APPL. SCI. BUS. ECON. VOLUME 5 (2) 05–15
ISSN 2312–9832

APPLIED SCIENCES AND BUSINESS ECONOMICS OPEN ACCESS

Management of Insect Pests of Cotton; More towards the Futuristic Approach

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Key words: Insect pests, New Skylines, Pink Bollworm, RIDL, Robots, SIT, Whitefly

ASBE
Applied Science & Business Economics

Abstract

Pakistan is an agriculture-based country. Most of the country's economy depends on the agriculture sector. Agriculture sector supports many people either through raising of crops or employment in industries. Among the crops grown, cotton crop dominates more than other as it serves as cash crop and play pivotal role in country's economy. Since last decade, cotton crop is facing high threats especially, by the insect pests as they have the potential to cause about 50 – 80 % loss in production. To manage cotton pests, a variety of control measures are being adopted especially chemical control. With continuous use of chemicals, insect pests have developed resistance against them in a last few years. Moreover, these chemicals are hazardous for many life kinds and ecosystems. Now, it is the need of hour to work on new skylines which are not only benign to humans and nature but also effective against insect pests and diseases in cotton. Some of the new methods to control pests include sterile insect technique, release of insects carrying a dominant lethal gene, sonic pest repellents, drone technology, biodegradable pheromones, smart systems, nanotechnology. Keeping in view the possible role of above techniques in pest management, a little review is being presented for our scientist as food for thought.

1. Introduction

Agriculture is the life line for economy of Pakistan which contributes 19.5% of the GDP. Among the crops grown in the country, cotton had a prominent place and is known as 'White Gold' because of high returns (Deshmukh et al., 2016). Pakistan holds 3rd, 2nd and 7th position world-wide in production, export of yarn, and cloth production, respectively (Bakhsh et al., 2009; Sial et al., 2014) and rank 4th in terms of consumption. Around globe, cotton has special place within the two neighbouring countries *i.e.* Pakistan and India (Hussain et al., 2005). Cotton alone serves as the source of income for more than 250 million people (Chapagain et al., 2006) in about seventy countries including the developed and under developed nations. Among them, four countries viz. China, USA, India and Pakistan produce 25%, 19%, 14% and 9% of global cotton, respectively which is about more than two third of the world's production. The share of major exporting countries (China, USA, India and Pakistan) in cotton is 41%, 35%, 15% and 10% (Sabir et al., 2011).

Cotton was first reported from Baluchistan while it was first cultivated in Indus valley somehow 3500 B.C. (Khan et al., 2009). Punjab and Sindh are major cotton cultivated provinces as these holds 80 % and 20% area respectively, in cotton cultivated acreage in Pakistan. The crop produces many products like lint, edible oil and seed cake. It also provides a source of income to non-growers especially to household women who involve in cotton picking which is still a hectic but important work (Sabir et al., 2011). However, Cotton area in the country is reducing on yearly basis. During the year 2017, 14.2 % of cotton area is reduced. In 2017, production of bales was also unsatisfactory, as it was only 10,671 (million bales) while in year 2015 it was 13,960 (million bales) and the same is with yield *i.e.* low in 2017 *i.e.*730 kgs / ha (Anonymous, 2017).

Illiteracy, less holdings areas, poverty, unaffordable prices of inputs, non-availability of labor, and diseases and insect pests are some limiting factors in cotton production. Among these, insect pests are most important, the intensity of which is being increased with climate change. A wide range of insect pests attack the crop including sucking and chewing ones. The intensity of infestation may vary yearly according to known and un-known factors. During 20th century, jassid and whitefly caused 18.78 % (Ali et al., 1995) and 38.7 % losses in cotton yield (Khan and Khan, 1995). Jassid (*Amrasca biguttula*) & whitefly (*Bemisia tabaci*), prefer humid conditions whereas elevated temperature favors thrips (*Thrips tabaci* and mites activity (Aheer et al., 1994; Khan and Ullah, 1994). Boll worms are also a threat to the cotton, but little bit development has been achieved against them using transgenic crops. Unluckily, the same appeared not so successful in the country due to controversial reports of purity of incorporated gene(s) (Sharma and Pampapathy, 2006; Hofs et al., 2004). Pink bollworm (PBW) *Pectinophora gossypiella* and spotted bollworm *Earias insulana* are much responsible for lowering down the yields (Abro et al., 2004; Hamed and Nadeem, 2010) by feeding on main fruiting parts (squares) (Gore et al., 2000; Ashfaq et al., 2006).

