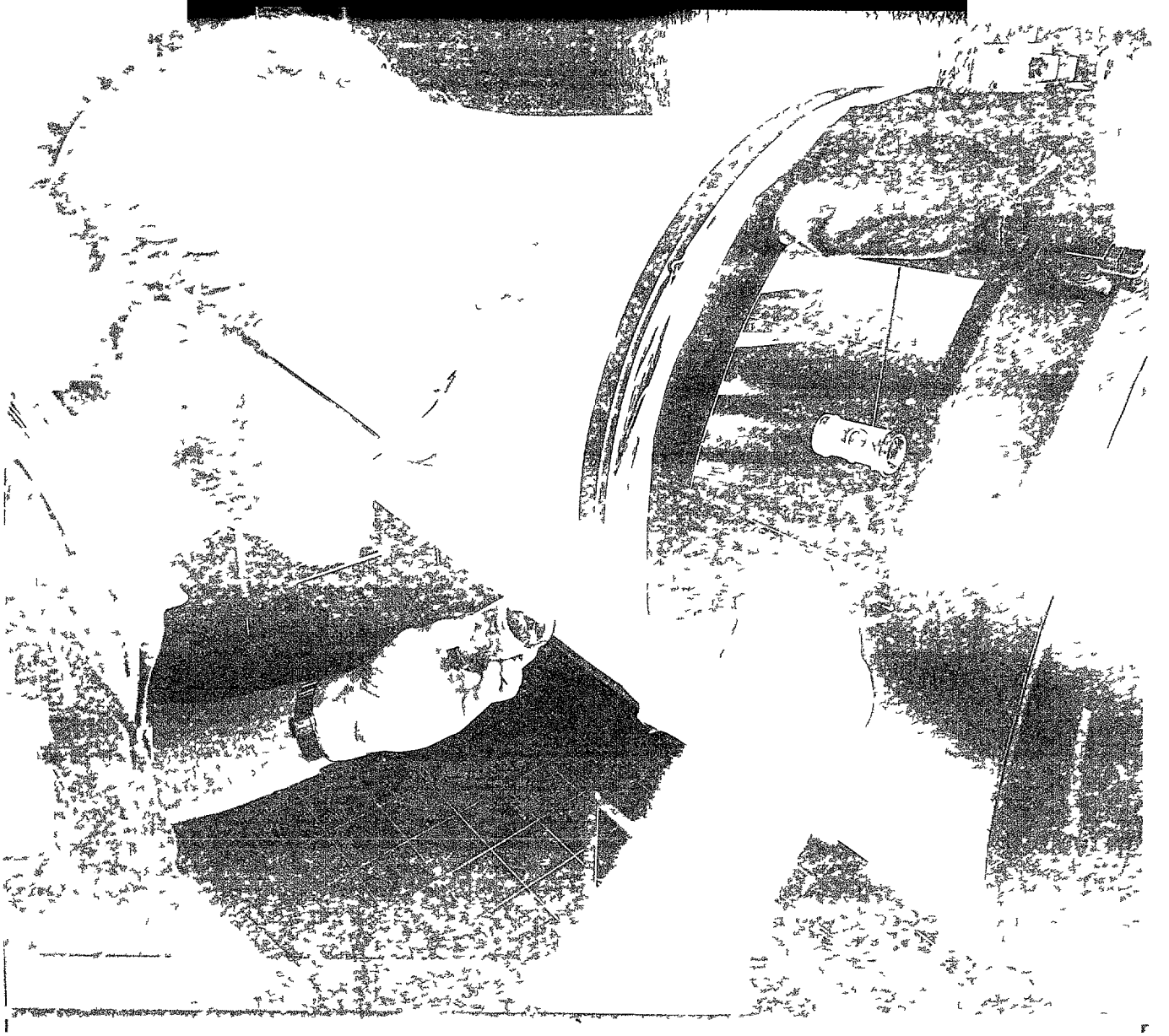
PN-ACF-040

Use of Pheromone Traps for Monitoring the Millet Stem Borer *(Coniesta ignefusalis)*



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Abstract

This bulletin explains what pheromones are, how they have been used in the management of pests, especially stem borers, the advances that have been made in the management of the millet stem borer (*Coniesta ignefusalis*), how to use the pheromone traps developed for this species, and the prospects for the integration of pheromone based methods into management strategies of this key pest in the Sahel

