Int.J.Curr.Microbiol.App.Sci (2017) *6*(11): 1476-1495

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 11 (2017) pp. 1476-1495**
Journal homepage: http://www.ijcmas.com

Review Article

https://doi.org/10.20546/ijcmas.2017.611.176

Area Wide Pest Management: Concept and Approaches

Pradeep Kumar Dalal[1]*, Mandeep Rathee[1] and Jaywant Kumar Singh[2]

[1]Department of Entomology, [2]Department of Plant Pathology,
CCSHAU, Hisar, 125004, Haryana, India
**Corresponding author*

Keywords

Area wide pest managemnent, Agriculture.

Article Info

Accepted:
12 September 2017
Available Online:
10 November 2017

A B S T R A C T

Pests cause widespread losses even if control measures are administered. They are hurting the prospects of many agricultural produce exporting countries. On numerous occasions developing countries have faced embargo owing to the presence of pests in the produce. Area wide pest management (AWPM) is clearly one of the strategies to mitigate such pests which pose threat to the people, crops, livestock and foreign exchange of the countries. AWPM is the long term planned campaign against pest population over a large geographical area. It not only involve traditional approaches like cultural and biological control but also advanced molecular based novel tactics like sterile insect technique (SIT), release of insect carrying dominant lethal (RIDL), Cytoplasmic incompatibility (CI) through *Wolbachia*. However, apart from these tactics some countries have made pest free areas (PFA) where, stricter norms and laws have been implemented to curb the movement of pest to these areas. AWPM is clearly; one of the methods which comply with sanitary and phyto-sanitary (SPS) measures of World Trade Organisation (WTO) and it has the potential to help producers, traders, packers and exporters, etc around the world.

Introduction

Pest cause colossal losses to the tune of 70 per cent if control measures are not administered and even if pest control measures are taken up pests cause losses to the tune of 40 per cent (Oerke *et al.,* 1994). Pests also pose threat to the agricultural trade by infesting the high value crops which is to be exported. The countries engaged in importing the agricultural produce take a serious not of this threat and they prevent this threat by imposing Sanitary and Phyto-sanitary measures (SPS) over countries exporting agricultural produce (Henson and Loader 2001). This measure is taken to prevent human life, livestock and crops from attack of invasive pests. In some situations countries also impose ban on consignments of agricultural produce from exporting counties if the desired consignment is found to have been infested with pests of quarantine importance. So an effective pest mitigation strategy is required which comply with SPS measures and prevent the agricultural trade to get affected. One such strategy is Area Wide Pest Management (AWPM). Few Scientists attempted to define AWPM strategy. Dickerson *et al.,* (1999) stated that "Area-Wide Pest Management is the systematic reduction of a target key pest(s) to predetermined population levels through the use of uniformly applied control measures over large geographical areas clearly defined by biologically based criteria".

As per Lindquist (2000) "An area-wide insect control programme is a long-term planned campaign against a pest insect population in a relatively large predefined area with the objective of reducing the insect population to a non-economic status".

Need of Area Wide Pest Management (AWPM)

Economics undoubtedly plays major role in the initial grower decision to participate in AWPM (Sexson and Wyman 2005), and deteriorating market condition may cause the grower to neglect or even abandon the crop in a field or an orchard. Farmers who cultivate crops with high economic value and low pest tolerance risk suffer greater losses than farmers who cultivate crops with a low economic value and high pest tolerance (Yu and Leung 2006). In the latter situation there are fewer incentives for farmers to cooperate through an Area wide approach, whereas in first case the economic advantages of participating in Area wide approach are much greater (Stonehouse *et al.,* 2007). This is particularly so for crops such as vegetables and fruit, or for some livestock or human diseases, where the acceptable threshold are so low that the presence of even a few pest or vector individuals often triggers the need for remedial applications (Vreysen *et al.,* 2007).

Using a mathematical model, Yu and Leung (2006) derived several favorable and unfavorable severable favorable and unfavorable conditions for implementing AWPM. In their view, AWPM is more like to succeed where the number of farmers is small and cultivated crops are similar (low farm heterogeneity). The stability of the cooperation among the farmers is enhanced by the short detection times and high discount rates. The model likewise demonstrates that a one- off suppression of the pest under the leadership of a third party facilitates the cooperation of heterogenous groups of farmers in AWPM.

AWPM is a very broad and flexible concept and is increasingly accepted for those situations of mobile pests where management at larger scale is advantageous to maximize the Area wide, not necessarily local, efficacy of management tactics (Cronin *et al.*, 1999). AWPM is needed to mitigate the problem of pests affecting the agricultural trade (Griffin 2000).

AWPM compared to other conventional approaches

The traditional approach to pest management is to treat the crop or commodity in a particular management unit before an economically significant infestation of the pest has developed. AWPM can be contrasted with traditional pest management in that pest management tactics are used over broad spatial area, often treating the whole area simultaneously to maintain the pest below economic levels or in some cases, completely eradicated it. AWPM has potential advantages over the traditional approach. Suppression across a broad area may result in reduced re-infestation by migration from nearby unmanaged areas, and the pest management tactics are employed may be more effective, particularly ecologically based tactics, when applied area-wide (Elliot *et al.,* 2008) (Fig. 2).

Benefits of AWPM

As per Carlson and Wetzstein (1993) following are the benefits of AWPM. AWPM is more beneficial to environment as it involves use of those control tactics which are selective in nature and does not pose any threat to natural enemies and other non-target organism in the environment.

It is more profitable as when benefit: cost ratio of using AWPM was calculated and compared to other conventional approaches, AWPM benefit: cost ratio found to be more.

AWPM is more effective as it not only treats target area but also treat the adjoining areas because of which movement of pest is impeded from unmanaged sites to managed sites and hence the effect of AWPM is long lasting.

Though the techniques in AWPM is expensive and cannot be afforded by individual farmer but when AWPM is implemented by an organization or cooperative group of farmers then the per capita cost of implementing this little expensive found to less as compared to other conventional techniques.

Models to be followed for AWPM

A recurrent concern for pest managers is the minimum size of the target area that needs to be considered for an AWPM programme to be technically viable and economically justifiable. Due to the lack of adequate practical experience and the absence of models, decisions were sometimes based on educated guesses rather than on sound, scientific principles. Therefore, a conceptual mathematical model was developed that can assist with estimating the minimum area that needs to be considered to successfully apply a series of control tactics according to the AWPM approach against insect pests for which there are adequate biological input data. To make the model applicable to a series of pest species amenable to AWPM, it was developed in a generic way with a minimum of identified assumptions included.

