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Use of Different Bio Rational Compounds for Storage- product Pests Control

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ABSTRACT

Development of insecticidal and fungicidal resistance, damage to non-target organisms, and treating acute and chronic effects to humans and the environment have created a need to embrace bio rational measures over chemical control against storage-product pests. Several species and strains of pests affect storage grains resulting in qualitative and quantitative loss. The losses of such pests have been found to be about 9%in developed countries and up to 20% in developing countries. The study assessed the bio rational measures such as the use of microbial, pheromones and food attractants, natural enemies, botanicals, and biological control that can be adopted alternately over chemical pesticides to suppress and control such storage-product pests. Rice weevil (Sitophilus oryzae), Khapra beetle (*Trogoderma granarium*), Angoumois grain moth (*Rhyzopertha dominica*), Pulse beetle (*Callosobruchus chinensis*), Red flour beetle (*Tribolium castaneum*), Potato tuber moth (*Phthorimaea operculella*), Long headed flour beetle (*Latheticus oryzae*) are some storage-product pests. Different pests, including Weevil (*Sitophilus* spp.), Lesser grain borer (Rhyzopertha dominica), Drugstore beetle (*Stegobium paniceum*), Cowpea weevil, (*Callosobruchus* spp.), and Angoumois grain moth (*Sitotroga cerealella*), were effectively controlled using a parasitoid Theocolax elegans. Application of essential oils of Cymbopogon citratus (Stapf) and Cymbopogon nardus (Rendle) for the control of Cowpea bruchid (*Callosobruchus maculatus* (F.) on rice grains (Oryza sativa) showed retardation of their oviposition and F1 emergence compared to a controlled experiment. 100% mortality to *Sarocladium oryzae* and *R. dominica* was observed after the application of Cucurbita

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maxima leaf extract against them within 3 days of treatment. The use of such bio rational compounds is inevitable to ensure food security and agricultural sustainability.

INTRODUCTION

The majority of the world population is dependent on agro-based enterprise in a direct and indirect way. A number of pests affect the crops starting from their early vegetative stage to flowering, fruiting, and harvest stage. Even after the harvest, these commodities are time and again affected by a wide range of pest categories, including bacteria, fungus, insects, rodents, and birds. Storage pests are those pests that are responsible for causing damage and thus, decrease the nutritive and economic value of the stored commodities. Approximately one-third of the global food production worth above $100 billion per annum is damaged due to more than 20,000 species of field and storage pests (Shukla & Toke, 2013) and (Yankanchi et al., 2014) highlighted that about 20-30% qualitative and quantitative loss is caused by tropical storage-grain insects and 5-10% by temperate A number of pest control strategies have been practicing with some questions raised each time about their effectiveness and consequences. The interaction of grains with insect pests is more compared to other pest categories. A number of stored products have been controlled using chemical insecticide (Arthur & Rogers, 2003), but due to limitation of scale or due to lack of adequate chemical control, interest in biological control measures is increasing. A number of biological pest control strategies are made available on a commercial scale (Prozell & Scholler, 2003). Stored grains and products are one of the major areas where such bio-control strategies are practiced. Pyralid moths are controlled using parasitoids (Stengard & Hansen 2005). In the same way, stored product beetles are also controlled using parasitoids alike (Scholler et al., 2006). Storage-product pests have created harm to the stored products by not only damaging the product and making it unfit to consume but also creating a huge economic loss. According to (Hagstrum & Flinn, 1995), such insect pests can have a great impact on stored grains and processed products from an economic perspective. (Campbell, Arthur, & Mullen, 2004) mentioned that these insects do not require a large amount of food as food accumulated on cracks and crevices, inside machinery, and under the floor is sufficient to feed them. It also makes it humans difficult to clean and manage such waste. The use of chemical pesticides can act as a check mechanism but unfortunately cannot be sustainable practice as a number of insect pests may develop resistance to them (Subramanyam & Hagstrum, 1995). The use of pesticides in agriculture has resulted in four-fold problems through trophic levels: health-related problems, environmental problems, yield loss due to non-target pesticide application resulting in pesticide-induced pests' resurgence, and finally, the financial burden to the farmers (Koirala et al., 2009). Due to the effects of pesticide use, farmers experience the symptoms of headache, eye burning sensation, skin irritation, teary eyes, weakness, and other infirmities and discomfort (Atreya, 2012). Further, effects of exposure to pesticides result in acute illnesses such as headache, skin irritation, respiratory and throat discomfort (Yassin, 2002). Long-term exposure to pesticides causes serious health issues such as chronic cancer, endocrine disruption, and neurological effects (EPA, 1999). Similarly, low-dose long-term

