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DEVELOPING EFFICIENT PHEROMONE AND TRAP FOR HELICOVERPA ARMIGERA HUB.-A CRITICAL ANALYSIS

Entomology

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ABSTRACT

The trap development for the Tobacco bud worm Spodoptera litura is still long way to go for perfecting for trapping with higher efficiency. (YASHIMA and TAMAKI,1974) started the developing a trap for this insect when TAMAKI et al.,1973 first identified its pheromone chemical. Later, based on the recommendation of TDRI, London, it was PAWAR et al.,1984 and 1988 perfected a trap for Helicoverpa armigera at ICRISAT. When RANGA RAO joined ICRISAT, he developed a procedure for trapping this insect. Further, on the above observations, NANDAGHOPAL and RATHOD (2007) reported a tarp with higher efficiency.

KEYWORDS:

sex Pheromone, Pheromone trap, Spodoptera litura, trap, India

INTRODUCTION

The first insect of target is Helicoverpa armigera Hubner is a polyphagous pest and widely distributed through out the world. To mention a brief nomenclature of Heliothis, it was during 1806, J. Hubner of Augsburg, Germany described the genus as Heliothis (Hemming, 1937). Later Ochsenheiner (1808) included species armigera among the 14 nominal species he placed in his concept of genus Heliothis. Bhatnagar and Davies (1978) recorded 50 species of crop plants and more than 150 alternative host plants in Andhra Pradesh.

The pheromone components for Helicoverpa armigera was first reported by PICCARDIA et al. (1977) followed by NESBITT et al. (1979, 1980) as given below:

1. (Z) - 11 - hexadecenal
2. (Z) - 9 - hexadecenal

These two components traps the male moths at the effective ratio of 97:3. Up to now, seven components of sex pheromone of the cotton bollworm H.armigera were identified, they were

1. (Z)-11-hexadecenal (Z11-16: Ald),
2. (Z)-9 hexadecenal (Z9-16: Ald),
3. hexadecanal(16:Ald),
4. (Z)-11-hexadecen-1-ol (Z11-16: OH),
5. (Z)-7-hexadencenal (Z7-16: Ald),
6. (Z)-9-tetradecenal (Z9-14: Ald) and
7. tetradecanal (14: Ald).

Interestingly, two sibling species, Helicoverpa assulta and Helicoverpa armigera both use

1. (Z)-9-hexadecenal and
2. (Z)-11-hexadecenal as their sex pheromone components as reversed ratios,

93:7 inH. assulta and
3:97 in H. armigera

This indicated that H. armigera genes appear dominant in determining the behavioral response and electrophysiological responses. Behavioral and electrophysiological responses of backcrosses of male F1 hybrids (H. armigera female × H. assulta male) with female H. assulta and H. armigera were close to that of H. assulta and H. armigera, respectively. However, backcrosses of female F1 hybrids (H. assulta female × H. armigera male) with male H. assulta andH. armigera showed reduced behavioral responses but normal electrophysiological responses compared to males of the respective parental line (ZHAO et al.,2006).

The earliest research from 1977, tested with virgin female in variety of sticky plates and water pan traps.Subsequently in cooperation with the Tropical Development Research Institute (TDRI) of London, a series of synthetic pheromone was tested. Eventually a synthetic pheromone mix was reported by NESBITT et al.(1979;1980) which attracted the males of H.armigera.

How trap was developed for this insect for H.armigera

The light traps have been operated at ICRISAT Center since 1977, the first having been commissioned in 1975 (BHATNAGAR et al.,1982). Lots of problems have been encountered in operation and sorting of insects. After the report of pheromones by PICCARDIA et al. (1977) followed by Nesbitt et al. (1979, 1980), it was Raulston et al.(1980) initiated a wind-oriented trap design for capturing H.armigera. Based on this clue, the Centre for Overseas Pest Research (COPR), London supplied a trap design for trapping H. armigera to ICRISAT and put to use by 1977 itself (PAWAR et al.,1984a).

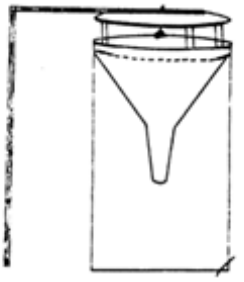

Fig.1. ICRISAT standard trap: a white plastic funnel (diameter 21cm) with an aluminum plate riveted above at a clearance of 5cm.The trap is fixed with a nut and bolt and pheromone source is suspended below the plate at the centre. Moths are retained in the polythene bag

wired below the funnel.