In Pakistan, most of our farmers believes on calendar sprays or injudicious use of chemicals for pest management as the only swift way to manage pests' attack. But use of chemicals is harmful for humans and the environment (Planas et al., 1997; Huber et al., 2000). In addition, such practices also give rise to resistance in insect pests and help them to resurge (Sattler et al., 2007). Beside all that, chemicals persist in soil and water which affect humans and serve as a major source of diseases (Arias et al., 2008). According to an estimate, just to manage insect pests, Pakistani farmers spend 300 million dollars annually on pesticides out of which more than 80 % of chemicals are used against bollworms (Rao, 2007; Arshad and Suhail, 2011).

So, keeping in view the afore-mentioned situation, we are going to review some modern / future oriented techniques which can be helpful in improving production and to overcome the worst present situation.

2. Review of Literature

2.1 Sterile Insect Technique

Sterile Insect Technique (SIT) was first conceived by Knipling (1937) with the purpose of controlling pest population by inducing sterility in males. Objectives of SIT have been successfully achieved against medical and agricultural insect pests (Knipling et al., 1968, Knipling, 1959) and in some cases also known as an integral part in area wide management (IP-AWM) for pests. The sterile male must attract the female in open conditions to mate but cannot pass any genetic material thus depressing the population.

Calvitti and colleagues in 1998 used sterile whiteflies (*Trialeurodes vaporariorum*) to access their efficiency with wild population on zucchini plants in green house. The results depicted that only 44% population after mating get successful hence showing its practical application in field. During the study, no negative effects were observed on plants and on yield (Calvitti et al., 1998).

In Texas, New World screwworm (NWS) (*Cochilomia hominivorax*) was problematic which infested 230,000 livestock animals and 55 humans. To prevent further infestation, substantial number of sterilized males were released to have a control over the population as documented by Reichard in 1991. In 1966, they observed no further attacks of screw worm and declared it as safe tool (Reichard, 2002).

Libya also faced the same situation which affected its economy badly due to which International Control Programme was launched to control *C. hominivorax* (Gillman, 1992).

One of the major disease vector (Tse-tse fly) in Island of Zanzibar (Africa) have been managed by releasing 7.8 million sterile males to ensure population suppression. Releases were done at various times to ensure that there were 50 males for every one female (Anon, 2001).

Various species of mosquitoes has been documented to manage successfully by using the same technique by various scientists in different countries. In south east Asia *Culex pipiens* is the main source of spreading filariases. To access its effectiveness in mosquitoes, Laven in 1967, performed experiments in open field and released sterilized males in contrast to field populations in Opko village (Rangoon). They observed that it was an effective strategy to control over the population as females are not able to produce. Practically, they made periodic releases of sterile males (50,000) in wild populations and within eleven weeks they succeeded to clear the area completely from mosquitoes (Laven, 1967).

In another work, on the cost of Florida (USA) this technique again proved to be successful in complete eradication of mosquitoes. Another study by Patterson and colleagues, reported to use 8,400-18,000 releases of sterile males (periodic release) and got successful in ten weeks (Patterson et al., 1970) while *Anopheles albimanus* was reported to control in EL Salvador (Lofgren, 1974).

An example of IP-AWM include the eradication of fruit flies. During the last century, a project was signed among three states (Guatemala, Mexico and USA) with the aim for eliminating fruit fly problem (Vreysen et al., 2006). During the first five years of starting the program (1977 – 1982), the authorities was successful in cleaning an area of 6,400 km^2 from flies but unfortunately during the campaign, flies started to show their presence in Mexico. For now, quarantine department was active enough to manage pest attack so, they launched an IPM strategy, which comprised of multiple techniques like cultural, chemical and genetic control (Villaseñor et al., 2000). For genetic control authorities released more than 2.5 billion male flies per week from a source in El Pino. This prevented the spreading of flies to further states (Enkerlin, 2005). As those states became free from fruit fly resultantly export of fruits and vegetables from Mexico had been boosted up to 3.5 billion US $ / year (Tween, 2004).

Although the many success stories have been reported for SIT, out of which some have been reviewed earlier, but in many cases, it was not proved to be so successful due to one or more limiting factors. Out of such factors, is less calling for mate than the wild population. To overcome the same, scientists tried to increase the calling efficiency of males. For example, in a field experiment, coupling efficiency of *Ceratitis capitata* had been enhanced up to 75 % by using Ginger Root Oil (GRO) (Shelly and McInnis, 2001). Todd and his team also evaluated the GRO at high and low level of elevation. There were more successful mattings in low levels of elevation as compared with high levels. Thus, GRO can be applied as mating promoter (Shelly et al., 2010).

