPM) présente une approche holistique de la gestion des ravageurs, optimisant les actions associées à au moins deux tactiques de lutte antiparasitaire sans réaction écologique. Cependant, une intégration efficace des composants IPM nécessite une approche interdisciplinaire qui inclut des entomologistes, des écologistes et des sélectionneurs de plantes pour des solutions durables de protection des plantes. Par exemple, il existe un potentiel d'utilisation et de renforcement des systèmes de défense directs et indirects des plantes pour améliorer la lutte biologique dans la protection des plantes. Si elle est déployée d'une manière bien étudiée et synergique, la résistance de la plante hôte peut donner des résultats intrigants pour l'IPM. La résistance des plantes hôtes (HPR) affecte à la fois les ravageurs et les agents de lutte biologique de diverses manières, ce qui implique que les caractéristiques des plantes destinées à la défense contre les insectes phytophages peuvent affecter les agents de lutte biologique. Cela présente une opportunité pour les sélectionneurs de plantes de développer des variétés de cultures adaptées à des agents de lutte biologique spécifiques. Les synergies entre résistance basale et lutte biologique restent inexplorées car les phyto-généticiens, les entomologistes et les écologistes travaillent de manière isolée, ce qui limite le potentiel d'exploitation des bénéfices de l'interaction entre la résistance des plantes hôtes et la lutte biologique. Les possibilités d'augmenter la durabilité de la résistance des cultures aux ravageurs en appliquant des mesures de renforcement de la résistance inhérentes en combinaison avec la lutte biologique sont intéressantes mais ont reçu beaucoup trop peu d'attention de la part des chercheurs de l'IPM. Une approche de recherche collaborative peut offrir des opportunités pour l'intégration de l'IPM en Afrique. Il est nécessaire de comprendre les processus biologiques de base et les interactions tritrophiques qui se produisent entre les plantes, les ravageurs et les espèces bénéfiques dans divers systèmes de production végétale. L'intégration de la résistance des plantes hôtes à la lutte biologique contre les arthropodes peut fournir une lutte efficace contre les ravageurs dans les systèmes de culture africains.

Mots clés : IPM, parasitoïde, sélection végétale, prédateur

Introduction

The integrated pest management (IPM) approach has been widely mentioned and included in policy documents (Stenberg, 2017) of many African countries. According to Stenberg (2017), IPM is a holistic strategy to address pest and disease problems using all relevant methods, with minimum application of chemicals. In fact, IPM is highlighted as the scientific study of the compatibility and optimization of actions associated with at least two pest management tactics. When effectively applied, IPM can contribute to management of ecological backlash; the failure of a pest management tactic or combination of tactics to achieve a long lasting economic suppression of a pest and involves the counter response of a pest population or other biotic factors in the environment to management tactics, diminishing their effectiveness. However, the holistic science of IPM has not been realized in most countries (Stenberg, 2017). The aim of IPM is to become less reliant upon expensive and unfriendly synthetic insecticides, especially as a prophylactic measure (Poppy and Sutherland, 2004). Current IPM programs are absolutely less efficient compared to the sum of the individually applied crop protection tactics (Barzman *et al*., 2015). Integrating IPM components requires interdisciplinary research programs that include entomologists, ecologists and plant breeders among others focusing on several crop protection methods. It is obvious that formulation of well aligned principles for synergistically combining traditional and appropriate IPM actions is needed to optimize crop protection efforts. Such synergy will patch up the deficiencies in the implementation of individual pest management elements.

Host plant resistance and biological control. For many years, many crop pests, aphids inclusive, were largely controlled with use of chemicals in field and greenhouse systems (Kityo *et al*., 2017).

However, insecticide ap-plication has attracted a lot of public health and environmental concerns for humans and noted to be associated with increased costs of production, with many cases of pesticide resistance also being reported. Two outstanding pest management components; host plant resistance and biological control stand out as key pillars in sustainable pest control (Peterson *et al*., 2016). Opportunities exist to use and boost the direct and indirect defenses of the plants to enhance biological control in IPM. Host plant resistance can be presented in plants as antibiosis, antixenosis or tolerance (Firdaus *et al*., 2012; Elsen, 2013). Biological control in pest management includes the use of predators, parasitoids/parasites and entomopathogens. Although biological control and host plant resistance can potentially contribute to IPM in synergy, the two tactics have unfortunately been developed in isolation. The effectiveness of biological control agents can be influenced by the host plant micro-environment and physiology. Thus, in manipulating plant traits in any breeding program, the implications of such manipulation to biological agents such as predators and parasitoids need to be considered as well. This provides an opportunity for breeders to breed plants that are adequately compatible with biological control agents. Plant breeding for host plant resistance has existed for a long (Poppy and Sutherland, 2004) and has evolved from traditional breeding to biotechnology to recombinant DNA technology (Wieczorek *et al*., 2012). With such technological advancement, a foreign gene can be transferred and incorporated into a host plant genome to introduce resistance against insects or ignite the production of volatile compounds which can attract the natural enemy of the pest after the host plant is injured by phytophagous insects (War *et al*., 2012).