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exposure to pesticides is linked to health-related issues like immune suppression, hormone disruption, diminished intelligence, reproductive abnormalities, and cancer (Gupta, 2004).

Storage-grain pests create economic loss as well as decrease the nutritional value of the stored products making them unfit to consume (Padin et al., 2002). The losses of such pests have been found to be about 9% in developed countries and up to 20% in developing countries (Philips & Throne, 2010). Developed countries have a number of infrastructures, a scientific environment for evaluation, and systematic policies enough to handle the havoc of such pests which developing countries lack. Biological pesticides can be alternative to chemical pesticides in a number of ways. The use of biological control measures may be more effective for pests of stored products as they may hide inside the storage room under sacs, types of machinery, holes, and other places difficult to access, and chemical control is difficult to carry out. The focus has been given to controlling stored bulk grains using a number of biological control measures. The potential of parasitic wasps like Theocolax elegans and *Anisopteromalus calandrae* to suppress and control a number of pest populations in bulk-grain storage in an effective way can be an example (Scholler & Flinn, 2000). Apart from that, *Beauveria bassiana*, Sorokin, *Nosema* spp., *Vuillemin*, *Mattesia* spp. and *Metarhizium anisopliae* have also been investigated and experimented with. But a limited field testing of such organisms has been carried out (Brower et al., 1995). Similarly, in the United States, the bacterium Bacillus thuringiensis (Bt) has been used as a grain-protectant and in India, it has been used to control Indian meal moth larvae (Brower et al., 1995). Lepidopteran pests are also challenging for the stored grain pests and a number of biocontrol agents have been practiced on them. Lepidopteran larvae that have been attacking stored grains are controlled effectively using the bacterium Bacillus thuringiensis, however, resistance has also been revealed (McGaughey & Beeman, 1988). Moth on stored products like nuts and fruits, particularly dry fruits, has been controlled using a Granulosis virus available on a commercial scale in the market (Vail, 1991).

A number of strategies apart from the biocontrol measures against storage-grain pests have been carried out, some of which include physical control (inert dust, ionizing radiation, light, and sound), thermal control (low-temperature control, high-temperature disinfection), ozonization, and fumigation. (Fields & Muir, 1996) mentioned that inert dust has been found effective in controlling a number of storage insects in North America and Africa. Diatomaceous Earth (DE), the fossilized remains of the diatoms, was made a chemical modification and Calcium Diatomaceous Earth showed the highest repellent, insecticidal and ovicidal effect against *Callosobruchus maculates* (Abd-El-Aziz & Sherief, 2010). (Valizadegan et al., 2009) reported that the use of ionizing radiation can be an effective and environment-friendly technique to manage storage-grain pests. Similarly, low temperature diminishes feeding behavior and fecundity and lowers the survival of storage pests (Logstaf & Evans, 1983). (Rajendran & Sriranjini, 2008) mentioned that phosphine and methyl bromide are two common fumigants used for storage pest control. Due to the less knowledge and concern about storage grain pests and their extent of damage, poor countries are still lagging behind. Synthetic insecticides and fumigants are major chemical control measures with greater effectiveness against stored-grain insects (Zettler & Arthur, 2000); (Benhalima et al., 2004). The use of such chemical pesticides, however, causes damage to consumers' health and environment and increases insecticidal

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resistance. The use of biological methods creates minimum to no chance of environmental hazards (Edde, 2012).

MATERIALS AND METHODS

A number of literature reviews regarding the harms and resistance mechanisms of insect pests due to chemicals and several ecological control measures were also studied. Journal articles, review articles, conference papers, the internet, e-newspapers, book, and book sections were the source of secondary information.

