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Mating Disruption in Insect Pests by Sex Pheromones: A Profound Integrated Pest Management Technique

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Abstract: Mating disruption or 'attract and kill' approach provides an excellent source for suppression of major lepidopterans' pest in agriculture field. Important success to date in pest management through mating disruption recorded to oriental fruit moth in peaches, pink boll worm, codling moth in pome fruit and pyralid moth in stored grain pest. Pheromonal formulations are efficient, non–toxic and species–specific that makes this technique different with conventional and synthetic insecticides which have adverse effects on environment and non–specific organisms as well. Large scale implementation of this technique resulted in significant reduction in pesticides use while maintaining acceptably low–crop damage level. Because of some problem like instant and mass control to pests with rich populations, these approaches should not be seen as stand–alone strategies but rather as one new and alternative plan within a suite of integrated pest management options.

Keywords: Mating disruption, Insect pests, Sex pheromone, Insecticides, Conventional pest management, Integrated pest management

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Introduction

The agricultural system is the vital support of human life on earth but it has been constantly challenged in terms of yield. It has been a practice of planting monoculture, that is, planting a single crop species. But in this, growth of desired crop is hampered by many factors including pathogens, parasites and pests (Dontelli *et al.*, 2017). Pests are organisms that might compete with or damage the crop species. They reduce the yield by means of reducing plant density, stunted growth and their death and in many other ways (NRC, 1985; Folnović, 2022). The latest data indicate that pests reduce the yield of agricultural crops in the world by 42% and in Europe by 28%. Chemical pesticides are often used to control pests which is based on substances that are toxic (poisonous) to

the pests. But over reliance on chemical control has led to many problems like development of resistance to insecticides and has polluted various components of water, air, and soil ecosystem (Gill and Garg, 2014; Tudi *et al.*, 2021). So, there is a need to implement an environmentally friendly integrated pest management (IPM) approach with new management tactics (microbial control, biological control, cultural control, mating disruption, insecticide rotation strategies, and plant resistance) for an alternative to chemical control (Mori and Evenden, 2013; Miller and Gut, 2015). The IPM approach is not only economically beneficial but also reduces the environmental and health risks (Shakeel *et al.*, 2017). The goal of using multiple tactics is to effectively suppress pests below injurious levels and avoiding outbreaks. Many tactics keep pest populations off–balance and avoids development of resistance to pesticides (Radcliffe and Hutchison, 2009). These tactics can be divided into cultural controls, biological control, chemical control strategies etc. All are equally important in implementing a successful IPM program.

METHODS OF PEST CONTROL:

Cultural and physical methods:

The cultural methods of pest management methods include mechanical tilling or plowing, hand pulling of the weed with all its roots. To suppress pest problems by minimizing the conditions crop need to live using water, shelter, and food. Simultaneously, the planting of plants that are adapted and suited to growing and flourishing conditions, at the right place, offering appropriate attention to their water and nutritional needs may reduce the attack of pests (Sparks, 2011). Strong plants resist diseases, outgrow weeds and are less likely to succumb to insects.

Insect traps can assist with detection and management of insect pests. There are several physical traps which is made from materials around the home and ease in application as well (Cloyd *et al.*, 2004). By preventing pest access to the host or area, or, if the pests are already present, physically removing them by some means (Sparks, 2011). Thus this could mean using barriers, traps, vacuuming, mowing or tillage, depending upon the pest and situation for better management.

Biological and genetic methods:

The biological method of insect pest management involves the use of natural enemies to reduce pest populations, indigenous and introduced, to aesthetically acceptable levels (Jeffers and Chong, 2021). Natural enemies play an important role in limiting the densities of potential pests (DeBach, 1991). Various success stories have occurred using biological control agents involving parasites, predators or diseases to control another organism. For example, *Bacillus popilliae*, a bacterium that causes the milky spore diseases, has been used with variable success in the control of Japanese beetle grubs. Biological control agents are complex, not totally effective and not always predictable. Interest in biological control has increased over recent decades for many reasons (Bailey *et al.*, 2009). First, a greater appreciation for environmental stewardship among regulators, growers, and the public has promoted development of more sustainable farming practices. Second, a number of arthropod pests have developed (Sanda and Sunusi, 2014). The application of pest–resistant plant varieties developed by classical plant breeding and genetically modified organism methods are now an innovative approach in insect pest management (Reddy, 2017). Recently, this category has been expanded to include genetically engineered pest resistance, such as Bt cotton, Bt corn or potatoes. The introduction of *Bacillus thuringiensis* (Bt) cotton has reduced the burden of pests without harming the environment and human health (Zafar *et al.*, 2020). There are also special uses of genetic techniques on pests themselves, such as release of "sterile male" insects. It is an advance technique known as the sterile insect technique (SIT), which involve the release of artificially (*in vitro*) reared sterile males, offers an