Resumé

Utilisation des pieges a pheromones pour la surveillance du foreur du mil (Coniesta ignefusalis) Cet ouvrage a pour but d'expliquer ce que sont les pheromones, leur utilisation dans la lutte contre les insectes nuisibles surtout les foreurs des tiges, les progres enregistres dans la maitrise du foreur du mil (*Coniesta ignefusalis*), la methode d'utilisation des pieges a pheromones mis au point pour la lutte contre cette espece ainsi que les perspectives d'integration des methodes a base de pheromones dans les strategies de lutte contre cet important ravageur au Sahel

Resumen

Uso de trampas de feromonas para monitoreo des barrenadores del tallo del millo perla (Coniesta ignefusalis) Este boletin trata de explicar que son las feromonas, como ellas han sido usadas en el manejo de plagas, especialmente en barrenadores del tallo como los adelantos han sido utilizados en el manejo de barrenadores del tallo en millo perla (*Coniesta ignefusalis*), como utilizar las trampas de feromonas desarrolladas para esta especie, y las perspectivas de investigacion basadas en los metodos de feromonas dentro de las estrategias de manejo de plagas en Sahel

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Preface

This bulletin has been developed as a follow up to the First Regional Training Workshop on the Use of Pheromone Technology in the Management of Cereal Stem Borers that was held, 30 Sep–5 Oct 1996, at ICRISAT Niamey, Niger It covers pheromones, their identification techniques, and use in crop protec tion (pest monitoring, mass trapping, mating disruption and attracticides) The pheromone compo nents of the millet stem borer *Coniesta ignefusalis* and procedures for making lures and pheromone traps are described Recommendations on where and when to place traps as well as on how to service them are given The book also presents methods to identify and record catches and to interpret results Future prospects for more effective monitoring of *C ignefusalis* by using pheromone traps are indicated

Acknowledgments

Photographs of Figures 2 4a 5 6 7 9a and 9d as well as the descriptive drawing of a gas chromato graph (Fig 4b) were provided by NRI Additional illustrations (Figs 1 9b 9c 10 and 11) were provided by O Youm

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The Millet Stem Borer Problem

The millet stem borer *Coniesta ignefusalis* (Hampson), is a damaging pest of pearl millet [*Pennisetum glaucum* (L) R Brown] in the Sahelian and subSahelian zones of Africa from Senegal to Sudan There are usually three generations of the pest in a year in the wetter areas (e g Nigeria) and two occasionally three in the drier regions (e g , Niger) of Africa

The damage is caused by the larvae feeding on the stem Attacks on young plants result in deadhearts Extensive larval tunneling in late sown millet by the second and third generations can cause disruption of the plant vascular system leading to crop lodging and inhibition of grain formation (Fig 1) If untreated damage normally ranges from 15–100% Towards the end of the rains, the larvae enter into diapause in the stems and stubbles and survive until the following season

Application of insecticides such as dimethoate and carbofuran can be effective even though the oviposition sites are hidden under the leaf sheaths However, this approach is not always economically viable Natural biological control by indigenous insects is generally ineffective Intercropping experiments have shown no clear benefits in terms of millet stem borer control Although fertilizer manipulation and host plant resistance (especially leaf hairiness) show some promise it is cultural control methods that currently make the most significant contributions to control of the millet stem borer Early sowing after the first rains and management of crop residues to limit the carry over of diapausing larvae to the following season are the most effective control methods However, there are economic factors limiting the farmers' willingness to modify their sowing practices and traditional uses of the stalks

There is evidently a great need to identify reliable crop loss assessment techniques for millet stem borer and also to develop a cheap reliable and low technology method of monitoring and control which does not have adverse effects on either the beneficial insects present in the field or the ecological health of the generally low input millet cropping systems The recent development of synthetic sex pheromones may provide a great opportunity to reach these goals This bulletin aims to explain what pheromones are how they have been used in the management of pests (especially stem borers) the advances that have been made in the management of the millet stem borer how to use the pheromone traps developed for this species and the prospects for the inclusion of pheromone based methods into integrated management strategies for this key pest in the Sahel

The ICRISAT Information Bulletin *Coniesta ignefusalis* a handbook of information" by O Youm K M Harris and K F Nwanze published in 1996 provides a thorough review of the biology distribution damage potential of the millet stem borer and measures for controlling it as well as an annotated bibliography on the species and its control

Figure 1 Lodging of windprone stems due to damage by Coniesta ignefusalis

Pheromones

What are Pheromones?