The prototype model creates a basis for a decision-support tool to assess the minimum dimensions of an intervention area required for the establishment of a pest-free area For the development of the model, two main situations were considered: (1) the control area is fixed in size (fixed-area model) and there is no advancing pest control front, and (2) the control area is expanding according to the “Rolling-carpet principle” as described in (Barclay *et al.*, 2011).

Hendrichs *et al.,* (2005) describe the basic spatial elements of an AW-IPM program. The first is the core area, in which the aim is to reduce (in case of a suppression strategy) or eliminate the pest species. The core area may contain the actual resource of value, but in other cases, removal of the pest from the core area may simply have a strategic value by protecting crops situated elsewhere or by protecting humans or livestock against disease vectors (in case of a containment or a prevention strategy). The second is a buffer zone that borders the core area on one or more sides and within which control methods attempt to kill the target insects within that zone, including those that enter the zone from outside. The buffer zone is defined as the region of an AWPM program that is large enough to prevent the pest insect from moving from outside the buffer to the core area before being destroyed by the control methods operating within the buffer zone.

In the case of the fixed-area model, there is a core area to be protected and a buffer zone on all sides of the core area. This model was followed in Chile for fruit fly eradication (Gonzalez and Tronsco, 2007). The Rolling-carpet model, there is a buffer on only one side and pest free zones on the other sides.

The width of the buffer zone is central to determining the minimum area of an AWPM program, since it defines the smallest possible program. Both these models consist of two components such as a biological component (i.e., dispersal) and an economic component (break-even analysis). The dispersal part describes the movement of the insects across the buffer zone and will determine the width of the buffer zone. The economic component of the model will, given a certain width of the buffer zone determined by the dispersal part, allow a calculation of costs and revenues of the control program and will determine the break-even size of the core area at which control costs equal revenues. The rolling-carpet model extends the fixed-area model by introducing a temporal element to the model, that is, the success of the control program permits the core area to be extended regularly when the buffer zone moves onwards. With reference to the scheme shown in Figure 1, the buffer zone will be moved to the right across the control zone to a point where all the area behind the new buffer zone is pest free (or an area of low prevalence is created). This outward movement of the buffer zone will be accompanied by an outward movement of the eradication zone of low prevalence and the population reduction zone.

This process could potentially be repeated until an entire pest population has been tackled (this would obviously require sufficient resources to maintain suppression and surveillance activities). This concept was referred to as the rolling-carpet principle (Hendrichs *et al.*, 2005), since it envisages a gradual movement of the buffer zone across the landscape. The eradication of the New World screwworm, *Cochliomyia hominivorax* Coquerel from Mexico to Panama is a large-scale example of an AWPM action program implemented according to this rolling-carpet principle (Wyss 1998).

Historical account of AWPM

There are numerous episodes in the history concerning AWPM using traditional tactics one of the episodes is described herein (Klassen 2005):

Cassava mealybug suppression

Cassava mealybug, *Phenacoccus manihoti* used to be impediment in Cassava crop in African continent. In 1973, Cassava in Central Africa was found to be attacked by the Cassava mealybug, *Phenacoccus manihoti* (Matile-Ferrero). The attack of this insect pest was so profound that it created starvation for 200 million people for whom cassava had become a staple crop. A team led by Dr. Hans Herren of the International Institute for Tropical Agriculture (IITA) successfully implemented the largest classical biological control programme in history. In 1981, a parasitoid, *Apoanagyrus lopezi* (DeSantis), found in Paraguay by A.C. Bellotti. The area wide aerial application of mass reared *A. lopezi* brought Cassava mealybug under control. For this effort Dr. Harren was conferred with World Food Prize in 1995 (Klassen 2005). Likewise many Area Wide programmes have been implemented throughout the World using traditional tactics which have been listed herein.

Approaches for area wide pest management

Since AWPM is needed for those pests for which low acceptable threshold is required hence those control tactics are required which are having large coverage, genetic control tactics like Sterile Insect Technique (SIT), Cytoplasmic incompatibility by *Wolbachia* and novel transgenic technique which involve release of insect carrying dominant lethal (RIDL) are found to be suitable. As per WHO Scientific group (1964) genetic control is "the use of any condition or treatment that can reduce the reproductive potential of noxious forms by altering or replacing genetic material".

Sterile Insect Technique (SIT)

SIT defined as "A method of pest control using area wide inundative releases of sterile insects to reduce fertility of a field population of the same species" (IPPC, FAO).Similarly Sterile Insect is defined as "An insect as a result of an appropriate treatment is unable to produce viable offspring." (FAO).

SIT has been known for its eradication of New World Screworm fly, *Cochliomyia hominivorax*. The Idea of this technique was conceived by Dr. E. F Knipling. It was in the year 1954-55 that Screworm fly got successfully eradicated from Curacao Island. Similar results were achieved from USA, Mexico and Libya. For this Dr. Edward F. Knipling and Dr. Raymond C. Bushland were awarded with World Food Prize (1992).

Knipling's SIT Model

As per this Model (Knipling, 1955)

Assumed number of wild female Population is 1000 and that of male sterile insect released in each generation is 2000

Males are mass reared and sterilized by irradiation of gamma rays of Co^{60}

In generation 1, 1000 wild females encounter 2000 sterile males hence probability of mating with sterile males as compared to 1000 wild males is 66.7%. So mating between sterile males and fertile wild females will be infructous with producing 66.7% infertile progenies which means female population decrease to 333.

When 333 females again encounter 2000 sterile males the probability of mating with sterile males as compared to 333 wild males rose to 85.7% hence 85.7% matings will be infructous and producing only 47 females in next generation so by the end of 4^{th} generation female population is eradicated.

Knipling (1955) also emphasized on following prerequisites before developing and applying SIT which includes

Estimates of natural population of target insect must be accurate

Rear enough sterile insects to over flood natural population

The released insect must be distributed uniformly

Irradiation must produce sterility without affecting competitive mating ability and longevity of insect.

Female should mate only once. If females mate frequently then males should also mate frequently

Components of SIT

There are four components of Sterile Insect Technique

Mass Rearing
Sterilization
Release
Monitoring

Mass rearing

Mass rearing of insects is conducted under laboratory conditions. The El Pino facility in Guatemala produces around one billion sterile male med fly per week, largest mass rearing facility in the world (Alphey, 2002).

Mass rearing is done only after estimating the wild population accurately and also keeping in mind the Sterile: Fertile male ratio to over flood the wild population of target insect (Knipling, 1955).

Mass rearing is done after feeding the population of insects with artificial diet.

Special consideration is given that diet must not pose any physiological threat to the insect and also the diet should be economical so that whole SIT programme does not become expensive.

Sterilization

There are two methods by which insects are sterilized these are

Chemosterilants
Ionic Radiations

Chemosterilants

Chemosterilants is any chemical that can inhibit the growth of gonads or interfere with the reproductive capacity of an insect.

