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Biorational control methods for protection of stored grain legumes against bruchid beetles

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ABSTRACT

Bruchid beetles such as *Callosobruchus maculatus* are known to the storage pests of grain legumes and cause tremendous damage. The main method to protect from them is chemical insecticides or fumigants. But, they would cause some problems such as environmental pollution, hazard to health. So, it is necessary to develop the grain legumes protection methods or systems using less chemical insecticides or fumigants from the perspective of integrated pest management (IPM). In this paper, I review the works of legumes grain protection methods without chemical insecticides or fumigants especially for the natural parasitoids, essential oils and other methods recently developed.

Keywords: Bruchid Beetles; Natural Parasitoids; Essential Oils; Temperature Management; Integrated Pest Management

1. INTRODUCTION

Chickpeas (*Cicer arietinum* L.) and cowpea (*Vigna unguiculata* Walp.) are important grain legumes grown in Asia, the Mediterranean, Australia, Canada, the USA, and Africa [1] and stored dry. However, they become infested by many insect pests both in the field and during postharvest storage. The most important pests of stored grain legume seeds are bruchid beetles (Coleoptera: Chrysomelidae: Bruchinae), such as *Callosobruchus maculatus* (F.) and *Callosobruchus chinensis* (L.) [2,3]. Even low initial infestation rates can lead to tremendous damage because of the beetles' high fertility and short generation times [4]. Each emerging female *C. maculatus* quickly finds a mate and, if food is readily available, produces about 100 offspring. After three or four generations, each of which takes only about a month, losses are severe [5-8]. Most subsistence farmers in developing countries rely on traditional storage structures, which are especially vulnerable to bruchid attack [9,10]. The use of insecticides or fumigants to protect the seeds from bruchids is effective, but these chemicals pose health hazards to farmers and consumers, cause environmental pollution, and cost money. Furthermore, insects develop resistance to insecticides, necessitating the application of larger amounts [11]. These problems can be reduced through the use of integrated pest management. This paper reviews alternative methods to protect against bruchid beetles. Breeding of crops for resistance to storage insects, especially bruchid beetles, has already been reviewed [12]. This paper focuses on parasitoids, essential oils, and recent new methods.

2. BIOLOGIAL CONTROL METHODS

2.1. Natural Parasitoids

Some wasps parasitize bruchid beetles (**Table 1**). Females of the wasps oviposit on the eggs, larvae, or pupae,

Table 1. Hymenopteran parasitoids species and their bruchid hosts.

Parasitoids species	Host species	Ref.
Anisopteromalus calandrae	*Acanthoscelides obtectus*	[13]
	Callosobruchus maculatus	[14]
	Zabrotes subfasciatus	[15]
Dinarmus basalis	*A. obtectus*	[16]
	C. maculatus	[17,18]
	C. chinensis	[19]
	C. subinnotatus	[20]
	Bruchidius atrolineatus	[16]
	Z. subfasciatus	[16]
Eupelmus vuilletii	*C. maculatus*	[18]
Uscana lariophaga	*C. maculatus*	[21]
	B. atrolineatus	[21]

and the emerged larvae feed on them. *Dinarmus basalis* (Rondani) (Hymenoptera: Pteromalidae) parasitizes late-instar larvae and pupae of a wide range of beetle species, having a stronger impact on beetle populations than other species such as *Eupelmus vuilletii* (Crawford) (Hymenoptera: Eupelmidae) [18,22]. *Uscana lariophaga* Steffan (Hymenoptera: Trichogrammatidae) parasitizes eggs of *C. maculatus* and *Bruchidius atrolineatus* Pic (Coleoptera: Chrysomelidae: Bruchinae). The release of *D. basalis* adults in suitable numbers and under suitable conditions reduced populations of *C. maculatus* drastically and halted seed weight loss for 6-7 months in West Africa [20,23,24], and controlled *Acanthoscelides obtectus* (Say) in Colombia [25]. *Uscana lariophaga* significantly reduced the numbers of *C. maculatus* adults, the rate of damaged beans, and seed weight loss in a traditional storage system in Niger for 3 months [26]. Tracking of the phenological relationship between *A. calandrae* and *C. maculatus* populations over 5 months suggested that *A. calandrae* reduced the *C. maculatus* populations [27]. However, these parasitoids need suitable temperature and humidity to be effective as biological control agents. And within closed storage systems, populations of both hosts and parasitoids can reach high densities, which could lead to high intra- and inter-specific competition among parasitoids for the host resource as, for example, among *E. vuilletii* females [28] and between *E. vuilletii* and *D. basalis* [18,22,29]. Such competition may reduce the parasitoids' effectiveness at biological control, although the coexistence of *U. lariophaga* did not change the ability of *D. basalis* to suppress *C. maculatus* and damage to beans [30]. Before parasitoids are used as biological control agents, it is necessary to take into account the costs and benefits associated with the optimum environmental conditions, numbers, kinds, and combination of parasitoid species.