RESULTS AND DISCUSSION

Storage Pests

The cumulative effect of all the storage pests is responsible for causing damage to the stored grains and other products. Insects are the major threats to the stored products, particularly grains. In fact, they interact and associate with the crops at the early stage, causing damage during the crop stand and during the storage alike. There are hundreds of species of insects causing the infestation of stored products. Rice weevil, maize weevil, Indian meal moth, Rice moth, Khapra beetle, etc., are some major grain insect pests. Alternaria, Fusarium, and *Drechsclora* are some fungi affecting grains during higher moisture states. Aspergillus and Penicillium are important fungi causing damage to the crops in the storehouse and at fields alike. Fungi degrade the quality of grains in many ways. (Multon, 1988) mentioned that such fungi are responsible for degrading the baking quality of wheat grain.

Several species of Rice weevil such as Sitophilus oryzae, S. zeamais and S.granarius have been found to be serious storage grain-pests of various crops such as rice, wheat, sorghum, maize, and barley. Khapra beetle (Trichoderma granarium) is another serious storage grain-pest of cereal crops like sorghum, maize, and barley. Pulse beetle (*Callosobruchus chinensis* and *Callosobruchus maculates*) is found to create huge damage on several stored products of pulses, beans, and grains (Ahmad, 1983).

The quality of the stored grains is impacted to a greater extent by rodents, particularly mice and rats. Damage to the storage structures, electrical installations, and water pipes has been reported (Smith, 1995). Mus musculus of the house mouse, Rattus norvegicus or the brown rat and *Rattus rattus* or the black rat affect field and stored-grain in many ways. According to (Lund, 1994), the nature, biology, and habitat of these rats have been extensively studied. Apart from these, other ground or tree squirrels affecting stored grains include *Citellus* spp., *Tamias* spp., *Xerus* spp., *Funiscurus* spp., and *Halosciurus* spp. (Smith, 1995).

Loss Assessment

Loss of the stored grains may be due to several storage pests, including insects, mites, fungus, and rodents. Consumption of grains or produces by insects involves not only direct kernel consumption but also detritus accumulation rendering it unfit for human consumption. They also damage grains for oviposition, making holes in grains. About 5-10% loss due to insects have been estimated which in the case of the tropics reach up to 30%. This has resulted in an annual loss of $200 million in the net value of the storage crops in the USA (Weaver & Petroff, 2004). In developing countries, the Pulse beetle (*Callosobruchus chinensis* L) has caused a huge qualitative and quantitative loss (Abrol, 1999; Alam 1971). The damage caused by pests results in a quantitative loss (decrease in the weight of stored grains), qualitative loss (decrease in size, unappealing shape, and accumulation of pest's wastes), as well as decreased viability of the seed. Psocid pests are annoying and problematic for godowns and storehouses (Kleith & Pike, 1995). They are found to cause visible grain damage and their loss (about 3% in a storage

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period of 6 months). *Prostephanus truncates* is a serious pest of corn, particularly unhusked corn in East and West Africa, causing greater damage (GASGA, 1987). One of the less-studied but greater threats to storage products is a mite. The quantitative loss caused by mites has not been documented properly (Kent, 1991). (Fleurat-Lessard, 1988) mentioned that they feed the germ part of the stored grains and release storage fungi and bacteria. Different species of fungi (Aspergilus) such as *Aspergilus halophilicus*, *A. restrictus*, *A. glaucus*, *A. candidus*, *A. ochraceus*, and *A. flavus* kill the germ of the grain and cause discoloration (Sauer et al., 1992). *Callosobruchus maculatus* (Fab.) (Coleoptera: Bruchidae) is a serious pest of cowpea (Boeke et al., 2004), causing its greater damage.