There are three types of chemosterilants

Alkylating Agents
Antimetabolites
Miscelleneous

Chemosterilants interfere with reproductive capacity by

Preventing copulation
Production of unviable eggs
Induction of dominant lethal mutation
Inhibiting development of progeny at any stage

Not much effort has been made to control agricultural pests by chemosterilants. Most of the experiments carried out in cage. An experiment where spiders fed a diet solely consisting of chemo-sterilised mosquitoes themselves became sterile (Bracken and Dondale, 1972). However, today, chemosterilants are not used for sterilizing mass-reared insects. Most chemosterilants are carcinogenic, mutagenic, and/or teratogenic, leading to environmental and human-health issues such as the integrity of ecological food chains, waste disposal, e.g. spent insect diet, and worker safety (Bracken and Dondale 1972; Bartlett and Staten, 1996). Insect resistance to chemosterilants is an additional concern (Klassen and Matsumura, 1966).

Sterilization by ionic radiation

Ionic radiation is chief source to cause sterility among insects. Following properties of radiations are taken into consideration while selecting it for sterilization process (Bakhri *et al.*, 2005).

Relative Biological Effectiveness (RBE)

The RBE of radiation is defined as the ratio of the dose of 200–250 kV X-rays required producing a specific biological effect to the dose of radiation required to produce the same effect. The RBE of radiation for the induction of chromosome aberrations depends on its linear energy transfer (LET — the energy imparted to a medium by a charged particle of a specified energy, per unit distance).

Radiation with a higher LET is more effective in inducing sterility, and most likely would yield insects that are more competitive (North 1975). However, a higher let also means that penetration is limited.

Penetrability

The Radiation used for sterilization must have high penetrability to uniformly sterilize each and every insect.

Safety

The radiation used for purpose of sterilization must cause radioactivity in the environment and also safe to insect and research workers. The radiation must not lower the competitive mating ability and longevity of insects.

Radiation source must be cheap and easily available

Radiation likes Gamma radiation from Cobalt-60 and Cesium-137 sources are used for irradiation of insects. High energy electrons and X-rays are other practical options.

Database of sterilization of insects

Database regarding sterilization of insects is released by International database of Insect Disinfection and Sterilization (IDIDAS). As per this database every insect has safe limit of sterilization at which there is no effect on competitive mating ability and longevity of the Insect. A suitable insect stage is chosen for irradiation causing effective sterility among insects.

Gamma irradiators

Gamma irradiators are used for the purpose of irradiating the insects for sterilization. Two types of gamma irradiators are used such as self-contained dry storage irradiators and large scale panoramic irradiators (Bakhri *et al.,* (2005)

Self-contained dry storage irradiators

Most sterilization of insects is accomplished using gamma rays from self-contained irradiators. These devices house the radiation source within a protective shield of lead, or other appropriate high-atomic number material, and they usually have a mechanism to rotate or lower the canister of insects from the loading position to the irradiation position.

Large scale panoramic irradiators

For large-volume irradiation, panoramic irradiators are more suitable. The source consists of either several Co-60 rods (pencils) arranged in a plane or a single rod that can be raised/lowered into a large irradiation room. When retracted from this room, the source is shielded either by water (wet storage), lead or other appropriate high-atomic number material (dry storage). Since isotopic sources emit gamma rays isotropically (in all directions), they may be surrounded by canisters of insects to increase the energy utilization efficiency, and several canisters can be irradiated simultaneously.

Impact of gamma rays over ovaries and testis of female and male med fly

With subsequent increase in gamma rays radiation dose level, the effect on both ovaries and testis of Mediterranean fruit fly found to be profound. The length and width of both ovaries and testis decreases with increase in radiation dose level.

Impact of sterilization

As per La Chance *et al.,* (1967) sterilization may lead to the inability of females to lay eggs (infecundity)

The inability of males to produce sperm (aspermia)

Inability of sperm to function (sperm inactivation)

The inability to mate

Induction of Dominant lethal mutations in the reproductive cells of either the male or female

Characteristics of induced dominant lethal

Dominant lethal mutations are characterized by the presence of chromosome bridges and fragments between dividing nuclei in the embryo (La Chance and Riemann, 1964).

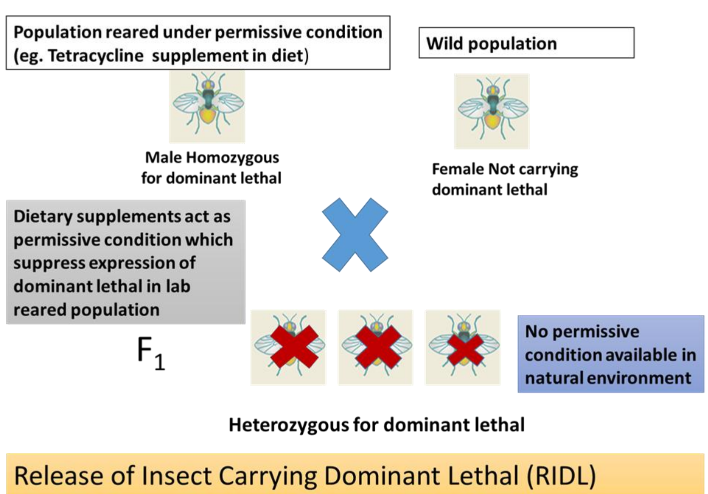
Confirming irradiated insect as sterile

As per Bakhri *et al.,* (2005), to confirm whether irradiated male insect is sterile or fertile. Some irradiated male insects are taken from the whole irradiated insect lot and allowed to mate with fertile female. If egg production after mating is unviable in nature then it can be confirmed that the irradiated male insect lot is sterile.

Fig.1 Farm by Farm management involves treating farm individually by the farmer, in the figure farmer have managed the field no. 1, 4 and 3 but left field no. 2 and wild host site unmanaged, so there is every possibility that pest from unmanaged site might move to managed site because of which the effort and capital invested by farmer in mitigating the pest goes in vein.

AWPM involves not only target site treatment but also adjoining areas which include wild host sites, adjoining fields and alternate host sites. This limit the probability of movement of pest from unmanaged sites to managed sites.