2.2 Release of Insects carrying a Dominant Lethal gene

Release of Insects carrying a Dominant Lethal gene (RIDL) is a next step or modified form of SIT and developed by Thomas in 2000, who abandoned the use of radiations to induce sterility. To make RIDL effective, dominant lethal gene is needed to be induced which will be under the control of female specific promotor *i.e.* vitellogenin. However, Tetracycline is added in insect diet to maintain colonies in the labs (Thomas et al., 2000). Lethal genes have successfully been developed against the most notorious pest of cotton *P. gossypiella*, Mediterranean fruit fly and mosquitoes.

Morrison and team has successfully developed RIDL strains of Pink Bollworm (*P. gossypiella*) of cotton for both sexes and evaluated in laboratory as well as in field cages. In the experiments, they showed that engineered pink larvae entered the cotton-boll but after entering larvae was stunted and 1 mm in length while in controlled, they started to pupate having the length of 10 mm. Thus, results depicted mortality rate from moderate to 100% (Morrison et al., 2012).

During a study in 2017, RIDL was evaluated against the Mediterranean fruit fly (*Ceratitis capitata*) and they concluded that engineered insects competed with wild population and effectively eradicated fruit flies in laboratory (Leftwich et al., 2014). another evidence to manage olive fruit flies (*Bactrocera oleae*) in which weekly releases of flies (OX3097D-Bol) carrying female specific fsRDL gene exploited wild population within days and that also well synchronized with the wild ones (Ant et al., 2012). RIDL have also been proved successful in controlling the Dengue vector mosquito (*Aedes aegypti*) as most promising and ecological friendly tool. During the studies, many researches have evaluated it and found to be effective under the lab and field conditions in isolated places like at Cayman Islands (Harris et al., 2012), Malaysia (Carvalho et al., 2015) and Brazil (Lacroix et al. 2009). The same technique was evaluated by de *et al.*, in 2011 in which modified mosquitoes (*Aedes aegypti*) destroyed the respective population within 10-20 weeks in laboratory cages (de et al., 2011).

2.3 Sonic Pest Repellents

A way of using sound to repel, deter or to kill the organisms of any choice belonging to insects, birds, mammals or rodents. Normally, human can hear or detect sound waves between 20 Hz and 20kHz. The frequencies below and above the said range are called as Infrasonic and Ultrasonic, respectively. Studies have been conducted to use ultrasonic waves against insect pests of field, household and stored pests (Aflitto and Tom, 2014) and almost all were limited to lab conditions, so far.

Ultrasonic analysis showed a negative effect on *Plodia interpunctella*, a pest of stored grain and to prove this, experiments were performed for ten times with new insect pairs each time. There was significant reduction in the pest availability under the ultrasonic waves and surprisingly, the weight of insect pests was reduced also (Huang et al., 2003). Some of the field pests like bark beetle (*Dendroctonus frontalis*) and field cricket (*Scapteriscus borellii*) have been found to lower their activity or have negative behavior by playing biological sounds (stress call / mating call) through a recorded channel (Huang et al., 2003; Aflitto et al., 2014). Pheromone as we know a widely used tool to attract fruit flies, and in an experiment, researcher used sound and pheromone at the same time to see the possible results. The results revealed that the fruit flies (*Anastrepha suspense*) were attracted more toward sound (53 %) as compared to pheromone (42 %) (Webb et al., 1983). Findings from another work showed that mosquito (*Aedes albopictus*) females were attracted towards acoustic signals of 400 Hz (Ikeshoji and Yap, 1990) while there were other evaluations proving that 400 Hz was more suitable for attraction rather than 350 Hz (Ikeshoji and Ogawa, 1988).

Electronic pest devices have their other uses too beside killing and trapping them. For instance, they are applicable in biological studies (Paur and Gray, 2011), programs (Frank and Walker, 2006; Frank, 1994), taxonomic studies (Chesmore and Ohya, 2004; Riede, 1998), population levels (Forrest, 1988; Mankin, 1994), diversity (Raman et al., 2007; Mankin, 1994) and for classification of insects within the distinct species. In a study, scientists performed the series of experiments in classifying the insect species using ultrasound and found that classification accuracy was not less than 79.4% in insect species belonging to different orders (Chen et al., 2014).

2.4 Drone Technology

Drone technology also called as Unmanned Aerial Vehicle (UAV), broadly used for application of pesticides, fertilizers and in pest scouting. Applications will be made through universal nozzle *i.e.* which can apply fertilizer and pesticide with the same nozzle. It can be worth to the farmers in keeping an eye to crop condition and not hazardous for nature and humans as it does not involve human. This technology can be used extensively for any field related activities and can work easily under the extreme weather conditions and where workforce is scarce or costly especially, in remote areas. It does have applications against the vector control in the areas where people do not have enough knowledge how to operate sprays.