Pheromones are chemical messages produced by one member of a species which produce a specific response in another member of the same species In mammals they may be used for territorial marking e g when a cat rubs the corner of its mouth against its owner s leg it is marking him/her as part of its territory" with secretions from a scent gland Some species of fish release a chemical message into the water when attacked by predators that warns other members of the species to swim away Ants produce alarm" pheromones which spur the soldier ants to at

tack Many ant species also lay "trail" pheromones after locating food sources allowing others to follow the trail Bark beetles emit "aggregation" pheromones which serve to attract other beetles to tunneling sites in the tree bark However, the insect pheromones that have attracted the most interest are the sex pheromones especially in Lepidoptera (butterflies and moths)

Sex pheromones are emitted by an individual that is ready to mate (usually the female) to attract members of the opposite sex The existence of sex pheromones in moths was demonstrated over 100 years ago, but it was not until the 1950s that the chemical structure of a sex pheromone was first identified (in the silk moth) Since then hundreds of lepidopteran sex pheromones have been identified and a large number of them artificially synthesized Male moths can detect the sex pheromone molecules of conspecific females at concentrations of less than one part in a thousand million in the air using specific detector sites on their antennae, and can orient themselves upwind towards the pheromone source (Fig 2) This is the major sensory mode used for mate finding in the Lepidoptera

The chemicals that form the basis of sex pheromones are generally a blend of 8 to 18 carbon acetates alcohols, and aldehydes and related compounds (see bibliography for list of species and materials currently identified) The attractant is species specific, either in terms of the type of compounds used and/or the proportions of compounds in the pheromone blend (Fig 3) As a consequence, artificial pheromone sources attract only members of one species, making pheromone baited trap counts very simple and ensuring that control methods based on artificial pheromones cause minimum disruption to the rest of the ecosystem

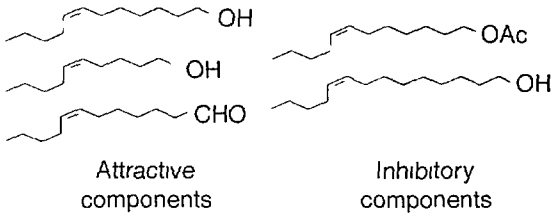

Figure 3 Chemical structure of components of the millet stem borer pheromone

Identification Techniques

Pheromones are produced by insects in very small quantities, typically of the order of 10^{9} g per night but techniques of pheromone identification have improved enormously since the 1950s

Mixtures containing the pheromone are collected by extracting the pheromone gland with a suitable solvent or by trapping the pheromone released by the insect usually the female in the case of sex pheromones This is then analyzed by gas chromatography (GC) in which the mixture is passed through a heated column The different components of the mixture take different lengths of time to pass through the column The quantity

Figure 2 A male red bollworm moth Diparopsis castanea *specific pheromone sites are located on its antennae*

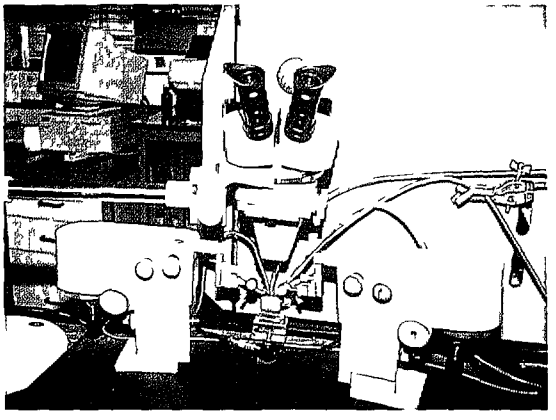

Figure 4a An electroantennograph (EAG) helps to measures the electrical changes that occur in the pheromone receptors on the moth antennae