Fig.2 Area Wide Pest Management v/s Conventional approaches



Male homozygous insect for dominant lethal which was reared under permissive condition when released in the wild population to mate with wild female then F1 progeny is produced, since these progenies are heterozygous for dominant lethal gene so this gene will express and cause mortality as also permissive condition is not present under natural condition. Permissive condition like tetracycline in the diet suppresses the expression of dominant lethal gene in Homozygous male

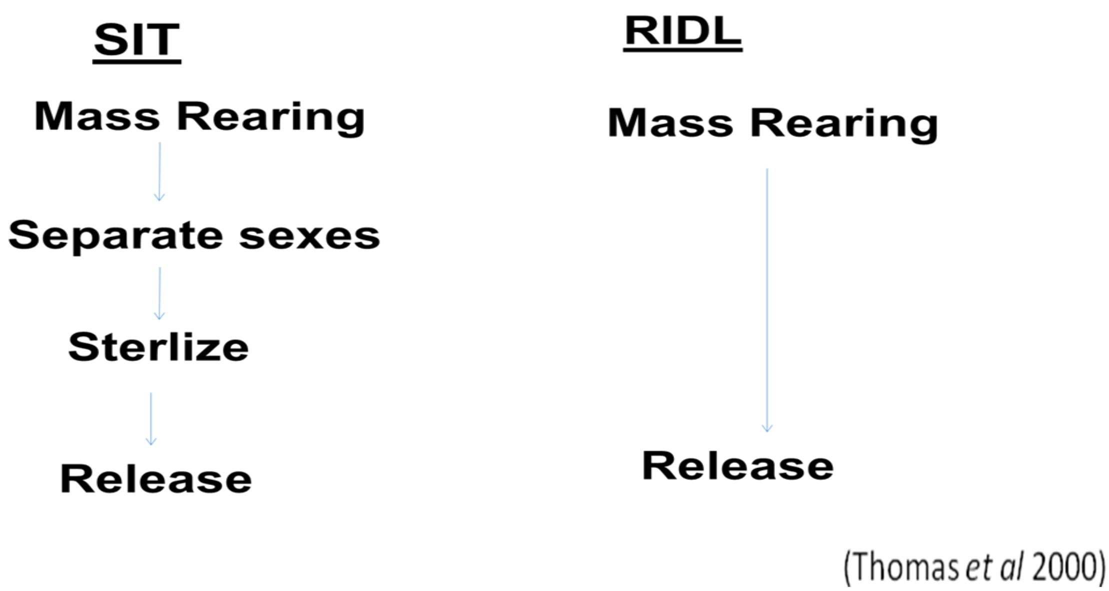
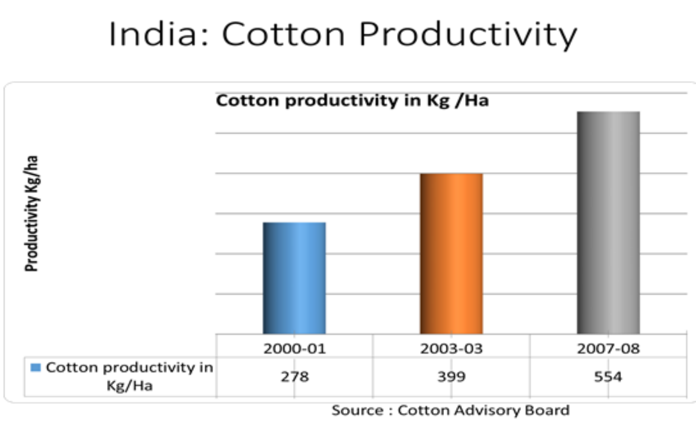
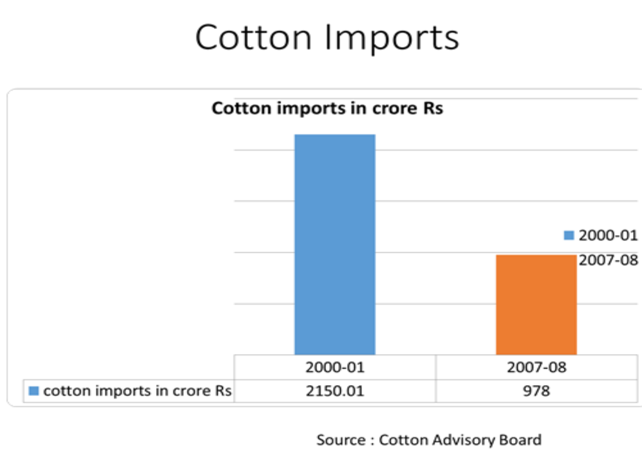


Fig.3 Graphical representation depicts Cotton productivity, exports and import prior to Bt cotton release and after Bt cotton release in India. The increasing trend in cotton productivity from 2000-01 to 2007-08. Also in cotton exports steep increase in cotton exports took place from 51.43 crore rupees to 10,270.21 crore rupees. Declining trend was noticed in cotton imports





Lindquist (2000) differentiated Area Wide Pest Management from other conventional approaches

Area Wide Pest Management	Conventional approaches
1. **Its treats all habitats of Pest infestation**	1. **It Defend only valuable entities like crop, livestock from direct pest attack**
2. **It is implemented by an organization solely dedicated to pest management in a region**	2. **It is Implemented by individual producers**
3. **It is a multiyear planning approach and proactive in nature**	**3. It requires minimal forward planning and reactive in approach**
4. **It relies on both traditional and advanced tactics of Pest management**	**4. It relies on traditional tactics of pest management**

Cassava Mealybug Suppression

Programmes	References
Anti-locust programmes in Africa, southwest Asia and China — some are coordinated by the FAO	Showler 2002
Area-wide control of the brown plant hopper, *Nilaparvata lugens* (Stål) in Indonesia and the Philippines	Oka 1991
Codling moth suppression; area-wide use of pheromone-mediated mating disruption in Washington State, Oregon and California	Calkins *et al.*, 2000, Coop *et al.*, 2000
Boll weevil, *Anthonomus grandis* Boheman eradication; pheromone trapping, insecticide treatment and cultural control	Cunningham and Grefensette 2000, Dickerson *et al.*, 2001
Global Malaria Eradication Campaign, initiated by the WHO in 1955, but disintegrated in 1969; malaria was eradicated in 37 countries, and in the end 74% of the people at risk were protected	Wright *et al.*, 1972

Knipling's SIT Model

Generation	Natural population of Female (Assumed)	Sterile Male insect Released	S:F Male ratio	Infertile Progeny(%)	No. of female in each generation
1	1000	2000	2:1	66.7	333
2	333	2000	6:1	85.7	47
3	47	2000	42:1	97.7	1
4	1	2000	2000	99.9	0

Following Insect Artificial Diets used to rear following insects

Scientific Name of Insect	Artificial Diet Used	References
Ceratitis Capitata	Autolysed Yeast- Larvae Hydrolysed protein- Adult	Moreira da *et al.*, 2012
Glossina palpalis	Freeze dried blood Silicon membrane covering defibrinated whole blood of cow	Lindquist *et al.*, Atoms for pest control, IAEA bulletin
Cochliomyia hominivorax	Honey and horse meat diet Blood + milk + egg Spray dried egg+Molasses	Squeezing out worm, USDA, 2001