A brief report on the development of trap for this insect has been presented in a National Seminar held at West Bengal (PAWAR et al.,1984b). A detailed report of the traps fabricated and tried is given in a International Congress of Entomology, held at Germany (PAWAR and REED,1984). As per the report the trap was constructed from locally available materials, that was modeled upon a trap supplied by TDRI, London, was found to be more effective. The males thus attracted was collected in a plastic bag through a funnel. This trap was designated as ICRISAT standard Trap (PAWAR et al.,1984).

They further attempted to a develop trap that could trap more males. The trap with a modification with an inverted, perforated conical baffle surrounding the dispenser, along with the USA wind vane trap and USA Texas cone trap. Of these traps tried the trap with an inverted, perforated conical baffle surrounding the dispenser trapped the higher males.

ICRISAT standard trap modified by inserting a perforated small yellow funnel (diameter 15cm)around the pheromone. This funnel trap is secured to the aluminum plate after the placement of pheromone source below the plate.

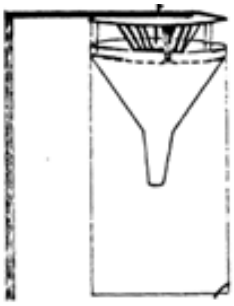

Fig.2 Modified ICRISAT standard trap

PAWAR et al.(1988) reported the longevity of the pheromone in dispenser up to 40 days. They have also fixed the height of the trap to be installed for different crops. They indicated that I m height for Chickpea, groundnut and up to 3m for pigeon pea.

Traps developed for H armigera in Pigeonpea ecosystem:

The efficacy of different types of pheromone traps and their modification was evaluated for their trapability of the male moths of Helicoverpa armigera in Pegionpea ecosystem in Saurashtra area of Gujarat. There was no significant difference in the performance of funnel traps, and the trap with funnel and flap. The trap without funnel and flap found to be efficient in capturing the moths. In these traps also when the distance between the lid and funnel (clearance space) was reduced from 4cm (normal) to 3 cm, the efficiency in trapability significantly increase (21.3-males/trap/alternate day) than any other type of trap. Interestingly, the lures of the gram pod borer also attracted males of the Pectinophora gossypiella. The trap, which shows the efficiency in trapping the moths of P. gossypiella was the similar trap as that of H. armigera with sleeve length of 23 cm (NANDAGOPAL et al.,2003).

Longevity, half life of lures of H.armigera

PAWAR et al.(1988) reported the longevity of the pheromone in dispenser up to 40 days. They have also fixed the height of the trap to be installed for different crops. They indicated that I m height for Chickpea, groundnut and up to 3m for pigeon pea.

Polymorphism in H.armigera

In India, KUMAR and SHIVAKUMARA (2003) have studied various composition of the the five components of the pheromones identified on various ratios at five locations. The two major components (Z)-11-hexadecanal : (Z)-9-hexadecanal : : 97:3 ratio trapped higher number of males in all the centres tested.

Blend	(Z)-11-hexadecanal	(Z)-9-hexadecanal	Hexadecanal	Hexadecanol	(Z)-11-hexadecanol
P1	55.84	3.9	27.27	1.3	11.69
P2	87	3	4	6	
P3	90.91	9.09			
P4	92	8			
P5	97	3			
P6	100				

Blend	Raichur	Dharwad	Ranebennur	Shimoga	GKVK	Mean
P1	3.87	2.68	5.84	1.53	0.01	2.3
P2	19.94	4.17	1.68	1.40	2.09	5.0
P3	7.29	1.20	5.01	1.86	2.78	3.0
P4	5.79	2.98	4.17	1.40	1.40	2.6
P5	58.94	64.28	45.00	41.48	41.67	41.9
P6	2.39	1.79	7.50	0.94	0.01	7.6
Mean	16.4	15.3	11.5	8.1	8.0	

P1:WU DEMING et al.,1997- P2: DUNKELBLUM et al.,1980 - P3:ROTHSCHILD,1978; ROTHSCHILD et al.,1982; WILSON et al.,1989 -P4:KEHAT et al.,1980; WILSON et al.,1989 - P5: NESBITT et al.,1980; KEHAT et al.,1980; ANONYMOUS,1982 - P6:BOURDOUXHE,1982.

The authors (KUMAR and SHIVAKUMARA,2003) have interpreted that in-spite of the variable response of moths to pheromone blends, it was interesting to find that 97 : 3 mixture of (Z)-11-hexadecenal and (Z)-9-hexadecenal, as previously recommended, was the best combination of synthetic pheromone lure for trapping H. armigera males. This result was confirmed across all the locations tested. However, the proportional catches of H. armigera moths to this combination varied from as low as 61 to 89% in different locations.