Biorationals For Storage-Product Pests Control

Microbials: Different forms of microbial or microbial pesticides have been used to limit the effect of a number of stored grain pests, particularly insects. Metabolites of an Actinomycete bacterium, *Saccharopolyspora spinosa* have been used to derive common bacterial insecticide Spinosad (an insecticide derived from bacteria *Saccharopolyspora spinosa*). Stored wheat grains suffering huge loss due to insects have been effectively controlled using that bacterial insecticide (Flinn et al., 2004). Spinosad loses its insecticidal property within a week when it is exposed to Ultra Violet rays of the sun, so it is difficult to use in open field conditions. But it has been mentioned that in a stored environment not exposed to sunlight; it can retain its insecticidal activity up to 12 months, making it effective to control lesser grain borer (*Rhyzopertha dominica* F.) and the Red flour beetle (*T. castaneum* Herbst) (Fang *et al*., 2002). Complete control and progeny suppression of the F1 at grain beetle (*Cryptolestes pusillus* Schonherr), the confused flour beetle (*T. confusum*), and the rusty grain beetle (*Cryptolestes ferrugineus* Stephens) have been observed by the use of 1mg of Spinosad per kg of wheat under stored condition.

Pheromones: Any chemical that is secreted or excreted by an individual organism and that triggers a response in members of the same species are termed as pheromones. As biorational compounds, pheromones can act as important controlling agents for a number of storage grain pests, particularly insects. They act as hormones outside the body of the organism that secrete it and create an effect on the organism receiving it. (Phillips *et al*., 2000) suggested that slow-release formulations of pheromone lures in the monitoring traps are available for about 20 different species of stored-product insects. Interpunctella, the cigarette beetle (*Lasioderma serricorne* F.; Coleoptera: Anobiidae), the Red and Confused flour beetles (*T. castaneum* and *Tribolium confusum* Jacquelin du Val, respectively), and the Warehouse beetle (*Trogoderma variabile* Ballion; Coleoptera: Dermestidae) are some major insects for which pheromones are used. Placement of the pheromones is a crucial aspect in order to make them effectively work. Responding beetles passed through a corrugation tunnel to the cup of oil and were killed due to suffocation in an experiment conducted (Barak & Burkholder, 1985). *P. interpunctella* males were attracted to pheromone-baited traps on flat landing sites, as mentioned by (Nansen et al., 2004).

Natural Enemies for Stored-product pest Application or release of any particular natural enemy depends upon the history and background information of the pest. Important considerations such as knowledge about lifecycle, behavior, mode of feeding, and so on are crucial before releasing any natural enemy for its control. Some natural enemies or predators kill their prey immediately after the attack, while some need to have a close bio systemic connection

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to killing the prey. The former comes under generalists and the latter under specialists. The Pirate warehouse bug (*Xylocoris flavipes*) preys on eggs and larva of insects feeding on the stored products (Arbogast, 1975) and comes under the generalist. Another example of such is the Histerid beetle (*Teretriosoma nigrescens*) which feed on beetles (Rees, 1985) According to (Poschko, 1993), such beetle feed on several families of the harmful beetle and thus, protecting stored grains and products from insect damage. (Wajnberg & Hassan, 1994) stated that egg parasitoids of *Trichogramma* Westwood are one of the potential generalist parasitoids used widely in the study of its potential on field crops. Different pests, including Weevil (*Sitophilus* spp.), Lesser grain borer (*Rhyzopertha dominica*), Drugstore beetle (*Stegobium paniceum*), Cowpea weevil, (*Callosobruchus* spp.), and Angoumois grain moth (*Sitotroga cerealella),* have been effectively controlled using a parasitoid *Theocolax elegans.* (Flinn, 1998) (Flinn & Hagstrum, 2001). Storage situation is one of the factors determining which type of natural enemy is to be used and how it needs to be handled and implemented. The association of generalists and specialists' predators for the control of different insect pests is preferred as the pest complex for several species is encountered while considering the storage pest control (Press et al., 1982).