environmentally friendly option for insect pest management (Welburn and Maudlin, 2012). The other most modern technique is the Genetic Pest Management (GPM) methods which release modified versions of a pest species to mate with wild pests in the target area and producing transgender or sterile individuals (Leftwich *et al.*, 2021). This technique can be proposed for a diversified range of applications in public health, agriculture, crop production and plant protection and conservation.

Chemical and behavioral methods:

The chemical control is based on substances that are toxic (poisonous chemical pesticides) to the target pests. The insecticides or chemical pesticides are applied directly to target pests as duct, smoke, gas, powder, granule, emulsion, spray, etc. to protect plants, crops, animals from pests, diseases, weeds, etc. (Thieme *et al.*, 2010; Nicolopoulou–Stamati *et al.*, 2016). Best control of many insects and weeds occurs at a particular stage in its life–cycle, which is usually during the early stages of development whereas at other times it would be less effective. For example, mole crickets are most susceptible to chemical control when they are small, usually during the months of May or June. If use of a pesticide is necessary, select the one that is most effective but least toxic to non–target organisms or least persistent in the environment (McCarty *et al.*, 1995). Behavioral methods include manipulation of adult insect behaviour using semiochemicals functioning as signal compounds. Semiochemicals are chemicals that mediate interactions between organisms (El–Ghany, 2020). Semiochemicals are subdivided into allelochemicals and pheromones depending on whether the interactions are interspecific or intraspecific, respectively (Mouden *et al.*, 2017). Pheromones may be further classified on the basis of the interaction mediated, such as alarm, aggregation or sex pheromone. It is the sex pheromones of insects that are of particular interest to agricultural integrated pest management (IPM) practitioners.

PHEROMONES IN INSECT IPM:

The concept of IPM is based on the recognition that no single approach to pest control offers a universal solution, and that the best crop protection can be provided by a fusion of various tactics and practices based on sound ecological principles. Pheromones are a commonly used component of many insect IPM programs (Tewari *et al.*, 2014). The existence of pheromones has been known for centuries, apparently originating in observations of mass bee stinging in response to a chemical released by the sting of a single bee. The first isolation and identification of an insect pheromone (silkworm moth) occurred in 1959 by German scientists. Since then, hundreds, perhaps thousands of insect pheromones have been identified by increasingly sophisticated equipment. Today we have a much clearer view of the limitations and possibilities associated with insect pheromones in IPM programs. The two primary uses of insect pheromones are for detection and monitoring of populations and for mating disruption (Flint and Doane, 1996). These uses take advantage of sex pheromones on which a vast majority of insect pests rely to mediate reproduction.

Synthetically produced sex pheromones have been successfully used for decades to monitor insect activity patterns, and are extremely valuable tools in Integrated Pest Management (IPM) programs. Synthetically produced pheromones used in the manufacture of "lures" (for pheromone traps) are typically blends of major chemical components, along with some minor components, which attempt to mimic the effects of naturally produced pheromones (Ferracini *et al.*, 2021). Mating disruption (MD) technology uses synthetically produced chemicals in large amounts to confuse males and limit their ability to locate calling females; the blends, however, are often restricted to major components released by females (disrupt rather than attract) (Benelli *et al.*, 2019; Ballesteros *et al.*, 2021). Several mechanisms exist for mating disruption, each of which may vary in importance

as a function of the type of dispenser being used and the insect species. The release of sufficiently large quantities of synthetic sex pheromone into the crop atmosphere interferes with mate location by-- (i) masking the natural pheromone plumes, (ii) affecting the males' ability to respond to calling females, and (iii) causing the male to follow "false pheromone trails" at the expense of finding mates.