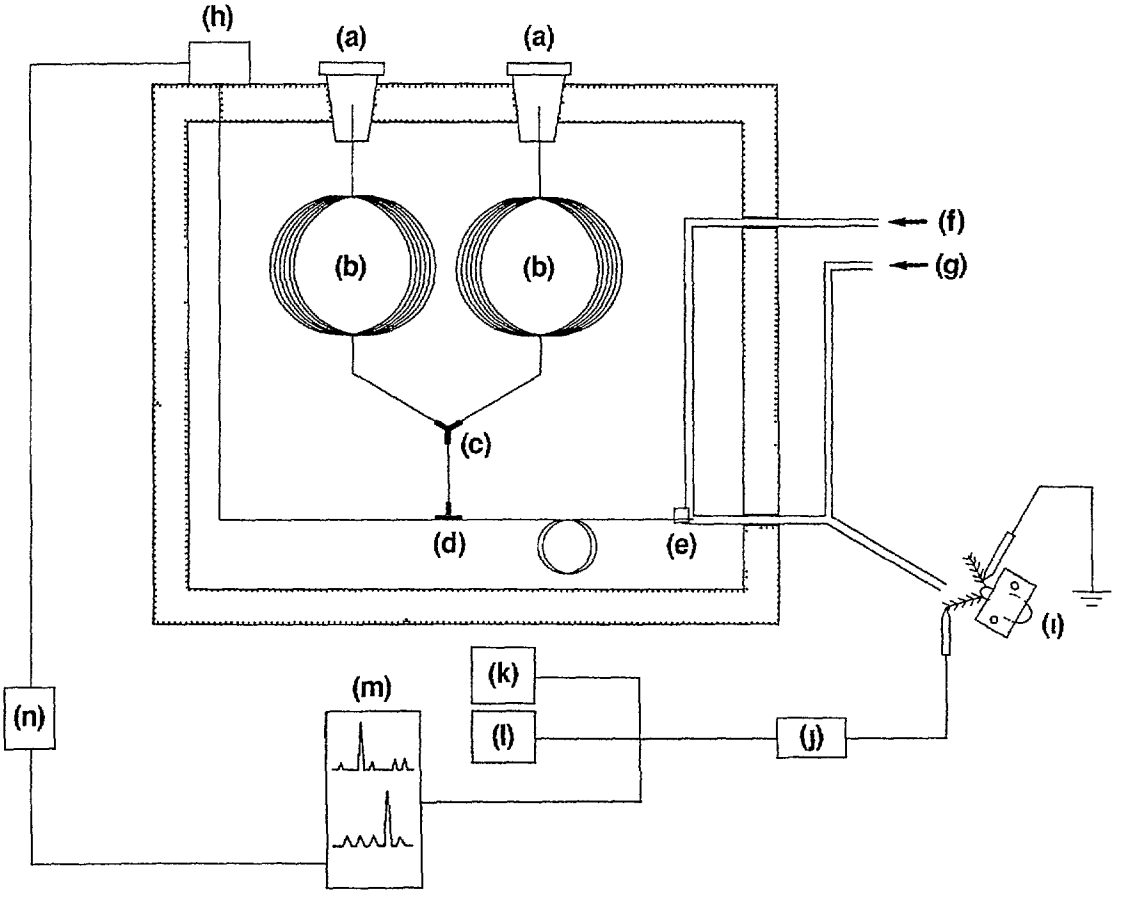

Figure 4b A gas chromatograph (GC) system a = injector points for the pheromones b = capillary columns c and d = Y tube connectors e = GC column outlet f = inlet for pulsed nitrogen flow g = inlet for constant bypass nitrogen flow h = GC column outlet to flame ionization detector (FID) i = electroantennograph preparation with insect j = a signal amplifier k = an oscilloscope l = a FM tape recorder m = a pen recorder for FID and EAG and n = FID amplifier

of each component is measured with a sensitive detector as it emerges from the column

In order to determine which components are detected by the insect usually the male in the case of sex pheromones the outlet from the GC can also be monitored with a device called an electroantennograph (EAG) In this technique tiny electrodes are inserted into the insect antennae to measure the electrical changes that occur in the pheromone receptors on the antennae when they are stimulated by a biologically active component (Figs 4a and b)

The biologically active components are isolated and their chemical structures determined by a variety of techniques including the use of a mass spectrometer linked to a gas chromatograph (Fig 5) These structures must then be synthesized and the synthetic chemicals tested individually and in mixtures for biological activity in the laboratory and field In the laboratory a wind tunnel (Fig 6) can be used in which the chemicals are released at the upwind end to test their attractiveness to male insects released at the downwind end The exact quantities and relative proportions of the synthetic pheromone components required to give optimum attraction can be determined, and the attractiveness of this blend compared with that of the female insect or pheromone gland extract