Botanicals

Plant-derived chemical compounds used for repellent, a deterrent for feeding and oviposition, disruption of the biochemistry, physiology, and behavior of insect pests are called botanicals. A number of spices crops like chili, garlic, turmeric, ginger, etc., and botanicals such as neem, bakaino, century plant, and, chinaberry, lac tree, etc., have been used effectively for insect pest control. (Shukla et al., 2007), (Srinivasan, 2008) mentioned that a number of plant products had been successfully tested with a good degree of result to act as a protectant against a number of stored-grain insect pests. Pigeon pea for 8 months against damage of pulse beetle experimented on neem seed oil@1% (volume/weight), mahua oil @1%(volume/weight), and oil of neem seed @4%(weight/weight) where they were proved to be repulsive and potent oviposition inhibitor. (Singal & Chouhan, 1997). Essential oils were also found to have a satisfying alternative against chemical insecticides for the control of coleopteran insect pests on stored grains. (Pérez et al., 2010). (Kirubal et al.,2008) mentioned that *C. chinensis* (L.) oviposition and F1 emergence were prevented on the red gram treated with 0.2%(v/w) ginger grass oil. Similarly, application of essential oils of *Cymbopogon citratus* (Stapf) and *Cymbopogon nardus* (Rendle) for the control of Cowpea bruchid (*Callosobruchus maculatus* (F.) on rice grains (Oryza sativa) showed retardation of their oviposition and F1 emergence compared to a controlled experiment. (Paranagama et al., 2003). 100% mortality to Sarocladium oryzae and *R. dominica* was observed after the application of Cucurbita maxima leaf extract against *Sarocladium oryzae* and *R. dominica* within 3 days of treatment (Rajasekharreddy and Usha Rani, 2010).

(Ho, 1995) mentioned that garlic (*Allium sativum*) has shown the repellent property to *Tribolium castaneum* and its oil was effective for killing *T. castaneum* and *Sitophilus zeamais*. Besides, it was also found to be effective to repel *T. castaneum* and *S. zeamais*. Turmeric (*Curcuma longa*) was found effective for repelling a number of stored insects. A number of storage pests are killed when 2% turmeric powder is mixed with rice and wheat (Jilani & Su, 1983). Almost every part of Neem (*Azadirachta indica*) is pesticide and its seed kernel is more effective. *Trogoderma granarium* is best controlled using neem products and pulse weevil is also controlled using 0.5% neem oil where it acts as a surface protectant (Ketkar,

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1987) Oil of lac tree (*Schleichera trijuga*) is used as a surface protectant against pulses weevil where its extract is used as a repellant and insecticidal against adult of *S. zeamais* and eggs of *T. castaneum* (Ketkar, 1987). Teotia & Tewari (1971) suggested that leaf and drupe powders (1 and 4%) of chinaberry (*Melia azedarach*) protect wheat against *S. cerealella*. Black pepper (Piper nigrum) is found to inhibit the development of F1 of *Callosobruchus chinensis* (Morallo-Rejesus et al., 1990). Also, the Clove tree (*Syzygium aromaticum*) has been found to repel a number of stored grain pests including *T. castaneum* (Grainge & Ahmed, 1998). Several botanicals have been found to be effective against stored product pests such as Century plant (*Agave americana*) (Grainge & Ahmed, 1988); Undi (*Calophyllum inophyllum*) against pulse weevils (Ketkar, 1987); and Indian privet (*Vitex negundo*) against stored grain-pests (Ahmed & Koppel, 1987).

Biological Control: A number of entomopathogenic fungi, nematodes, bacteria, predators, parasitoids, and wasps are used as biological control of several storage-product pests. (Weaver & Petroff, 2004) suggested that the commercial availability of biological control agents is limited except when scaled up for organic production. Entomopathogenic fungi (EPF), among different biological control measures, are effectively used as promising commercial products against a variety of insects under open field conditions such as termites (Rath, 2000). Unfortunately, not much progress has been made regarding their commercial availability under storage conditions. (Kaur et al., 2014) mentioned that conidia of the entomopathogenic fungus have been used in the dry or mixed form (with rice grain) against stored-grain insects. An experiment conducted by (Sedehi et al., 2014) for different isolates caused moderate to high mortality at their different stages (immature stage and adult stage). The conidia of a *Beauveria bassiana* were suspended in a mixture of corn oil and mineral oil and applied against *Sitophilus zeamais* where oil suspension formulation among different formulations showed a higher effect. (Batta et al., 2010) suggested that, *Sitophilus granarius*, *Rhyzopertha dominica*, *Sitophilus oryzae,* and *Tenebrio molitor* were effectively controlled using liquid formulations of entomopathogenic fungus.