From the above table it is clear that the blend of (Z)-11-hexadecenal and (Z)-9-hexadecenal at 97 : 3 ratio performed well in all the testing centers ranging from 41 to 64 males trapped in all the centers. It is the blend that worked efficiently in trapping the males (mean of 50.3 males) in all the centers compared to 2.5 males in the component (Z)-11-hexadecanal (100%) and 5.9 males in P2 blend i.e., (Z)-11-hexadecanal:(Z)-9-hexadecanal:Hexadecanal:Hexadecanol :: 87: 3: 4: 6.

So, with this available data it cannot be claimed as to the presence of any polymorphism in H. armigera in Indian conditions having tested only in Karnataka state. Of-course, polymorphism is anticipated in H. armigera due to the fact that very disparate combinations of pheromonal components are suggested in different countries of the Old World. However, these were on a much larger geographical scale. For example, genetic variability of 22 populations of H.armigera was studied by comparison of allozyme frequencies at 15 loci. Seven loci were polymorphic at the 99% level. Populations originated from the south of France, Portugal, Morocco, Tunisia, Burkina Faso and Ivory Coast. Populations from France and Portugal showed significant differences when comparing allele frequencies. On the other hand, in northern and western Africa, no significant difference exists even when comparing populations located on either side of the Sahara desert (SAMUEL NIBOUCHE et al.,1998). In a field trials at various locations in India to assess sex pheromone response of H. armigera males to varying blends of its two sex pheromone components impregnated with 0 : 100 to 15 : 85. of Z-9 :hexadecenal to Z-11 : hexadecenal results geographical variation in response of males suggesting polymorphism (TAMHANKAR et al.,2002).

The genetic relatedness among H. armigera occurring on different host plants prevailing in South India was studied using PCR-RAPD. Genomic DNA was isolated individually from five larvae collected from each of 10 different host plants (except in okra). PCR-RAPD

analysis was carried out using a set of 20 random primers which had produced repeatable banding patterns from a original set of 60 primers. A set of 155 amplicon levels were available for analysis, of which 154 were polymorphic (SUVAMA PATIL et al.,2006). Similarly, larvae of H. armigera exhibit a body-color polymorphism that is most distinct in the final instar. Larvae also had a certain degree of plastic response to the diet change, which indicates larvae can adjust body color as they change the part of the host plant where they feed. Although the adaptive consequence of similar body color to plant part is still unknown, diet-induced body-color polymorphism in H. armigera (AZUSA YAMASAKI et al.,2009). Specimens were collected from several provinces in Iran from tomato. The genomic DNA from H. armigera larvae collected during summer 2006-2007 from five different places were subjected to polymerase chain reaction (PCR) using 10 different SSR primers. The highest numbers of 14 markers were produced by the primer HaSSR1, followed by 9 markers by HaSSR6 with high degree of polymorphism 75–100%. The primers HaSSR6, HaSSR4, HaC87 and HaD47 were found to be highly informative to differentiate populations with a polymorphism information content value of 100 percent. Ten tested SSR primers produced 46 bands in geographical populations. Within population genetic diversity based on Nie s gene index ranged from 0.188 to 0.250 Molecular variance analysis showed significant within and between population variance (NADER GOL MOHAMMAD ZADEKHIABAN et al.,2010). It has been reported that the morphometric characterization of twelve geographic populations of cotton bollworm, H. armigera occurring in south Indian cotton ecosystems was done at larval, pupal and adult stages over three cropping seasons. Traits such as length and weight of larvae, pupa and length and width of the wing, length of fore-, mid- and hind femur, male reproductive organ-length of genital capsule, valves, and ejaculatory duct, female reproductive organ-length of appendix bursae and ductusbursae at adult stage were measured across three years. Populations significantly differed for most of the traits studied. It was evident that populations from northern parts recorded higher phenotypic attributes compared to those from southern parts of south Indian cotton ecosystem. Besides larval, pupal and adult external phenotypic traits, attributes of male reproductive organ viz., length of genital capsule, valves, and ejaculatory duct and female reproductive organ viz., length of appendix bursae and ductusbursae differed significantly among populations (FAKRUDIN BASHASAB et al.,2007).