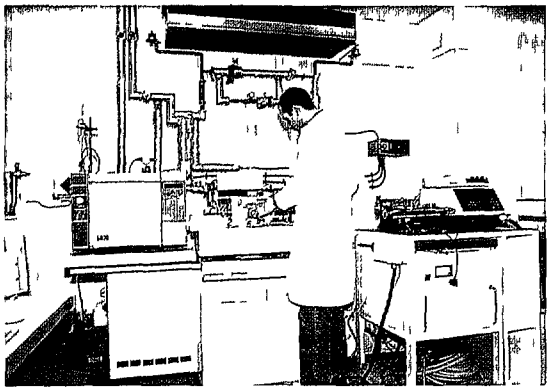

Figure 5 Using a mass spectrometer linked to a gas chromatograph scientists isolate biologically active components of pheromones and determine their chemical structures

The artificial pheromone blend is then tested in the field to establish whether it can attract male insects to traps (Fig 7) A suitable dispensing system must be devised that releases the pheromone over a prolonged period of several weeks In addition the quantities and relative amounts of the synthetic pheromone components must be further refined to produce a lure that is at least as attractive as a virgin female insect If the field trials are successful the artificial pheromone is then ready for testing in population monitoring or control

With these techniques a pheromone can sometimes be identified using a few tens of insects a far cry from the 500 000 female moths that were used to identify the silk moth pheromone in the 1950s

Figure 6 Synthetic pheromones are released in a wind tunnel at the upwind end to test their attractiveness to male insects released at the downwind end