By introducing many sources of the sex pheromone into the ecosystem, the probability of the male finding the female is reduced, as is the likelihood of successful mating. As a result, mating is either delayed (with a subsequent negative effect on overall fertility) or prevented. If female moths do not mate, they cannot lay fertile eggs and, if their mating is delayed, they will lay fewer fertilized eggs in their lifetime. Consequently, the subsequent population is reduced, and fewer larvae are present to cause crop damage.

MATING DISRUPTION IN INSECT PESTS:

Mating disruption offers a much different approach to insect pest management than traditional insecticides (Benelli *et al.*, 2019; Ballesteros *et al.*, 2021). Conventional programs typically use insecticides to target the damaging life stage (in most cases, the larva). In contrast, pheromones target the reproductive life stage (the adult), thus preventing the development of the damaging life stage (Mori and Evenden, 2013; Miller *et al.*, 2015). Pheromones used in mating disruption are species–specific and are thus highly selective. They are generally non–toxic and will not control other pests. It is important to thoroughly understand this fundamental difference before beginning a mating disruption program (Carter and Fraser, 2003). Mating disruption is a pest management approach which is invented to control number of insect pests by introducing artificial stimulant that destruct the individuals and disrupt mate localization, thus prohibiting mating and blocking the reproductive cycles. Mating disruption by sex–pheromones is a sustainable, productive and majorly used pest management technique. Many other schemes such as meddling with vibrational communication are also being developed (Foster and Harris, 1997).

MATING DISRUPTION BY SEX PHEROMONE:

Mating disruption includes the use of sex–pheromones which resist male insects finding female partner and thus prevent mating. Pheromones are chemicals which are produced by an insect to interact with other individuals of the same species and they are of different types including trail pheromones, alarm pheromones and many more. Sex pheromones are chemicals produced by female partners to draw attention or attract males from long distances to mate and are relatively common in the insects of lepidopterans (moth and butterflies). Each species has its own specific blend of sex pheromones. In most cases it is a female moth or butterfly that emits sex pheromones and the male follows the pheromone trail or plume to discover the female partner (Arakaki *et al.*, 2013). Three important elements accounts for the fascination of insect sex pheromones and their usefulness for insect management-- (i) these are species specific, (ii) active in very low amount, and (iii) non–toxic to animals. The advancement in technologies and hard works of many scientists have identified and synthesized pheromones in many different insect species. When a small proportion of a species pheromone is taken into a rubber tube or plastic dispensers and placed in a trap, then males partner of that species get attracted towards the trap.

DIFFERENT MECHANISMS INVOLVED IN MATING DISRUPTION:

Artificially produced sex–pheromones are greatly valuable tools in integrated pest management (IPM) technique. Synthetically created pheromones which are used for the manufacture of lures (for pheromone trap) are typical fusion of major chemical components along with some minor components which mimic the effects of naturally produced pheromones by insects (Mori and Evenden, 2013; Miller and Gut, 2015; Miller *et al.*, 2015). The more closely the synthetically produced blend matches the naturally produced