Database of Sterilization of Insects

S no.	Common/Scientific Name of insect	Stage treated with Radiation	Amount of radiation (Gy)	Induced Sterility
1.	**Onion Fly,** *Delia antiqua*	**6-8 days old pupae**	**30-40 Gy**	**Low egg hatch Full Competitive male**
2.	**Mexican fruit fly,** *Anastrepha ludens*	**Female/Male pupae (3 days before emergence)**	**Female-20Gy Male-30-40Gy**	**100%**
3.	**Oriental fruit fly,** *Bactrocera dorsalis*	**Male / Female 3 day old Pupa 2days before emergence**	**Male/Female -100 Gy 50-90 Gy (Air)**	**Male –99% Female-100% 99.8-100%**
4.	**Gram Pod Borer,** *Helicoverpa armigera*	**Pharate**	**200 Gy**	**63% 100% F1**
5.	**Pink Bollworm,** *Pectinophora gossypiella*	**Pupa**	**100-150 Gy**	**>88%**
6.	**Sweet potato whitefly,** *Bemisia tabaci*	**Male / Female adult**	**Male: 80Gy Female: 70Gy**	**Male-99% Female-100%**
7.	**Red Rust flour Beetle,** *Tribolium casteneum*	**Egg**	**60-80 Gy**	**100%**
8.	**Brown planthopper,** *Nilaparvata lugens*	**Nymph Male/female-5th instar**	**Male-62 Gy Female-25 Gy**	**100%**
9.	**Angumois grain moth,** *Sitotroga cereallela*	**Male / Female adult**	**Male/female: 200 Gy**	**97.17%**

Various SIT programmes followed

S.no	Sterile Insect technique against Insect Pests	Countries	Reference
1.	**New World Screwworm,** *Cochliomyia hominivorax*	USA Mexico Libya	Lindquist *et al.*, 1992
2.	**Mediterranean fruit fly,** *Ceratitis capitata*	Various parts of Latin America	Hendrichs *et al.*, 1995
3.	**Codling moth,** *Cydia pomonella*	Canada, USA and Switzerland	IAEA, 2001 and Thacker 2002
4.	**Tsetse fly,** *Glossina palpalis*	Zanzibar island, Tanzania	Joint FAO/IAEA Division www.iaea.or.at:80/programs
5.	**Onion fly,** ***Delia antiqua***	Netherlands	Thacker (2002)
6.	**Pink bollworm,** *Pectinophora gossypiella*	California, USA	Thacker (2002)
7.	**Boll weevil,** *Anthonomous grandis*	Lousiana, USA	Thacker (2002)
8.	**House mosquito,** *Culex quinquefasciatus*	Florida, USA	Thacker (2002)
9.	**Malarial mosquito,** *Anopheles ludens*	El salvador	Thacker (2002)

Various other sexing mechanisms apart from genetic sexing

Sexing Mechanism	Insect	Reference
Pupal weight difference	*Anopheles albimanus*	Seawright *et al.*, 1978
Ecloison time difference	*Ceratitis capitata*	Franz *et al.*, 1994
Insecticide resistance gene in male	*Anopheles culicifacies*	Baker *et al.*, 1981
Pupal Colour	*Ceratitis capitata*	Rossler 1980
Size difference	*Aedes aegypti*	Carvalho *et al.*, 2014

Various conditional dominant lethal genes

Conditional Dominant lethal gene	type	Insect	Reference
Notch ^{60g11}	Cold sensitive	*Drosophila melanogaster*	Fryxell and Miller 1995
tsl	Temperature sensitive lethal	*Ceratitis capitata*	Kerremans and Franz 1995

List of Insect pests controlled by RIDL

Scientific Name of insect	References
Ceratitis capitata	Gong *et al.*, 2005
Anastrepha ludens	Fu *et al.*, 2007
Aedes aegypti, A. albopictus	Phuc *et al.*, 2007
Pectiniphora gossypiella	Simmons *et al.*, 2007

Release of sterile insects

Release of sterile insects is done by two methods

Aircraft release
Ground release

Aircraft release involves release of insect via auger from a chilled container. Aircraft release is required to release insect in inaccessible and remote areas. Aircraft release found to be more precise and site specific.

Whereas, Ground release done with the help of opening bags containing sterile insects in predetermined spots.

Monitoring

Monitoring is done to know whether the target insect pest has been suppressed or not. This is done by distinguishing sterile insect with wild insect collected in the trap in insect released area. Sterile insects prior to release are usually marked with a fluorescent powder to distinguish sterile insect from wild insect. With the help of novel transgenic technique also now a day's Green fluorescent Protein Marker (GFP) and Red Fluorescent Protein Marker (Ds Red) are introduced in the sterile insect prior to release. This is done to enhance more precise monitoring of insects. Since fluorescent powder wither away with time

A study was conducted by La Chance and Crystal (1965) to know the impact of gamma radiation and alkylating agent in inducing dominant lethal in both immature oocyte and mature sperm. It was found that maximum induction of dominant lethal was induced by gamma radiation at 12000 rad in immature oocytes where as in case of mature sperm maximum induction of dominant lethal was found to be caused by tretamine (Alkylating agent) at 0.06%.

SIT has also been conducted in India; SIT was carried out in Poothuruth Island in Kerala against Red Palm Weevil (RPW). Island has an area of 2 hectares with 460 palms, separated from mainland by 3 kilometres. RPW can migrate up to 900m in single flight. First estimation of RPW natural population was carried out. Thereafter, release of sterile male RPW with Sterile: Fertile male ratio of 10:1 was done in natural population. Monitoring was carried out by Ferrolure traps.

When Data was analyzed it was found that number of females trapped with males in ferrolure traps decreases subsequently with passing of days (Krishnakumar and Maheshwari, 2007).

Insect transgenesis

Insect transgenesis has enhanced two aspects of Sterile Insect Technology such as

Monitoring
Genetic Sexing

Whereas, transgenesis also acted as a method of pest control

Insect transgenesis is the transfer of cloned genetic material from one species to other. This transfer is carried out with the help of transposable elements. Transposable element is a mobile DNA sequence with terminal inverted repeats that encodes a transposase enzyme. Transposase catalyses excision and random insertion within chromosomes. *Mariner, Minos, Hermes and Piggyback* have been most widely used transposable elements in insect.

Transgenesis aiding monitoring

With the advent of modern transgenic technology in insects, now fluorescent protein marker which can be Green Fluorescent protein marker (GFP) and Red Fluorscent protein marker (DS Red) can be introduced into insect genome (Matz *et al.,* 1999; Tsien, 1998). This helps in distinguishing released sterile male insect from wild insect, so as to confirm whether the pest is controlled or not (Alphey 2002).