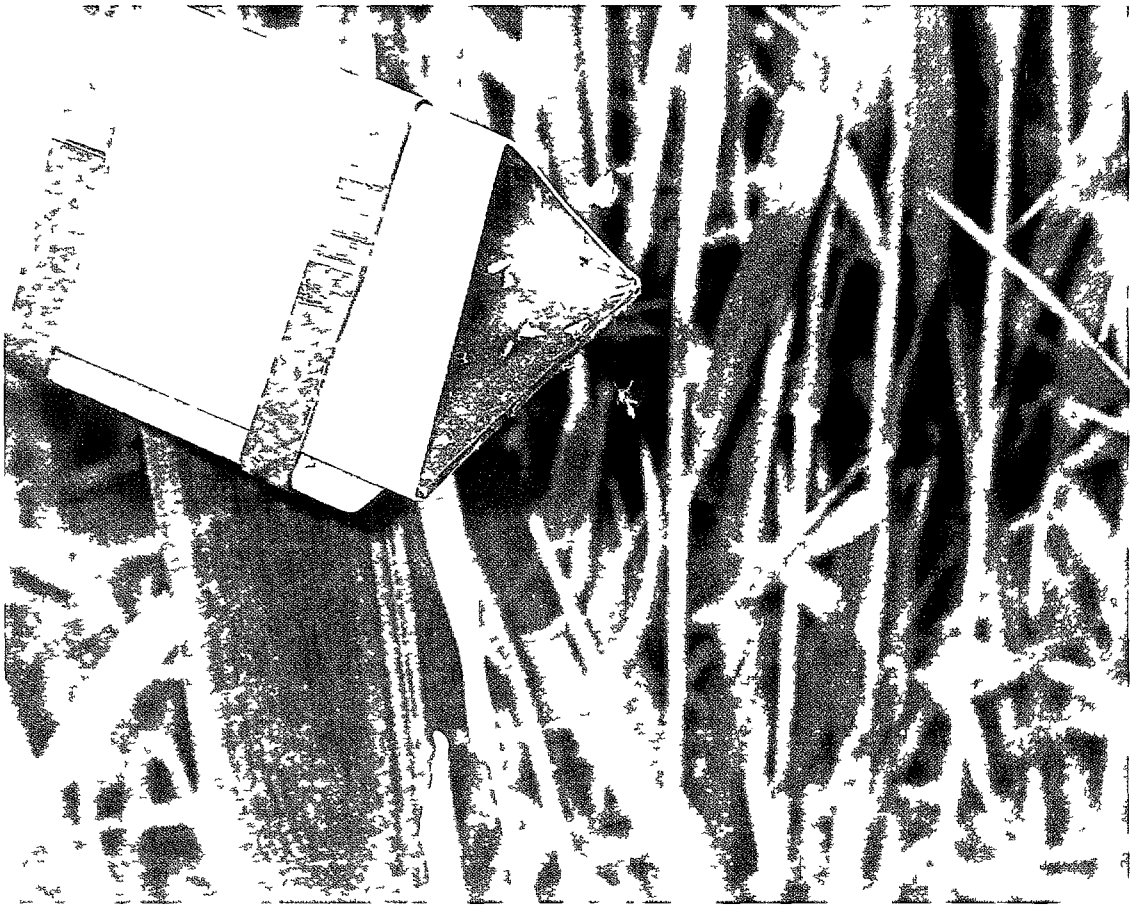

Figure 7 A male pea moth Cydia nigricana, *approaching a pheromone baited trap*

How are Pheromones Used in Plant Protection?

Monitoring population events using pheromone traps Since sex pheromones are species specific a pest species can be trapped and counted without the distracting presence of other insect species—an advantage not provided by other methods such as light traps A large number of trap types has been produced mostly involving a sticky surface water or a dry funnel as the trapping medium The pheromone is typically formulated in a slow release dispenser containing 1 mg or less of the active ingredient and can remain attractive in the field for several weeks These simple traps can be deployed in the field to detect the presence of a species (a common quarantine practice near ports and airports) the date of first occurrence in a crop (which may be useful in timing control measures) or to follow the progress of a number of pest generations (Fig 8) Correlating trap catch numbers with larval damage in subsequent generations has however proved difficult for most species, as a number of factors such as weather host crop stage and pest control measures intervene

Nevertheless because of their ease of operation insect monitoring traps have become commercially available for about 250 species Many of these are now available for orchard and vineyard pests (significant monitoring systems include nine moths four flies and three bugs) or pests of field crops (12 moths and two beetles) In particular they have a valuable function in the detection of pests of stored products (three moths 10 beetles and two cockroaches) giving ad

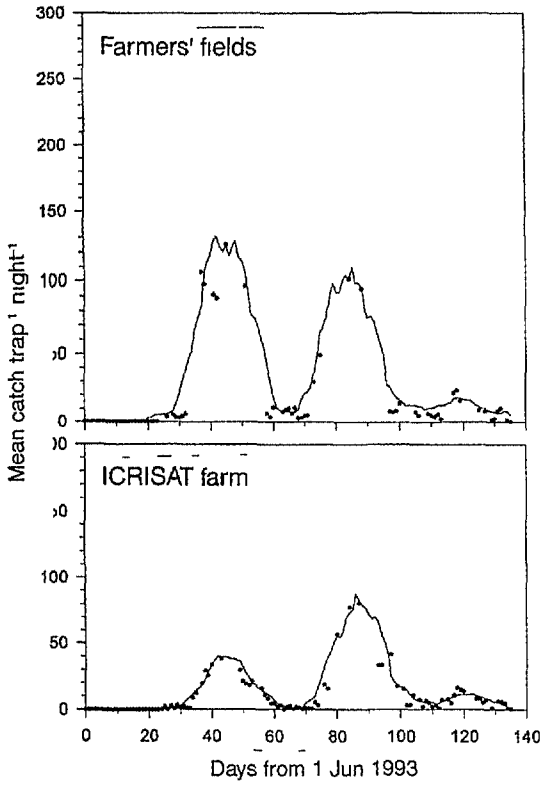

Figure 8 Millet stem borer catches in farmers' fields and at ICRISAT Niamey Niger 1993

vanced warning of outbreaks of migratory pests (e g, African armyworm, *Spodoptera exempta* (Walker) in eastern Africa) and in the monitoring of forest pests which would otherwise be extremely difficult to sample (six species of moths and five of beetles)

Mating disruption This is the preferred method of insect control with pheromones Pheromone mediated communication between the sexes is disrupted by saturating the environment with a synthetic pheromone This reduces the number of matings and therefore the numbers of fertile eggs and larvae on the plants Much effort has gone into the development of long lasting pheromone dispensers which can be distributed in the field Sprayable microencapsulated or polymer bead formulations, laminate flakes hollow fibers, hand applied twist ties PVC resins and many other dispensers have been successful to varying degrees (Figs 9a to d) The quantity of pheromone that must be released in order to disrupt mating is small varying from a few mg to a few hundred mg hectare^{-1} day^{-1} depending on the species The density of dispensers can be surprisingly low (as little as 100 ha^{-1} for pink bollworm control in cotton) The effect can be long lasting (several months from one application in some cases) and is specific to a single insect species Beneficial organisms are not harmed However the mechanism by which mating disruption is achieved is still not clearly understood