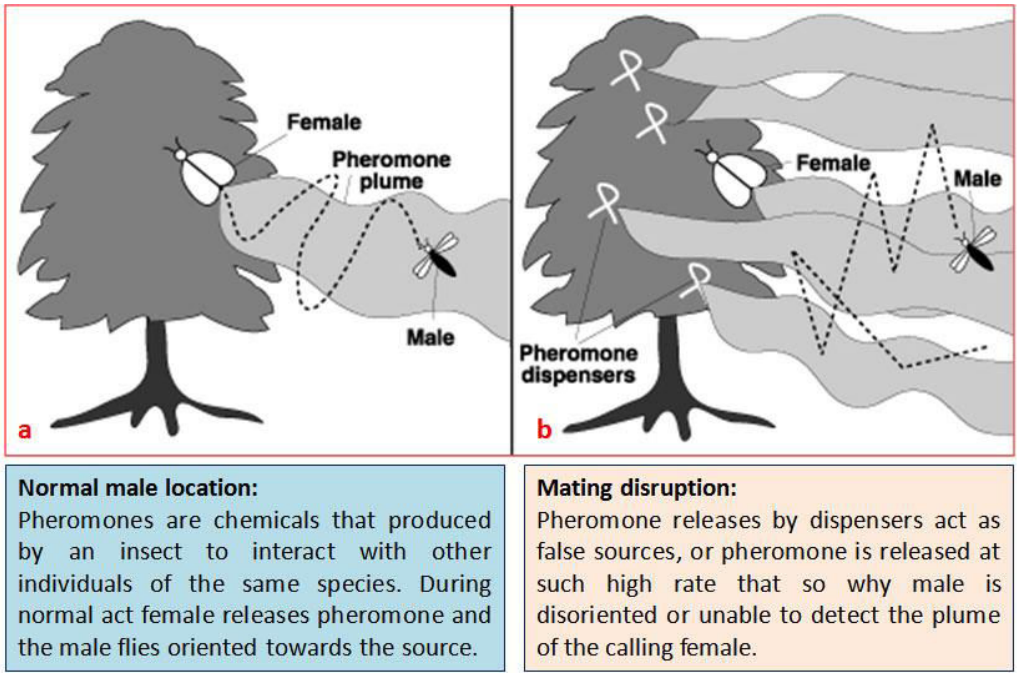

Fig. 1: Mechanism of mating disruption in codling moth (Source: Murray and Alston, 2020).

pheromone by pheromone emitting female known as the "calling female", the stronger will be the response by searching mates. Mating disruption program uses artificially produced pheromones in excess amount to confuse male insect partner and in turn resist their ability to uncover calling females (Fig. 1).

Mating disruption technique provides a much different approach to insect pest management than traditional insecticides. Traditional programs usually use insecticides to target the damaging life stage of insects whereas pheromones point the reproductive life stage i.e. adult, therefore resisting the development of the damaging life stage. Pheromones are species–specific, highly selective, non–toxic and generally control single pest population (Thomson *et al.*, 2001). Many mechanisms have been proposed for pest species to explain how mating disruption works and it is possible that more than one mechanism could be operating at the same time to achieve control.

Adaptation or habituation:

Long time exposure of a stimulus can affect the proper functioning of sensory organs or nervous system of an insect. Adaptation results when sense organs e.g., antennae in moth are exposed continually to high and steady levels of pheromone (Kaissling, 2014). Adapted sense organs recover rapidly in 2 to 3 second when the pheromonal source is removed. Habituation takes place when high concentration of pheromone inhibits the insect's ability to respond for several minutes to few hours. Habituation could play a typical role in mating disruption by making male individual less receptive for long time after exposure to high pheromonal concentration. The insects come upon a vast repertoire of chemicals in their natural environment that can signal positive stimuli like the presence of a food source, a potential mate, or a suitable oviposition site as well as negative stimuli such as competitors, predators, or toxic substances reflecting danger (Depetris–Chauvin *et al.*, 2015). The deviation from signal because of habituation or other causes may lead to insect deviation from territory and thus can be utilized in IPM.

False pheromone trails and masking:

This mechanism considers that the male partner can still sense and respond to the pheromonal source (Kaissling, 2014). If numerous pheromonal

sources are placed on the field or orchard, male would invest time and energy following false pheromonal trails and if there are more false source, possibility of a male finding a calling female would be very low. Ideally, false pheromonal source is evenly distributed and emit some amount of pheromone as calling female. Olfaction is an essential sensory modality for insects and their olfactory environment is mostly made up of plant–emitted volatiles (Conchou *et al.*, 2019) that can be used to deviates the insect pest and IPM. Masking takes in account that the male sensory system is working normally. In this case, the background level of pheromone is very much high and uniform to suppress the odor trail from a calling female. Here males normal navigation system for finding their mate become useless in the pheromonal cloud.

Unbalanced sensory input:

Pheromones present in the members of lepidopterans have different components, even different species have same components but in different ratios which makes the difference. If the altered ratio of pheromone is released, males might not be able to find the natural pheromonal blend released by the female (Reisenman *et al.*, 2016). And if they receive impulses that are out of balance with the one their sensory system is designed to pick up, their mate seeking behavior might be inhibited. Anti–pheromones are chemical that resemble the true pheromone produced by calling female or they might have different chemical structure but it might be possible that they are competing for the same receptor site present on the sensory organ of the male partner and they block mate location.