During the development of various UAV's practical and theoretical analysis of data shows that UAV's can effectively apply pesticides, fertilizers and can help in controlling pest (ME et al., 2016) while most published works concluded to have a bright future in doing agricultural operations (Rehman et al., 2016; Spoorthi et al., 2017). More precise application of drones depicts that they can sense about the plant's health and more widely, they can easily do assessment of pest on every plant *via* cameras and other sensors like thermal and infra-red etc. A company named as 3D robotics, gained success in developing an autopilot UAV system for vineyard which will itself control time of monitoring field operations including take-off and landing.

In the year 2017, agricultural drones in Punjab (Pakistan) has been allowed to help farmers in weeds and pest detection and for applying fertilizer and pesticides. While it can also be used in other agricultural departments (Anonymous, 2018).

2.5 Biodegradable Pheromones

Pheromones are naturally produced volatile compounds to attract insects. Chemicals are produced synthetically mimicking pheromones with the character of slow release by using a device as a medium. These artificially synthesized chemicals are mixed with naturally biodegradables like starches and thermoplastic polymers and can be used to attract the target insects (Rama et al., 2002).

Many biodegradable pheromones have been reported to be used against the insect pests. According to a study, Electrospun Mesofibers was used against the *Lobesia Botrana* (Lepidoptera: Tortricidae). The product if used at commercial level, will boost up the existing IPM programs and will serve as major pest controller in viticulture as well in horticulture. In South Germany, people are applying biodegradable pheromone mechanically with weed removal machine doing both operations with the same in vineyard (Hummel et al., 2015).

Ecodian dispensers has also been made for the control of field pest mentioned above. Findings of Anfora and colleges suggest that it stimulates the antennae of male insect and evaluated in combination with baits in which dispensers capture more organism than baits. Baits was also lured with females, but the results were negative hence, proving the feasibility of being using at commercial level (Anfora et al., 2014).

Ecodian CF™ has been tested for the lepidopteran insect *Grapholita funebrana* (Lepidoptera: Tortricidae) which is a major pest in plum orchards causing a major loss in production. *G. funebrana* was controlled using a fake trail pheromone (Ecodian CF™) for two seasons in two orchards with zero pesticide use. Riolo and his team showed that respective insect was controlled by using the same and the life span of one application is 75-80 days. Their data showed that number of infested fruits was higher in chemically controlled orchards rather than in experimental area (Riolo et al., 2010).

2.6 Smart Systems

Such systems are an array of various mechanical tools like tablets / smart phones, GPS, GIS and input data collecting devices (weather stations, infra-red sensors for soil moisture and crop condition) which can do work without involving much of the human in an efficient way. It can be either linked to a wire to operate with server or can be wireless (Anurag et al., 2008).

Fukatsu and group presented a smart device in crop management *i.e.* field server as a sensor network to work in fields. This will help the farmer in choosing activities depending on the situations like when and which fertilizer to apply or spray the crop. An additional feature is that it can also control a limited number of machines (Fukatsu and Nanseki, 2009). Datir and Sanjeev, proposed a wireless system to manage downy mildew disease in grapes, which uses GPS in which the main server has access to the internet web pages and can collect the data of choice. After data collection, it will send information to the farmer *via* tablet or other electronic devices and waits for the farmer's command (s) (Datir and Sanjeev, 2014).

Efficiency of robots in chemical spraying in India has been tested with the aim of practically adopting the technique especially in green house. The system used wireless medium of Bluetooth to convey information in audio-visual mode. This system is like a master (human) and slave (robots) with the completion of orders given by master regarding spray (Sulakhe and Karanjkar, 2015) and any other field operation.

2.7 Nano Technology

Nano technology is a new horizon in science which can alter the chemical or the physical properties at the molecular level (Fakruddin et al., 2012) to boost their effectiveness. Nano technology can be defined as 'the manipulation or self-assembly of individual atoms, molecules or molecular clusters into structures to create materials and devices with new or vastly different properties (Joseph and Morrison, 2006). The word 'Nano' has been derived from Greek language with the meaning of dwarf / small while in technical form, Nano means 10^{-9}. The reason to assign word 'Nano' was the use of extremely small particles ranging from 1-100 nm less than the size of a virus which is about 100 nm (Bhattacharyya et al., 2010). Chemicals at Nano scale are trending now a day in various products like pesticides and fertilizers to be used effectively and efficiently in managing pests and crop production.