Transgenesis aiding genetic sexing

In some SIT programmes sexing or sorting of male from female is needed prior to sterilization. These SIT programmes do not require sterile females as they are acting as impediment by causing injury by oviposition in fruit flies and biting nuisance in mosquitoes. Transgenesis helps in sorting of male from female by introducing female specific expression of lethal gene in insect genome which is made conditional by binary tTA- expression system (Alphey, 2002). This allows mortality among females only hence males can be easily sorted out.

Transgenesis in pest control

Transgenesis can itself act as a control method by release of insect carrying a dominant lethal (RIDL). RIDL is one such technique which does not require any use of radiation for sterilizing the insect, hence RIDL is an answer to limitations of SIT i.e. reduced competitive mating ability and longevity in irradiated males. In RIDL, insects are not sterile but they carry a conditional, dominant, sex specific homozygous lethal gene (Thomas *et al.,* 2000). These released insects mate with wild insects. All the progeny are heterozygous for a dominant lethal, which when expressed cause mortality. A chemical additive in diet such as tetracycline which acts as permissive condition allows transgenic insect strain to be reared. Permissive condition absent under natural environment, so offspring die

A Pink Bollworm Strain LA1124 carrying conditional lethal gene was developed using RIDL. It brought larval mortality ranging from 60 to 92% in Laboratory tests (Simmons *et al.,* 2007).

As per Morrison *et al.,* (2012), a transgenic pink bollworm had survivability of 100 per cent under permissive condition but without permissive condition mortality was also 100 in different strains of transgenic pink bollworm

Wolbachia induced cytoplasmic incompatibility

Wolbachia is an obligate intracellular and maternally transmitted α proteobacteria. They reside in reproductive tissues of invertebrate hosts.

They are found in 60 per cent of insect species. *Wolbachia* causes reproductive alteration such as

Parthenogenetic development
Convert genetic males into females
Killing males in early developmental stages
Cytoplasmic incompatibility

Cytoplasmic Incompatibility (CI) by *Wolbachia*

Cytoplasmic incompatibility results in mortality of the embryos produced (Bourtzis 2007)

Unidirectional CI

Wolbachia Infected males mated to uninfected females. It results in 100 % egg mortality in *Culex pipiens*

Bidirectional CI

When both males and females carrying incompatible *Wolbachia* strain mates

An experiment was conducted by Alam *et al.*, (2011) to know the larval deposition rates in different crossing types involving male and female *Glossina morsitans*, Tsetse fly with or without carrying *Wolbachia.*

It was found that Crossing types which involve Male tsetse fly carrying *Wolbachia* when mated to Aposymbiotic female led to significantly less larval deposition rate as compared to other mating types.

AWPM and its impact on economy

Under AWPM, emphasis is laid on "Off-Shore" actions and exclusion.

Off-Shore action – "Pest-risk mitigation in the areas of production, certification at the point of origin, and pre-clearance at the port of export" (NPB 1999).

For this Pest Free Areas are created by Countries to prevent any pest threat in the areas of agricultural production (Rohwer, 1992; Malavasi *et al.*, 1994).

"A pest free area is an area in which a specific pest does not occur as demonstrated by scientific evidence" (FAO 2002). It includes large geographic areas, including entire countries that are certified free of tropical pests of economic importance.

Example - Chile, Japan or New Zealand free of tropical Fruit Flies

Fruit fly free areas in India

As per the report Incentivizing Agriculture (2012) released by Rashtriya Krishi Vikas Yojana, Govt. of India. Three districts in Gujarat such as Surat, Valsad and Navsari are fruit fly free zones in India. These zones have mango orchards.

These areas achieved a control of 85% Mango fruit fly, *Bactrocera dorsalis.* A total of 1,10,640 traps were distributed among farmers, Orchard sanitation was carried out and damaged fruits were treated with Methyl Parathion before being dumped into pits.

This Project costs around Rs 7.86 crores and benefitted farmers to the tune of 49 crores. An estimated benefit of Rs 81,840 per hectare is achieved by spending a mere Rs 350. Benefit: cost (233.8: 1).

Significance of pest free area, case study: Chile

Chile earned the status of Fruit Fly Free Area in 1994. SIT was used in the National Fruit Fly Detection System. Post-harvest treatments of fruits are not required now.

This raised the demand for quality Chilean fruits in World fruit market and strengthened its economy (Gonzalez and Troncoso, 2007).

Exclusion of pest, case study: Australia

Australia has some Fruit Fly Free Areas against *Bactrocera tryoni*. Fruit Fly Free Areas are located inside Fruit Fly Exclusion Zones (FFEZ). Quarantine department have restricted the entry of some fruit commodities inside FFEZ. Quarantine department has also installed precautionary signboards and fruit dumping bins at the FFEZ entry points and highways. Heavy fine is imposed if someone found with restricted fruit commodity inside FFEZ (Jassup *et al.*, 2007).

India's cotton story: from deficit to surplus

In India, Bollworm complex which include insect pests like American bollworm, Pink bollworm and Spotted Bollworm used to wreck havoc in the cotton crop. In the late 90s and early 2000 large quantities of cotton had to be imported by India. The Bt cotton hybrids were first commercially released in India in 2002. By 2011, 7 million farmers had adopted Bt on 26 million acres, around 90% of the total Indian cotton area (Kathage and Qaim 2012). India reached the peak productivity of 554 kgs /Hectares in the year 2007-08. Bt increases profit by 1,877 Rs per acre, equivalent to a 50% profit gain over conventional cotton (Kathage and Qaim, 2012). Now India is among the exporters of cotton due to surplus yield of cotton (Fig. 3).

To reap benefits just like cotton in India, AWPM should be adopted in other crops. Stiff competition in global agriculture trade and demand for quality agricultural produce has given boost to AWPM. AWPM is need of hour to counteract insect pests of public health and agricultural trade importance. Now a days advanced technologies like Geographical Information System (GIS) is also given due emphasis in locating pest infestation sites. This technology can help immensely in mitigating the pest in more precise and site specific manner. Many counties face temporary ban on account of pest infestation in export commodities of fruits and vegetables, this affect the livelihood of producers, traders, packers and exporters, this problem can be curbed by introducing AWPM programme on regional basis in countries which have wide geographical areas.

References

Alam U, Medlock J, Brelsfoard C, Pais R, Lohs C, Balmand S, Carnogusky J, Heddi A, Takac P, Galvani A and Aksoy S (2011) *Wolbachia* Symbiont Infections Induce Strong Cytoplasmic Incompatibility in the Tsetse Fly *Glossina morsitans*. *PLoS Pathog* 7: 1-12.