METHODS OF SEX PHEROMONES DISPERSAL FOR MATING DISRUPTION:

The MD (mating disruption) dispensers should be placed in the field shortly before first male flight (biofix) to inhibit/delay mating through any of the applicable methods. There are different types of mating disruption products in the market to check the pests' population through MD approaches: (i) hand applied dispensers, (ii) sprayable formulations or pheromones, (iii) machine applied formulations, (iv) meso-dispensers, and (v) mega-dispensers (Welter *et al.*, 2005).

Hand applied dispensers:

Hand applied dispensers to be productive and effective should release a small amount of pheromone over approximately 140 days (Murray and Alston, 2020). The hand–applied dispensers have been currently used are cidetrak–CM, isomate–C Plus, isomate–CTT, and Checkmate.

(i) *Cidetrak–CM*: It is a clip–on dispenser which uses a novel packaging of the pheromone in an internal and external shell which will prevent oxidation. It releases pheromones with lowest pheromone rate. The field analyses in Michigan and Washington have shown that this product is effective in preventing injuries.

(ii) *Isomate–C Plus*: It is polyethylene tube twist–tie dispenser filled with pheromone, showed uniform or steady rate of emission through 1st and 2nd generation of codling moth. The field testing has showed excellent results with this product.

(iii) *Isomate–CTT*: It is similar to isomate–C Plus, but it consist of twin tubes (TT), so that it has double pheromonal volume, and work at the half rate of C–Plus.

(iv) *Checkmate*: This product is least efficient because major amount of pheromone degraded on the dispenser surface.

Sprayable pheromones:

Micro–encapsulated pheromones are encapsulated in a polymer capsule which controls the pheromone release rate. Polymer capsules are minute and durable to be used in water through air blast sprays in the same manner as traditional pesticides. This property makes them very attractive for use by fruit growers. Their persuasive activity is normally up to 6 to 4 weeks, which gives them some adaptability in pest management approaches but they require to be reapplied various times in a season against a target pest. During rainfall residual activity get reduced therefore, sticker type sprays are

recommended and currently available effective material is check–Mate OFM–F which is for the control of oriental fruit moth. Various formulations for several insects like codling moth and various species of leaf–roller and wood–boring insects have been tested and sold commercially, but they are unable to give satisfactory or reliable control (Carter and Fraser, 2003).

Machine applied formulations:

Machine applied formulations like flakes, fibers or wax droplets serve as another option for automated delivery of pheromones. These minute or point sources commonly called as female equivalent formulation because they release pheromone at about the same rate as calling females (Miller and Gut, 2015). Experiment on small plot displayed that application of such formulations could provide high rate of mating disruption. Example include distribution of paraffin wax drops of 0.1 ml containing 5% pheromone at 8,200 and 27,300/ha entirely disrupted mating of Oriental fruit moth under heavy population densities. The most successful commercial adaptation of machine applied formulations has been achieved for the gypsy moth (Thorpe *et al.*, 2006). Advantages of these methods include low cost and rapid distribution of several thousands of point sources per hector. Unluckily, important factors limiting the commercialization of this technique for pest excluding gypsy moth include the low effectiveness of product adherence to crop foliage, short field life and lack of rain–fastness following machine or aerial application. The thinking behind this female equivalent formulation approach was that numerous point sources competing with calling female would improve efficiency comparative to hand–applied devices which are used at low densities (Miller *et al.*, 2010). The conclusion is that calling female equivalent formulations provide more opportunities to male to search for actual female over the period of their lifetime than do the reservoir dispersals, thus declining the myth of their preventing mating.

Meso–dispensers:

These are passive devices which release comparatively more pheromone than the standard reservoir dispensers. The higher release of pheromones by meso–dispenser greatly reduces the labor required for hand application (Kazemzadeh *et al.*, 2019). A novel controlled release system called the Metered Semiochemical Timed Release System (MSTRS) was field tested for disruption of the black headed fire worm.