In a detailed study, population genetic structure of Indian H. armigera using five Exon-Primed Intron-Crossing (EPIC)-PCR markers, nested alternative EPIC markers detected moderate null allele frequencies (4.3% to 9.4%) in loci used to infer population genetic structure but the apparently genome-wide heterozygote deficit suggests in-breeding or a Wahlund effect rather than a null allele effect. Population genetic analysis of the 26 populations suggested significant genetic differentiation within India but especially in cotton-feeding populations in the 2006–07 cropping season. In contrast, overall pair-wise FST estimates from populations feeding on food crops indicated no significant population substructure irrespective of cropping seasons. A Baysian cluster analysis was used to assign the genetic make-up of individuals to likely membership of population clusters (BEHERA et al.,2013).

A novel set of five polymorphic di- or trinucleotide microsatellite loci suitable for population genetic study were developed from an enriched genomic library for the insect cotton bollworm, H. armigera, and cross-amplifiability of these and other published loci was tested in a closely related species, the tobacco budworm, H. assulta. The expected heterozygosity at these loci ranges from 0.62 to 0.91 in the cotton bollworm. The observed allele numbers varies from 4 to 12 in the limited number of individuals tested. Although a large proportion of cloned microsatellite sequences are present in multi-copy in the cotton bollworm genome, the overwhelming majority of the finalized polymorphic diallelic loci are tri-nucleotide microsatellites - an unexpected outcome, which should facilitate subsequent genotyping analysis (YA-JIEJI et al.,2005). Since sequence variation of the target genes different populations of the target pest is the possible limiting factor in the application of RNAi in the field, a study was undertaken to elucidate the sequence polymorphism of five important genes (actin, glutathione S-transferase, cytochrome P450, chymotrypsin and serine protease) from the fruit borer, H. armigera. An off-target minimized region (500 bp) was identified for dsRNA synthesis from all the above sequences and the nucleotide variations in this region were analysed in silico to design common siRNAs for each of the target genes that could be further utilized for downstream applications (ASOKAN et al.,2012). In this preliminary study diversity among 5 cotton bollworm, H. armigera populations from different geographic regions of North Karnataka, Indian state was done using RAPD markers. Nineteen selected RAPD markers generated a total of 58 PCR amplicons, of which 26 were polymorphic across all 5 populations. An average of 6.44 amplicons per primer was noted. All populations could be differentiated from one another using specific primers; specific band(s) could be potentially used to differentiate individual populations. On a larger scale, genetic differences among populations appear to result from low dispersal rates between populations (YENAGI et al.,2012).

The polyphagous nature and high extent of morphological variability in H. armigera field populations often lead to a mismatch and inconsistency between actual trap catches and ground truths while using the commercially available combination of 97: 3 Z-11: Hexadecenal (Z11–16: Ald) and Z-9: Hexadecenal (Z9–16: Ald) sex pheromones. Field trials conducted simultaneously at New Delhi and Sirsa in Haryana in chickpea crop conclusively proved that sex pheromone polymorphism exists in H. armigera at variable loadings of 1, 5 and 10 mg, the three ratios evaluated (97: 3, 93: 7 and 90: 10 Z-11 and Z- 9 Hexadecenal) gave almost identical catches of male moths. It is concluded that if only one ratio is used in monitoring of the pest it reflects only about 1/3rd of the actual field population. Therefore it is crucial that bouquet of blends be used for effective monitoring of the pest (TANWAR et al.,2006). In Mediterranean population, the genetic structure of the cotton bollworm, H. armigera was studied in the eastern Mediterranean. Moths were sampled in six locations (five in Israel, and one in Turkey) and their genetic relationship was analysed using RAPD-PCR. Three 10-oligonucleotide primers revealed 84 presumptive polymorphic loci that were used to estimate population structure. Results reveal low level of genetic distances among Israeli and Turkish populations. The estimated values of FST and for the eastern Mediterranean populations were very low across all populations, indicating a high level of gene flow. Four distinct RAPD-product profile types were defined, and found in all Israeli and Turkish populations. Although no isolation by geographical distance was detected, topographical barriers may play a role in such isolation (XIAOFENG ZHOU et al.,2000).