Interactions between plant resistance and biological control. Plant resistance affects both pests and beneficial organisms such as parasitoids and predators as biological control agents (Hassanali *et al*., 2008). For example, predatory bugs used for biological control usually suck plant sap, or nectar (Heisswolf *et al*., 2010) which affects the behavior and performance and efficacy of the predators depending on the quality of the sap. Parasitoids are exposed to the plant material that their herbivorous hosts suck from plants, and are thus indirectly affected by plant-resistance traits (Stenberg, 2012). Physical plant defenses structures such as trichomes exert effects on biological control agents (Peterson *et al*., 2016) which could be positive or negative. These examples demonstrate that plant traits intended for defense against phytophagous insects affect biological control agents in a number of ways. This presents an opportunity for plant breeders to develop plant varieties that are fit for specific biological control agents. Plant volatile compounds too could be used to improve biological control through resistance (Pappas *et al*., 2017) although a numbers of limitations remain to be sorted out. For example, attraction of biological control agents to volatile-emitting crops can still work best at small scales which is characteristic of African farming systems and communities (Dixon *et al*., 2001). Through more detailed studies, it is possible to understand how to attract and retain sufficiently large numbers of biological control agents in Africa's cropping systems in order to optimize the interaction of host plant resistance and biological control.

Basal resistance for IPM interaction with biological control. Research related to plant priming in IPM context is scarce (Stenberg, 2017). Part of the foreseeable risk is that when basal plant defenses are induced, biological agents such as parasitoids and predators, may be exposed and actually affected by the induced defenses systems and response (Pastor *et al*., 2012). However, in the few studies that have explored the effects of plant vaccination on predation, some positive effects on predation rates have been detected (Stenberg, 2017). For example, induction of cotton defenses induced omnivorous thrips (*Frankliniella occidentalis*) to switch from feeding on host cotton plants as pests to feeding on herbivorous spider mite eggs (Agrawal *et al*., 1999; Agrawal and Klein, 2000). The predatory bug Macrolophus pygmaeus, which is often used as a biological control agent, can induce proteinase inhibitor (PI) activity and accumulation of transcripts of the PI-II gene in tomato (Pappas *et al*., 2015), consequently reducing pest pressure. Thus, some biological control agents could be introduced to plantlets in nurseries for priming (vaccination) and then hitch-hike with the plants to the final growing areas to provide biological control service (Pastor *et al*., 2012). Besides these fascinating results, many possible synergies between basal resistance and biological control have not been well explored, and can are available as virgin areas of plant science and IPM research.

Optimization of biological control for IPM interactions with host resistance. Modern agriculture is characterized with pests developing counter-resistance against pests, which is indicated as resistance breakdown in plants due to ecological backlash. Research suggests that biological control agents can benefit plant breeders ' efforts in the plants' in designing strategies for developing resistant varieties for effective pest management (Agrios, 2005). With support of biocontrol agents, durable resistance can be realized since biological control agents decrease the differential pest fitness between resistant and susceptible cultivars and delay the development of counter-resistance in pests (Harvey-Samuel *et al*., 2015). In a study conducted by Schuler *et al*. (2003), the diamond back moth evolved counter-resistance to Bt broccoli much more slowly in the presence of lady beetles. The opportunity to enhance the durability of host plant resistance through integration with biocontrol are interesting but have not received enough attention by IPM researchers (Pappas *et al*., 2015). Both evolutionary modeling and manipulative experiments are needed to increase our understanding of the interactions involved (Rusch *et al*., 2010) and the circumstances needed to prolong resistance via biological control (Zuparko and Dahlsten, 1994). The fact that plant breeders, entomologists and ecologists work in isolation most times limits the potential for exploitation of the benefits of interaction between host plant resistance and biological control. A collaborative research approach can provide opportunities for IPM integration in Africa.

The tri-trophic concept of interaction between host plant resistance and biological control In a typical crop-insect interaction, there are three trophic levels. The first level is that of a plant feeding on the soil, the second is that of herbivorous insect pests feeding on the plants and the third one involves predators and parasitoids feeding on the insects. There is tension between any two feeding levels. Members in the lower level struggle to reduce feeding by their enemies, while members in the higher feeding levels struggle to increase their capacity to consume (Srivastava and Bell, 2009). There is therefore a potential for members in alternate trophic levels to form an alliance and act in a mutualistic manner. The plant may for example provide favourable conditions for the natural enemies of the insect pests or the natural enemies may create favourable environment for the plant by reducing the pest population. These actions and reactions among the three different feeding levels constitute tri-tophic interactions. It is clear that what a plant feeds on will affect the herbivore, which in turn may affect the predator, and parasitoids. It is therefore important to be aware of the plant effects up the trophic systems in integrating plant breeding and biological control to manage various pests. Tri-trophic interactions can be semio-chemically mediated, chemically mediated or physically mediated. Semiochemically mediated interactions can influence herbivore populations only via the action of natural enemies. In contrast, certain chemically and physically mediated interactions can affect herbivore population dynamics directly. It follows that, many if not all plant based mechanisms that mediate tri-trophic interactions correspond to mechanisms that are also associated with host plant resistance. Therefore, all HPR mechanisms are likely to interact directly (independent of the herbivore) or indirectly (via the herbivore) with the third trophic level. The effects on biological control of plant induced changes in herbivore life history parameters depend on the specific nature of natural enemy-herbivore interactions. Effects on a generalist natural enemy would be expected to be different from the effects on specialists. A good understanding of these mechanisms and interactions between host plant resistance and biological control provides insights and opportunities for resistance breeding.

Conclusion

Host plant resistance and biological control can play important roles in the regulation of insect pest populations providing a double-edged sword against pests. However, there is need to carefully and synergistically integrate the two approaches to optimize the effectiveness of their interactions in IPM. Thus, it is important to understand the basic biological processes and tri- trophic interactions that occur among plants, pests and beneficial species in various crop production systems in Africa through collaborative research.

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