Mega–dispensers:

This is an ultra sparsely dispersed approach which stores and releases the insect mate attractant via aerosol devices that emit very large quantities of pheromone mechanically. These mega dispensers are distributed at densities of only 2.5 per hectare, but each unit of them releases minute quantities (mg) of pheromone at every 15–30 min over a 6–12 h cycle. These extremely low density devices provide a controlled uniform emission rate and a stable environment for the pheromone prior to its release. These aerosol emitters have been tested over large varieties of pests and commodities, but the only noticeable commercial adaptation has been used for disruption of codling moth in pome fruits and nut crops in the Western United States. Regardless of its working, major risk associated using mega–dispensers is that their low distribution density will leave areas of little with no pheromone coverage where mate finding can occur and aerosol treated crops are known to be problematic (Isaacs *et al.*, 1999).

APPLICATIONS OF MATING DISRUPTION:

Mating disruption has been applied on more than 20 insect species and used on more than 750,000 hectares worldwide. This approach against variety of insect pest has been commercially adopted from the last ten years. This technique was first applied on the Pink– bollworm (*Pectinophora gossypiella*) in 1978 and its application increased largely over the past two decades. Codling moth and oriental fruit moth holds the most attention (Isaacs *et al.*, 1999).

Pheromone–based mating disruption is used worldwide for management of the internal fruit feeding codling moth, *Cydia pomonella* (Stelinski *et al.*, 2013). It is a serious pest of apples and pears. Mating disruption techniques is applied in orchard against high population of codling moth. Like other moth species, female codling moth emits species specific sex–pheromone called codlemon that sensed by male partner and attract them for mating. Male swiftly follow the pheromone plume directly to the female. But when the orchard is saturated with synthetic codlemon, mating is disrupted as the males are inhibited or restricted in their ability to find female partner through Isomate–C Plus, Isomate–CTT, puffers and sprayable formulations. Monitoring trap has been used for monitoring codling moth population in orchard. Every monitoring trap comprises three essential components i.e. design of the trap, pheromone baited lure and sticky surface needed to retain the moth. Three most commonly used traps are the wing, large delta and diamond traps (Gut *et al.*, 2009). These traps are essential to determine pest pressure and need for supplemental insecticides. High load codlemon lure i.e. Mega or 10X has been the traditional growers standard. DA and DA–combo are newly established lures which have been used to attract male and female codling moth and have improved trapping effectiveness (Witzgall *et al.*, 2010).

Oriental fruit moth (OFM) is one of the serious pests of apples, peaches, plum, cherry, pear and rose in many commercial orchards worldwide by the 2nd and 3rd generation of OFM. Efforts have been taken to develop methods of mating disruption like polythene dispensers which is marketed as an Isomate M. Various field trials have shown great success in controlling this pest using various hand–applied technologies. But the failures also occurred at borders as a result of the migration of mated females from nearby untreated host.

Mating disruption against this model moth has been done by various methods including aerial formulations and using dollops of SPLAT which releases 2–componet pheromone similar to the pheromone released by calling female. This pheromonal technology applied manually in streets, garden trees and shrubs in California and commercial orchard worldwide. In all the cases the treatment with pheromonal formulation reduced the insect population greatly without causing any effect on environment as by using insecticides. In California the treatment with synthetic pheromone formulation reduce catch to virgin females by 86% and reduce the occurrence of mating by 93% compared with three untreated control (Soopaya *et al.*, 2015). Hence, MD is a promising eradication technique, although it is species–specific whose pheromonal composition is known and potentially available in large quantities.

Pink bollworm (*Pectinophora gossypiella*) has been the focus of an intensive, long–term and productive mating–disruption effort in the United States (Staten *et al.*, 1997). Various strategies have been used (e.g., applications of hollow fibers, chopped laminate flakes, spray–able micro–encapsulated pheromone, twist–tie ropes or laminate membrane dispensers) for field operated successful mating disruption of high moth in the Coachella Valley that in turn resulted significant decline in insecticide application. But the seclusion and area wise suppression of populations enhanced the efficacy of the mating disruption technique, similar to later experiences with codling moth (Welter *et al.*, 2005).