Particular successes have been recorded with pink bollworm [*Pectinophora gossypiella* (Saunders)] in Egypt—where the whole cotton crop is treated with pheromones—and over significant areas in the USA with grape moth [*Lobesia botrana* (Busck)] in Germany the oriental fruit moth (*Cydia molesta*) on stone fruit and codling moth [*Cydia pomonella* (L)] on pip fruit worldwide A range of other species has also been controlled over smaller areas in tomatoes artichokes tea and apricots Much research has been concentrated in this area and over 15 companies are marketing mating disruption materials

The environmental benefit of pheromone control is clear Depending on the stability and complexity of the pheromone components costs can be comparable with or less than the corresponding toxic chemical control programs However pheromone application methods are labor intensive or involve the use of special machinery Furthermore, their specificity although an advantage environmentally makes commercial development more difficult than might be the case for a conventional insecticide which is effective over a range of pests and crops

Mass trapping As a logical extension of trapping to monitor flight activity, attempts have been made for many years to trap a significant proportion of the pest population to achieve control Pheromones have been used for this purpose though it should be noted that most of these materials attract only the male It is therefore essential to have a good understanding of the biology of the pest before attempting control by this method, as mated females may fly into the crop from beyond the pheromone treated area undermining the effect of the removal of males In general, the treated area must be large in terms of the insects' normal flying range

Mass trapping has been most successful with aggregation pheromones which attract both males and females Integrated control of forest