2.2. Essential Oils

Several plants and constituent bioactive substances, also called "insecticides of plant origin" or "botanical insecticides", have been tested against seed beetles. The effects of essential oils from some plant species on adult mortality, oviposition, F_1 adult emergence, and other behaviors of bruchid beetles, especially *C. maculatus*, by contact and fumigant treatment have been reported (**Table 2**). Essential oils comprise mainly monoterpenes,

Table 2. Sources of essential oils, target species, and effects and types of treatment.

Plants	Effects	Contact or fumigation	Ref.
Taget species: *C. maculatus*			
Alpinia calcarata	Adult mortality, oviposition and adult emergence	C, F	[34]
Azadirachta indica	Oviposition and adult emergence	C	[35]
Cinnamomum zeylanicum	Adult mortality, oviposition and adult emergence	C, F	[36]
Citrus limon	Adult mortality	F	[37]
C. reticulata			[37]
Cymbopogon giganteus	Adult mortality, oviposition, hatching rate	F	[38]
C. nardus			[38]
C. schoenanthus	Mortalirty in different developmental stages	F	[39]
C. winterianus	Adult mortality, hatching rate, adult emergence	C	[40]
	Oviposition, Repellency, adult emergence	F	[40]
Elettaria cardamomum	Adult mortality, oviposition	F	[41]
Eucalyptus citriodora	Adult mortality, hatching rate, adult emergence	C	[40]
E. staigeriana	Oviposition, Repellency, adult emergence	F	[40]
	Adult mortality, hatching rate, adult emergence	C	[40]
Foeniculum vulgare	Oviposition, Repellency, adult emergence	F	[40]
	Adult mortality, hatching rate, adult emergence	C	[40]
	Repellency, adult emergence	F	[40]
Hyptis spicigera	Adult mortality	C	[42]
H. suaveolens			[42]
Lippia multiflora			[42]
Micromelum minutum	Adult mortality, oviposition and adult emergence	C, F	[36]
Ocimumame ricanum	Adult mortality	C	[42]
Plectranthus zeylanicus	Oviposition, Repellency, adult emergence	C, F	[43]
Taget species: *C. subinnotatus*			
Cymbopogon giganteus	Adult mortality, oviposition, hatching rate	F	[38]
C. nardus			[38]

sesquiterpenes, and low-molecular-weight aromatic compounds [41]. Some monoterpenoids affect mortality at all developmental stages and oviposition [42]; and 1,8-cineole from *Alpinia calcarata* (Rosc.) (Zingiberaceae) affects adult mortality, oviposition, and F_1 emergence [31]. However, essential oils are likely to affect predators as well. For example, essential oils of *Cymbopogon nardus* (L.), *Cymbopogon schoenanthus* (L.), and *Ocimum basilicum* (L.) increased the mortality of *D. basalis* larvae and pupae that parasitized *C. maculatus*, as well as *C. maculatus* [43]. In contrast to genetically modified legumes expressing *α*-amylase inhibitor-1 of *Phaseolus vulgaris* L. or cysteine protease inhibitors, which are resistant to several bruchid species and should be compatible with the use of parasitoids [44], essential oils might not be compatible with the use of parasitoids.

2.3. New Methods

Temperature management is one of the most promising tools for controlling pests of stored grain [45]. Studies of the effects of both low and high temperatures on mortality of *C. maculatus* at different life stages give varying results, depending on the methods [46,47]. Although temperature control offers a way to disinfest beans, potential problems include the effect of the treatment on the beans and the cost of the equipment. Although low temperatures do not harm seeds, high temperature stimulated the germination of mung beans [48]. Further research of the effects of temperature, especially high temperature, is needed.

Hermetic storage bags (SuperGrainbags; GrainPro, Concord, MA, USA), which reduce internal oxygen levels, increased *C. maculatus* mortality and reduced invasion from outside when used to store cowpea [49].

3. CONCLUTION

Several methods may protect stored beans from bruchid beetles without the need for chemical insecticides, but adequate control might depend on a combination of methods. Combining methods would also reduce the likelihood of the development of resistance [11]. Neem oil could be combined with resistant cultivars for the management of *C. maculatus* [50]. The combination of arcelin, a protein associated with insect resistance in *P. vulgaris*, with biological control by *D. basalis* increased the mortality of *A. obtectus* relative to *D. basalis* alone [51,52]. Such combinations would support integrated pest management of bruchid beetles while reducing the use of chemical insecticides or fumigants.

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