Creative and effective alternatives to insecticides are also required for the stored grain pests. Mating disruption by pheromonal formulation is not used entirely as management practice but it is used to reduce insecticides use. Improved MD technique by sex–pheromone blend which closely match the naturally produced pheromone can be used for pest control at low population level (Phillips and Throne, 2010). Pyralid moths are the most widespread key pest of stored grain product and their control majorly relay on insecticides. Because of human health concern an alternative bio–chemical management

system such as pheromone mediated mating disruption has been used which is found to be effective, self–sustainable, residue free measure to control stored product moth. Though most of the insect's pheromones are species–specific but various stored grain product in the pyralidae family shares common pheromonal components. Female *Plodia interpunctella* produce (Z,E)–9,12–tetradecadien–1–ol acetate as the common sex pheromone which is also produced by the component of the sex pheromone of *Ephestia cautella, Ephestia elutella* and *Ephestia kuehniella* (Bao–Jian *et al.*, 2022). A novel assay system was used to examine the impact of commercial mating disruption dispensers on Indian meal moth *Plodia interpunctella* (Hübner) (Lepidoptera: Pyralidae) (Wijayaratne and Burks, 2020). This system of pest management is compatible with other IPM techniques and will not harm the moth natural predators.

ADVANTAGES OF MATING DISRUPTION:

There are many advantages of mating disruption in insect pest management as a technique IPM because of efficient species specificity and eco–friendly in approach. These are-- (i) Mating disruptions by pheromonal formulations are highly effective in controlling low to moderate pest population, (ii) MD is a pest control method in which pest doesn't control resistance, (iii) Traditional insecticides based control method, directly kill the pest, on the other hand mating disruption program confuses the male insect from accurately identifying a mating partner (Welter *et al.*, 2005), (iv) It is species–specific i.e. it doesn't harm other non–targeted insects. Therefore this allows the suppression of single pest species only, and (v) MD products and insect pheromones are safe for humans i.e. they don't have any adverse effect on humans.

Hence, the use of MD is beneficial in situation where frequent travel in the crop is essential. Mating disruption product have very good fit in IPM programs because they are species–specific, compound used are natural occurring, non–toxic and safe to beneficial and other non–target organism. Though the increase in secondary pest is possible with the removal of broad spectrum insecticides, but the reduction of insecticides can lead to the increase in the population of beneficial insects which will further reduce the various insects pest population (Carter and Fraser, 2003).

LIMITATIONS OF MATING DISRUPTION:

High degree of selectivity may also be a significant hindrance to large–scale implementation, in cases where secondary pests become a problem when insecticides are eliminated. Insecticidal uses targeting the key pest many a times unintentionally control other pests as a secondary benefit. For example, outbreaks of leaf rollers (such as *Pandemis pyrusana*) have been reported in California apple orchards applying pheromone–disruption programs to control codling moth without organophosphates (OPs) (Walker and Welter, 2001). Similar results were observed in apple orchards using the mating disruption of codling moth, when the OP azinphos–methyl was removed, populations of the wooly aphid (*Eriosoma lanigerum*), lightbrown apple moth (*Epiphyaas postvittana*), San Jose scale (*Quadraspidiotus perniciosus*) and budworm (*Helicoverpa* spp.) get increased (Nicholas *et al.*, 1999). Because of following characteristics these have certain limitations-- (i) High development and production cost, (ii) Lack of identified pheromones for some pest species, (iii) Requirement for specialized application technique, and (iv) Need to supplement the pheromone programme in high pest population.

Conclusion

Pest is the major threat to the agriculture system as it affects its yield by damaging the crops. To control the insect pest, traditional methods of insecticidal applications have been used to control the pest population, which has adverse effect on environment and non–pest organisms. But the discovery of species–specific pheromone as mating disruption technique resulted as an excellent source for suppression of insect pest population which is species specific, non–toxic and

environmental friendly. Different methods have been used to disrupt the mating between insect pest. This program does not kill the pest, rather resist male insects from finding female partner and thus prevent mating. Mating disruption by sex–pheromone is highly sustainable, productive and majorly used pest management technique which reduces the dependence on insecticides. However, this approach holds some constrains also that is not functional on high insect population. Hence, should not be seen as standalone strategy but rather as one plan within a suite of integrated pest management option.

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