At Northern Cameroon, 19 populations (504 larvae) were sampled in different locations, dates and host plants (6 villages, 6 dates, 5 host plants). Their genetic relationship was analysed using 10 polymorphic microsatellite markers. Despite the high polymorphism (5 to 50 alleles per locus), results reveal low level of genetic distances among locations, collection dates and host plants. Subsequently, larval sampling from Africa Senegal, Mali, Burkina-Faso, Togo and Cameroon and two samples from Madagascar and from Australia indicating a high level of gene flow between these locations and the high migration capacity of the pest . Samples from Thailand, China, Pakistan and France were added to this study but it has been impossible to infer the presence of distinct populations. The opportunity to use neutral markers as microsatellites to understand population dynamics of H. armigera is discussed (VASSAL et al., 2008). Thirteen allozymes, -glycerophosphate dehydrogenase (-GPDH), acid phosphatase (ACPH), alkaline phosphatase (ALP), aldehyde oxidase (AO), esterase (EST), glutamate oxaloacetate transaminase (GOT), hexokinase (HEX), leucineaminopeptidase (LAP), lactate dehydrogenase (LDH), malate dehydrogenase (MDH), malate enzyme (ME), phosphoglucomutase (PGM), xanthine

dehydrogenase (XDH), were analysed by polyacrylamide gradient gel electrophoresis with double stain method. The genetic variations of 9 allozymes within and among 5 geographic populations were investigated. Among the 13 loci examined, 6 loci were polymorphic and 7 loci were monomorphic. The percentage of polymorphic loci was 46.15%. As calculated with the results of AO, GOT, LAP, LDH, ME and XDH, the average heterozygosity of H. armigera was 0.1160.Among Nanjing, Chengdu, Wuxue, Hengyang and Hami populations, their mean genetic distance was 0.0008〜0.0293 and mean genetic similarity was 0.9707〜0.992 (GUANG et al.,2000).

To use the pheromone technology in field conditions, monitoring, mass trapping and mating disruption are followed. Monitoring is the first step to find out the occurrence of any pest as adult male. Based on the catch in traps, further decision are to be made.

Monitoring H.armigera

Pheromone traps have several features ideal for monitoring: they are the most sensitive sampling technique, are species specific, require little maintenance, and can be operated by non-entomologists also (WALL, 1990). To monitor this species of moths, first ICRISAT used light trap and even started a net work with AICRIP centres as early as 1977 (BHATNAGAR et al.,1982). Pheromone traps are easy to operate, hence, ICRISAT had collaboration with the (AICRIP) as net work in 1981 at 11 locations (PAWAR et al.,1983). A pheromone trap network was used to study the temporal and spatial variations in the abundance of the pod borer, H. armigera in India. The pattern of pheromone trap catches was similar within any given agroclimatic zone but there were also obvious changes with latitude in patterns of trap catches (SRIVASTAVA et al.,1990). Studies with sleeve type pheromone traps indicated that 22 moths/trap/night correspond to 10% damage' to the reproductive parts in cotton by H. armigera. Based on the pheromone trap catches, action for controlling this pest should be initiated when the moth catches exceed 7 moths/trap/night (PRASAD et al.,1993). The pheromone trap monitoring revealed the period of moth activity of H. armigera from 3rd -4th week of February to 2rd - 3th week of May with a peak during 2nd -4th week of April in the field. The correlation coefficient between egg counts and pheromone trap catches, were also significantly positive (PAL et al.,2014). In chickpea crop (Cicer arietinum L.) the peaks in the pheromone trap catches of male moths were invariably followed by the peaks in egg and larval counts. The correlation between pheromone trap catches of weekn-1 and egg counts for weekn=0 were positive, r = +0.35 in 1986 and positive and significant r = +0.69 (SRIVASTAVA and SRIVASTAVA, 1995). A study was carried out for monitoring numbers of moths of the cotton bollworm, H.armigera using pheromone, blacklight and popular twig bunch traps at 3 locations in southern Xinjiang, China in 1997 resulting water tray traps (28 cm×10 cm) was 14.4 times more catch than that in popular traps (JIAN et al.,2001). Pheromone traps were installed at 1.5 m from the ground in peas (Pisum sativum var. Green Feast) in Pakistan. First moth was appeared on 25th and 23th April 1994-95 and 1995-96 seasons respectively. Four peaks of the pest infestation were observed each years. 1st peak (13 and 16 months) was recorded on 09-05-95 and 12-05-96 respectively (MALIK et al.,2003). Pheromone traps were installed at 1 m from the ground in tomato (Lycopersicum esculentum). First moth, in the field was appeared during 04th and 03rd weeks of transplantations each year (1995-96) respectively. Maximum mean number of moths (11 and 09) were captured during 11th and 08th weeks of transplantations. A total mean number of 63 and 45 moths were captured during the two years of study respectively. The study strongly recommends the use of pheromones than pesticides against the said pest in tomato (MALIK et al.,2003).