Entomopathogenic nematodes are endoparasites (lethal) of insects (Gaugler, 2002). Their trial has been successful in controlling insect pests of soil under field conditions (Kaya & Gaugler, 1993)). Though they have not studied in detail a greater range for storage pest control, they exhibit some characteristics that make them perfect biocontrol choices. They have low toxicity to vertebrates (Bathon, 1996) and some species are commercially available (Grewal, 2002). Other important characteristics of such nematodes include tolerance to a number of pesticides (Koppenhofer, et al., 2000), wide host range (Capinera & Epsky, 1992) and active host finding ability (Campbell & Lewis, 2002). They have been taken as effective biocontrol agents for a number of storage-grains insects. They are used to control storage insects belonging to Pyralidae (Shannag & Capinera, 2000) and Curculionidae (Shapiro & McCoy, 2000). (Morris, 1985) demonstrated the effectiveness of nematodes for controlling storage product insects like *Tenebrio molitor* L and *Ephestia kuehniella* Zeller.

C. cephalonica, along with other different insect pests such as thrips, aphids and mealybugs in cropping systems of Sub-Saharan Africa and the Mediterranean region, has been effectively controlled using Anthocorid bugs (Zhang et al., 2012); (Efe & Cakmak, 2013); (Wang et al., 2014). One of the important biological control agents used against stored-grain pests such as moths, mites and bruchids is a predatory bug, X. flavipes (Rahman et al., 2009). Eggs and larvae of lepidopteran pests, sucking pests

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like mealy bugs, aphids, thrips, mites, and stored insect pests have been effectively controlled by using a biocontrol agent *Blaptostethus pallescens* (Kaur et al., 2019). The highest mortality (51.66%) of rice weevil (Sitophilus oryzae L.) was observed by the mixture of mix *B. bassiana* ARSEF 5500+ *M. anisopliae* ARSEF 2974 isolates (Bello et al., 2000).

Monitoring for The Stored-Grain Pests

Monitoring for the stored-grain pests helps to identify and isolate pest populations which prevent qualitative and quantitative loss of stored commodities. It also suggests the practitioner get to know the effectiveness of the particular Integrated Pest Management (IPM) technique for a particular storage-product pest (Campbell et al., 2002). The technique of pest monitoring depends upon the type and nature of the pest, commodity, and type of storage method. Bulk commodity storage, pheromone attractant, food attractant, white painted bins are some monitoring strategies and techniques. Besides, modern monitoring techniques involve near-infrared spectroscopy for parasitoid stored products and electronic nose technology for grain spoilage detection. The effectiveness of pheromone traps can be increased by using food attractants for Flour beetles (*Tribolium* spp.) as well as attraction to Attagenus, Trogoderma, and *Anthrenus larvae* (Burkholder & Ma, 1985). Near-Infrared Spectroscopy (NIRS) has been used for the application of agriculture and food technology (Panford, 1987). It has been used for the detection of infested and un-infested wheat kernels to identify internal insect pests of wheat (Dowell et al., 1988). Similarly, it has been used in wheat to distinguish unparasitized and parasitized weevil larvae by wasps (Burks et al., 2000). (Magan & Evans, 2000) suggested that electronic nose technology has been used in recent years for the rapid detection of grain quality by taking grain properties such as odor and volatility into consideration.

CONCLUSION

The use of chemicals for storage-product pests' control has resulted in a number of complications such as effects to non-target organisms, insecticide and fungicide resistance, acute and chronic health hazards, and so on. Biological pesticides can be alternative to chemical pesticides in a number of ways as they are environment friendly and applicable in the long run. Natural enemies, including predators and parasitoids, can be used for pest control; however, important considerations such as knowledge about lifecycle, behavior, mode of feeding, and so on are crucial before releasing any natural enemy. Botanicals or the plant-derived chemical compounds such as *Allium sativum*, *Curcuma longa, Melai azadirach, Azadirachta indica,* etc., can be used as a repellent deterrent for feeding and oviposition, disruption of the biochemistry, physiology, and behavior of insect pests. As biorational compounds, pheromones can act as an important controlling agent for a number of storage grain pests, particularly insects. Emphasis on the promotion, scaling up and commercialization of the bio rational methods should be given so that it will effectively control the pathogens without developing resistance on one hand and recovering the environment on the other.

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CONFLICT OF INTEREST

The authors claim there is no conflict of interest.

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