Alphey L (2002) Re-engineering the sterile insect technique. *Insect Biochem Mol Biol* 32: 1243-47.

Anonymous (2013) Cotton productivity, imports and exports in India 1996-97 onwards. Http://*cotcorp.gov.in/statistics.aspx*

Baker R H, Sakai R K and Raana K (1981) Genetic sexing technique for mosquito sterile-male release. *J Hered* 72: 216-18

Bakhri A, Mehta K and Lance D R (2005) Sterilizing Insects with Ionic Radiation In Dyck V A, Hendrichs J and Robinson A S (ed) *Sterile Insect Technique:*

Principles and Practice in Area-Wide Integrated Pest Management. Pp 233-68. IAEA – Springer, Dordrecht, The Netherlands.

Barclay H J, Matlock R, Gilchrist S, Suckling D M, Reyes J, Enkerlinn W R and Vreysen M J (2011) A Conceptual Model for Assessing the Minimum Size Area for an Area-Wide Integrated Pest Management Program. *Int J Agron* 2011: 1-12.

Bartlett A C and R T Staten (1996) The sterile insect release method and other genetic control Strategies. *http://ipmworld.umn. edu/chapters/bartlett.htm.*

Bourtzis K (2007) *Wolbachia*-Induced Cytoplasmic Incompatibility to Control Insect Pests? In: Vreysen A S, Robinson A S and Hendrichs J (ed) *Area-Wide Control of Insect Pests*. Pp 125-36. Springer, Dodrecht, The Netherlands.

Bracken G K and Dondale C D (1972) Fertility and survival of *Achaearanea tepidariorum* (Araneida: Theridiidae) on a diet of chemosterilized mosquitoes. *Can Entomol* 104:1709-12.

Calkins C O, A L Knight, G Richardson and K. A. Bloem. (2000). Area-wide population suppression of codling moth, pp. 215–219. In K H Tan (ed) Proc: *Area-Wide Control of Fruit Flies and Other Insect Pests. International Conference on Area-Wide Control of Insect Pests* and the 5th International Symposium on Fruit Flies of Economic Importance, 28 May–5 June 1998, Penang, Malaysia. Penerbit Universiti Sains Malaysia, Pulau Pinang, Malaysia.

Carlson G A and Wetzstein M E (1993) Pesticides and pest management,. In G.A. Carlson G A, Zilberman D and Miranowski J A (eds) *Agriculture and environmental resources economics*.Pp 268-318 Oxford University Press, Oxford, UK.

Carvalho D O, Nimmo D, Naish N, McKemey A R, Gray P, Wilke A B B, Marrelli M T, Virginio J F, Alphey L, Capurro M L (2014) Mass Production of Genetically Modified *Aedes aegypti* for Field Releases in Brazil. 83:1-10

Coop L B, Kogan M, and Bajwa W (2000) Areawide codling moth: extending the principles and lessons learned outside the project and to other commodities, pp. 176–83. In *Proc: Areawide Program for Suppression of Codling Moth: Summary of the Effect of Five Years of Control*. Washington State Horticultural Association, 95th Annual Meeting, 8 December 1999, Wenatchee, Washington, USA.

Cronin J T, Turchin P, Hayes J L and Steiner C A (1999) Area-wide efficacy of a localized forest pest management practice. *Environ Ent* 28: 496-504.

Cunningham G L and W J Grefenstette (2000) Eradication of the cotton boll weevil (*Anthonomus grandis*) in the United States — a successful multi-regional approach. Pp 153–57. In Tan K H (ed) *Proc: Area-Wide Control of Fruit Flies and Other Insect Pests. International Conference on Area-Wide Control of Insect Pests*, and the 5th International Symposium on Fruit Flies of Economic Importance, 28 May–5 June 1998, Penang, Malaysia. Penerbit Universiti Sains Malaysia, Pulau Pinang, Malaysia.

Dickerson W A, Brasher A L, Brumley J T, Carter F L, Grefenstette W J, and Harris F A (2001) Boll weevil eradication in the United States through 1999. The Cotton Foundation, Memphis, Tennessee, USA.

Elliot N C, Onstad D W and Brewer M J (2008) History and Ecological Basis for Areawide Pest Management. In: Koul O, Cuperous G W and Elliot N (ed) *Areawide Pest Management Theory and*

Implementation. Pp 15-33. CAB International, Oxfordshire, UK.

Franz G, Gencheva E and Kerremans P (1994) Improved stability of genetic sex-separation strains for the Mediterranean fruit-fly, Ceratitis capitata. *Genome* 37: 72–82.

Fryxell K and Miller T (1995) Autocidal biological control: a general strategy for insect control based on genetic transformation with a highly conserved gene. *J Econ Ent* 88:1221-32.

Fu G, Condon K C, Epton M J, Gong P, Jin L, Condon G C, Morrison N I, Dafa'alla T H, and Alphey L (2007) Female-specific insect lethality engineered using alternative splicing. *Nat Biotech* 25:353-357.

Gong P, Epton M, Fu G, Scaife S, Hiscox A, Condon K, Condon G, Morrison N, Kelly D, Dafa'alla T, Coleman P,and Alphey L (2005) A dominant lethal genetic system for autocidal control of the Mediterranean fruitfly.*Nat Biotech* 23:453-56.

Gonzalez J and Tronsco P (2007) The Fruit Fly Exclusion Programme in Chile In: Vreysen A S, Robinson A S and Hendrichs J (ed) *Area-Wide Control of Insect Pests*. Pp 641-51. Springer, Dodrecht, The Netherlands.

Griffin, R.L. (2000) Trade issues and area-wide pest management. In Tan K H (ed) *Area-Wide Control of Fruit Flies and Other Insect Pests*. Pp. 49-53, Penerbit Universiti Sains Malaysia, Pulau Pinang, Malaysia.

Hendrichs J, Vreysen J B, Enkerlin W R and Cayol J P (2005) Strategic options in using sterile insects for area-wide integrated pest management. In Dyck V A, Hendrichs J and Robinson A S (ed) *Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management.* Pp 563-600.

Henson S and Loader R (2001) Barriers to agricultural exports from developing countries: the role of sanitary and phytosanitary requirements. *Wld Dev* 29: 85-102.

IAEA – Springer, Dordrecht, The Netherlands.

Jassup A J, Dominiak B, Woods B, Lima C P F D, Tomkins A and Smallridge C J (2007) Area-Wide Management of Fruit Flies in Australia. In: Vreysen A S, Robinson A S and Hendrichs J (ed) *Area-Wide Control of Insect Pests*. Pp 685-97. Springer, Dodrecht, The Netherlands.