2.7.1 Nano Pesticides

Medically important insects had been found to slow down their activities by spraying Nano pesticides in which temephos and imidacloprid were encapsulated in polyethylene glycol (PEG) by melt dispersion method. They showed satisfactory results against the larvae of *Culex quinquefasciatus* by using the slow release pathway (Bhan et al., 2014). By mixing PEG with essential oil (s) (EO) is effective against *Blatella gramanica* (Chhipa, 2017). The garlic oil having PEG is proved to be effective against the stored pest, *Tribolium castaneum* which was controlled to 80% after a period of five months. This shows its effectiveness against the pest (Yang et al., 2009).

2.7.2 Nano Herbicides

Experts have developed Poly epsilon-caprolactone (PCL) Nano capsules against *Raphanus raphanistrum* (an obnoxious weed in winter crops) to reduce the harmful effect of atrazine (a post emergence herbicide). Experiment was performed in field of *Zea mays* to see its effect and no harmful effect to crop was observed but adverse effect was depicted on the weed. After a period of 120 days, de and team again evaluated and found the product still viable and working (de et al., 2015). Poly epsilon-caprolactone (PCL) Nano particles serve to increase the effect of Atrazine and its use in low amount protects the environment. Another study performed by Oliveira et al. also showed the reliable results and herbicide was used in the presence mustard plants (Oliveira *et al*., 2015).

2.7.3 Nano Silica Particles as Pest Control

Spodoptera litura (Lepidoptera: Noctuidae) is known to cause heavy damage to our valuable crops such as cotton. Nano particles like CdS, Nano-Ag and Nano-TiO_2 are found to be effective against second instar larvae at different concentrations of LC_{50}. LC_{50} of Cds, Nano-Ag and Nano-TiO2 found to be effective at 508.84, 1403.14 and 791.10 ppm, respectively. Among them CdS particles was the most efficient as the mortality rate is comparatively high *i.e.* 21.41 to 93.79 % followed by Nano-TiO2 18.50-73.79% at 150 and 2400 ppm, respectively (Chakravarthy et al., 2012).

Nano silica particles can also be used with pesticides as additives or alone giving a promising control over the pest already mentioned. A study in Egypt, different combinations were used *i.e.* ZnO, CuO+Vertimec, ZnO+Vertimec, and CuO Nanoparticles and Vertimec. Among them, ZnO and CuO+Vertimec proved to be more effective than others by giving a mortality rate of 100 %. Malformation and liquefaction were also observed in larvae under study (Ahmed et al., 2014).

The suspension concentrates of Nano sized as well as micro sized chlorfenapyr were tested against cotton bollworm. Nano sized chlorfenapyr showed better results than micro sized in terms of mortality (20-80%) of the pest (Song et al., 2012). Some scientists suggested that Porous hollow silica nanoparticles (PHSNs) combined with validamycin have a potential to be used in agriculture (Liu et al., 2006) while Nano sized Calcium Carbonate and Nano Alumina retarded the development of stored grain pests; *Sitophilus oryzae* and *Rhyzopertha dominica* (Buteler et al., 2015) and pathogen, *Rhizoctonia solani* (Qian et al., 2011).

2.7.4 Nano Silica Particles as Disease Control

Toxic effects of Nano-Ag have been documented against the fungi, *Candida albicans* and *Saccharomyces cerevisiae*, showing to have vast application in near future (Nasrollahi et al., 2011). Nano silica was found to be very effective against bacterial blight even in minute quantity reduced to 1000 times less than the recommended dose (Mondal and Mani, 2012). Copper based bactericide also showed positive results under low dose against the bacterial spot disease in tomato (Ocsoy *et al*., 2013). Mishra *et al*., demonstrated the use of bio fabricated Nano silica to be highly effective against *Bipolaris sorokiniana* causing spot blotch disease in wheat. Interestingly, at low concentration *i.e.* 2, 4 and 10 µg/ml of bsAgNPs caused the complete inhibition of the pathogen while satisfactory results were obtained in case of *Magnaporthe grisea* (Jo et al., 2009; Mishra et al., 2014).

3. Conclusion

Cotton is an important crop not only for Pakistan but for the whole world. As thousands of people are associated with, however, insect pest situation is not so good. Farmers everywhere mostly rely on the use of synthetic pesticides to manage pests, but the extreme use of chemicals is becoming problematic like resistance in insects and degradation of environment. Thus, compilation is being presented for new and futuristic approaches and techniques to deal with pests. We do know that some of the afore mentioned techniques are not in line with cotton pests yet are given as food for thought for scientists to work on the same.

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