Sex pheromones proved more effective for monitoring the adult moth of all species except H. armigera, ie. 48 adults were captured by light traps and only 26 were caught by pheromones. P. gossypiella was very attractant to sex pheromones, only 2 % were captured through light trap, but response of Earias species were positive to both techniques, here also pheromones seemed more successful in capturing the adult moth than light trap with little variation in both years (SHAH et al.,2011) SHARMA et al.(2012) monitored H. armigera male moths through pheromone traps in chickpea crop field at village Kapren, dist. Bundi during 2011-12. Maximum number of male moths trapped were 105.66/trap/week, while maximum number of larvae was 30.0/10 plants recorded during 12th standard week (19 March -25 March). Maximum and minimum temperature had positive correlation with male moth catches and larval population while, relative humidity had negative correlation.

Mass Trapping of H.armigera

To standardize number of pheromone traps required for mass trapping of H. armigera in pigeon pea, an experiment was carried out with pheromone traps @ 30, 40 & 50 /ha was installed. The highest moth catches (9630 during first year and 11272 during second year with an average of 10451 per ha) were recorded in the plots installed with 50 traps /ha. Further, the pigeon pea crop having treatment of 50 traps /ha recorded the lowest population of eggs (3.95 /twig) and larvae (2.89 /twig) as well as per cent pod damage (7.96) and found significantly superior then 30 and 40 traps/ha. Thus, 50 traps /ha was found effective in annihilation of males of H. armigera (SHANOWER et al.,1999). Pheromone traps installed at 4 m from the ground in apple (Pyrusmalus Linn., Rosaceae: Pomoidea) canopy in the two adjacent apple orchards in Quetta, Balochistan, Pakistan, first moth, in the orchard, was appeared on 22nd and 8th March during 1995 and 96 respectively. Population climax of the moth was observed was 32 moths on 7th April36 moths on 27th March during 1995 and 96 respectively. The study reveals that pheromone traps could affectively be used for the scouting/control of the said pest in apple canopy (MALIK et al.,2002). In Paksitan, pheromone traps were installed at 1.5 m from the ground in okra (Abelmoschus esculentus L.). First moth, in the field, was appeared during 7th and 6th weeks of traps installation each year 1995 and 1996, respectively. Maximum mean numbers of moths (11th and 7th) were captured during 9th and 7th weeks of traps installation, when the average temperatures were 28.38 and 25.78oC each year, respectively. The adult pest remained in the field till 11th and 4th August 1995 and 1996, respectively. The study strongly recommends the use of pheromones over pesticides against the said pest in okra (MALIK et al.,2003).

Mating disruption of H.armigera

Two tests were conducted in 1995 in order to compare a blend of five components of H. armigera pheromone with a blend of two components for mating disruption. The application consisted of 2000 ropes/ha, each with 80 mg pheromone. A new combined formulation, HPROPE, containing 175 mg of the H. armigera two component blend and 65 mg of P. gossypiella pheromone was tested in 1996 for mating disruption of both pests. Application of 625 ropes/ha caused a high level of suppression of mating of H. armigera females for at least 94 days and that of P. gossypiella females for 161 days. The pheromone release rates were c. 625 mg/day/ha for H. armigera and 162 mg/day/ha for P. gossypiella (KEHAT et al.,1998). A slow release PVC resin formulation, Selibate (R) HA, containing a 97:3 mixture of the major (9Z-hexadecenal) and minor (11Z-hexadecenal) components of the female sex pheromone of H. armigera was applied at a rate of 40 g active ingredient ha-1 during August 1996. The formulation was applied at a rate of c. 250 pieces per hectare. A high degree of trap catch shutdown (indicating mating suppression) was observed throughout the pheromone treated area during the whole of the season compared to non-pheromone treated farmer practice fields. Night observations confirmed that mating disruption occurred in the pheromone treated area as a smaller percentage of mated females were collected from this area compared to farmer practice fields. A greater percentage of tethered female H. armigera moths retrieved from farmer practice fields had successfully mated compared to tethered females retrieved from the pheromone treated area (CHAMBERLAIN et al.,2000).

To conclude, it is the scientists viz., PICCARDI, et a.(1977) and Nesbitt et a.(1979;1980) who have discovered the actual pheromone

chemicals of H.armigera and ROTHSCHILD et a.(1978;1982) and RAULSTON et a.(1980) initiated the trap development . Later through ICRISAT, Pawar et al.(1984;1988) have developed more efficient trap for this insect for farmers use in fields.

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