Kathage J and Qaim M (2012) Economic impacts and impact dynamics of Bt (*Bacillus thuringiensis*) cotton in India. *Proc Natl Acad Sci* 109: 11652-56.

Kerremans P and Franz G (1995) Use of a temperature-sensitive lethal mutation strain of medfly (*Ceratitis capitata*) for the suppression of pest populations *Theoret Appl Genetics* 90: 511–18.

Klassen W (2005) Area-wide integrated pest management and the sterile insect technique. In: Dyck V A, Hendrichs J and Robinson A S (ed), Sterile Insect Technique. Principles and Practice in Area-wide Integrated Pest Management. Pp 39-68. Springer, Dordrecht, The Netherlands.

Knipling E F (1955) Possibilities of insect control or eradication through the use of sexually sterile males. *J econ Ent* 48: 459-62.

Krishnakumar R and Maheshwari P (2007) Assessment of the Sterile Insect Technique to Manage Red Palm Weevil Rhynchophorus ferrugineus in Coconut In: Vreysen A S, Robinson A S and Hendrichs J (ed) *Area-Wide Control of Insect Pests*. Pp 475-85. Springer, Dodrecht, The Netherlands.

La Chance L E and Crystal M M (1965) Induction of Dominant lethal mutation in Insect oocytes and sperm by gamma rays and Alkylating agents : Dose-response and joint action studies. *Genetics* 51:699-708.

La Chance L E and Riemann J G (1964) Cytogenetic investigations on radiation and chemically induced dominant lethal mutations in oocytes and sperm of the Screw Worm fly. *Mutation Res* 1:318.

Lindquist D A (2001) The advantages of area-wide insect control. I: *Proc Seminar Madeira Med*: *Sterile Insect Technique as an Environmentally Friendly and Effective Insect Control System*. pp 55–61, Região Autónoma da Madeira and European Union, 12–13 November 1999, Funchal, Madeira. Madeira Regional Direction of Agriculture, Portugal.

Malavasi A, Rohwer G and Campbell D S (1994) Fruit fly free areas:strategies to develop them. In Calkins C O, Klassen W and Liedo P (ed). *Fruit Flies and the Sterile Insect Technique*. Pp 165–80. CRC Press, BocaRaton, Florida.

Matz M V, Fradkov A F, Labas Y A, Savitsky A P, Zaraisky A G, Markelov M L and Lukyanov S A (1999) Fluorescent proteins from nonbioluminescent Anthozoa species. *Nat Biotech* 17:969-73.

Moreira da S N, Tatiana Rodrigues de O S, Vanessa S D, Iara S J, Leandro de J B, Clicia M J B, Mariangela V L S (2012). Mass-rearing of Mediterranean fruit fly using low-cost yeast products produced in Brazil. *Scientia Agricola*. doi:10.1590/S0103-90162012000600004

Morrison N I, Simmons G S, Fu G, O’Connell S and Walker A S (2012) Engineered Repressible Lethality for Controlling the Pink Bollworm, a Lepidopteran Pest of Cotton. *Plos one* 7: e50922. doi:10.1371/journal.pone.0050922

National Plant Board (NPB) (1999) Safeguarding American plant resources. A stakeholder review of the APHIS-PPQ safeguarding system. USDA, Animal and Plant Health Inspection Service, Washington, D.C., USA.

North D T (1975) Inherited sterility in lepidoptera. *Ann Rev Ent* 20: 167–82.

Oerke E C, Dehne H W, Schohnbeck F and Weber A (1994) *Crop Production and Crop Protection: Estimated Losses in Major Food and Cash Crops*, Pp 72-88 Elsevier, Amsterdam, The Netherlands.

Oka N (1991) Success and challenges of the Indonesia National Integrated Pest Management

Phuc H K, Andreasen M H, Burton R S and Vass C (2007) Late-acting dominant lethal genetic systems and mosquito control. *BMC Biol* 2007:5-11.

Programme in the rice-based cropping season. *Crop Prot* 10: 163–65.

Rohwer G G (1992) Recommendations concerning fruit fly management/ eradication in the Western Hemisphere. OIRSA/NAPPO Bulletin Number 10: 34–39. San Salvador, El Salvador.

Rossler Y (1980) 69 — Apricot” a synthetic strain of the mediterranean fruit fly, *Ceratitis capitata* (Diptera.: Teprhitidae) with sex-limited pupal color and eye color marker. *Entomophaga* 25: 275-81

Seawright J, Kaiser P, Dame D, Lofgren C (1978) Genetic method for the preferential elimination of females of *Anopheles albimanus*. *Science* 200: 1303–04.

Sexson D L and Wyman J A (2005) effect of crop rotation distance on populations of colarado potato beetle development of area wide colardo potato beetle pest management strategies *J econ Ent* 98: 716-24

Showler A T (2002) A summary of control strategies for the desert locust, *Schistocerca gregaria* (Forskal). *Agri Ecosys Environ* 90: 97–103.

Stonehouse J M, Mumford J D, Verghese A, Shukla R P, Satpathy S, 5 Singh H S, Jiji T, Thomas J, Patel p, Jhala R C, Patel R K, Manzar A, Shivalingasamy T M, Mohanta A K, Nair B, Vidya C V, Jagadale V S, Sisodiya D B and Joshi B K (2007) Village area wide fruit fly suppression in India: bait supplication and male annhihlation at vil5lage level and farm level. *Crop Prot* 26: 788-93

Thacker J R M (2002) An Introduction to Arthropod Pest Control. Cambridge University Press, Cambridge, UK.

Thomas D D, Donnelly C A, Wood R J, Alphey L S (2000) Insect population control using a dominant, repressible, lethal genetic system. *Science* 287:2474–76.

Tsien R (1998) The green fluorescent protein. *Ann Rev Biochem* 67: 509–44.

Wright J W, Fritz R F and Hanworth J (1972) Changing concepts of vector control in malaria eradication. *Ann Rev Ent* 17: 75–102.

Wyss JH (2000) Screw-worm eradication in the Americas In: Tan KH (ed) *Area-wide control of fruit flies and other insect pests*. Pp 79-86. Penerbit Universiti Sains Malaysia, Penang.

Yu R and Leung P (2006) optimal pest management: a reproductive pollutant perspective. *Int J Pest Mgmt* 52: 155-66.

How to cite this article:

Pradeep Kumar Dalal, Mandeep Rathee and Jaywant Kumar Singh. 2017. Area Wide Pest Management: Concept and Approaches. *Int.J.Curr.Microbiol.App.Sci.* 6(11): 1476-1495.
doi: https://doi.org/10.20546/ijcmas.2017.611.176