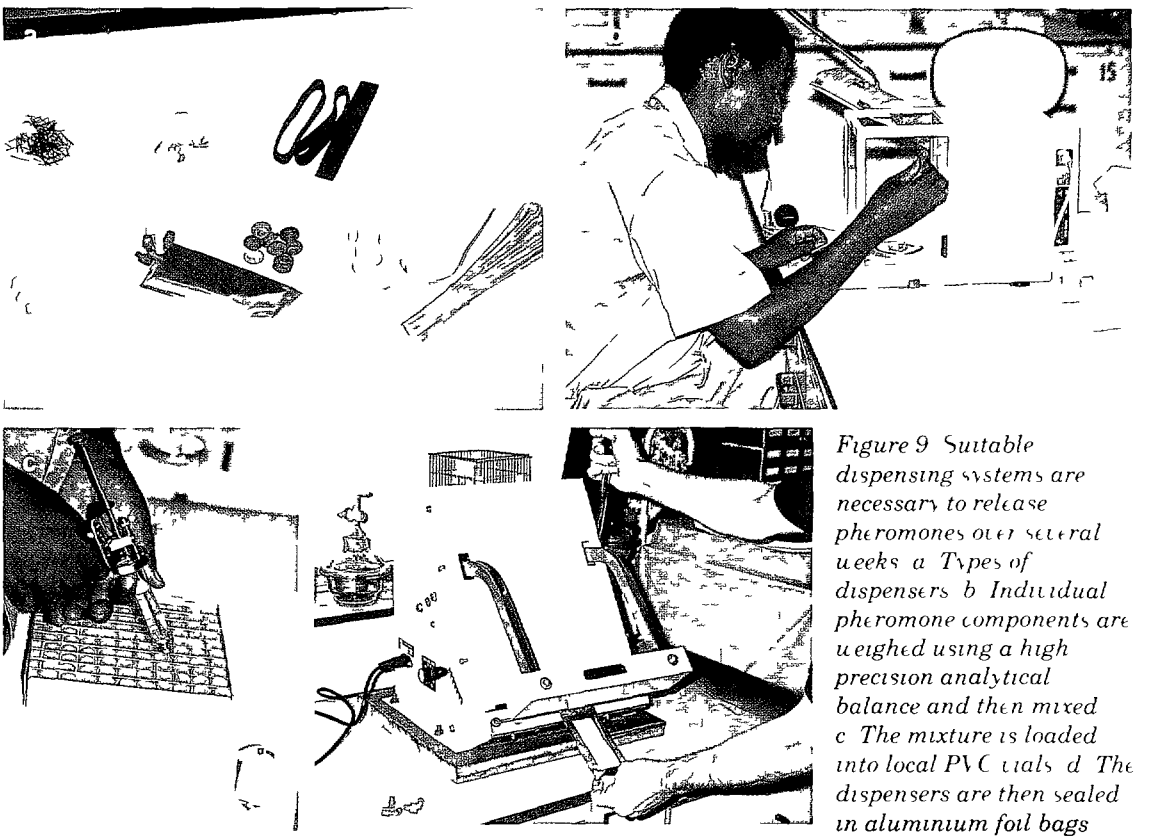

Figure 9 Suitable dispensing systems are necessary to release pheromones over several weeks a Types of dispensers b Individual pheromone components are weighed using a high precision analytical balance and then mixed c The mixture is loaded into local PVC vials d The dispensers are then sealed in aluminium foil bags

pests such as the spruce bark beetle [*Ips typographus* (L)] in Scandinavia and of the fir beetles (*Dendroctonus* spp) in Canada and the USA has been greatly advanced in this way Pheromone traps are also playing an important role in the control and in some cases eradication of the cotton boll weevil [*Anthonomus grandis* (Boheman)] in the Americas Traps are also in use for limiting infestations of cockroaches and various biting and nuisance flies However successes with this technique amongst the Lepidoptera have been rather fewer perhaps because only the males are affected and the fecundity of the females is generally high The gypsy moth [*Lymantria dispar* (L)] in North American forests and the cocoa pod borer [*Conopomorpha cramerella* (Snellen)] in Malaysia are exceptions where mass trapping has made a significant contribution to pest control

Attracticide In this approach the target insect is attracted to a pheromone source that has been treated with insecticide, rather than to a trap This method requires less pheromone than mating disruption uses far less insecticide than conventional control operations and allows many more sources to be deployed than is possible with mass trapping A number of companies have attracticide products for pink bollworm control in cotton and success has been reported with the diamondback moth (*Plutella xylostella*) on *Brassica* spp

Use of Pheromones for Managing Other Stem Borers

The pheromones of three species of rice stem borers have been identified [*Chilo suppressalis* (Walker)] *Scirpophaga incertulas* (Walker) *Sesamia inferens* (Walker) and of two species in sorghum/maize [*Chilo partellus* (Swinhoe)] and [*Busseola fusca* (Fuller)] All the components are 14 16 or 18 carbon acetates alcohols and alde

hydes These pheromones are generally consid ered unsuitable for control using mass trapping owing to the high insect densities commonly ex perienced However commercial use for control by mating disruption has been demonstrated for the rice stem borer in Spain using 20 g of phero mone ha ', and encouraging results have been re ported for this species from Japan, Korea and the Philippines Disruption trials with *S incertulas* were similarly promising in India Recent work with *Busseola fusca* on maize in Kenya has also demonstrated successful mating disruption for up to 8 weeks with one application of pheromone Pheromone traps are being used to monitor popu lations in a number of other species, families, and orders

Millet Stem Borer Pheromone Identification and Field Trials

Collaborative work between scientists of ICRISAT Niamey and the Natural Resources In stitute (UK) found five biologically active com pounds in hexane washings of female millet stem borer pheromone glands A blend of three of these—two alcohols and an aldehyde—was shown to be more attractive than virgin female moths in field tests in Niger Further work showed that the most attractive blend contained the three compounds in a 100 5 3 3 ratio Addi tion of either or both of the other two compounds reduced the attractiveness

Pheromone Traps

Experiments have been conducted at ICRISAT Niamey Niger to compare the effects of various trap designs and trapping surfaces on the capture of male millet stem borer moths with artificial pheromone lures A water based trap has been proved to be the most efficient and cost effective The measurements given below provided optimal trapping efficiency Deviating significantly from this design (even in such details as the proportion of the water surface covered by the trap lid) is likely to result in reduced catches and a reduction in the comparability of trap catches between dif ferent areas The trap system described below was tested through the West and Central African Millet Research Network in Benin, Burkina Faso, Gambia Ghana, Mali Niger Nigeria, and Senegal It has worked well in all the areas in which it has been tested suggesting that there are unlikely to be separate geographic races of the millet stem borer, which would have required the development of different pheromone blends

How to Make Traps

The trap consists of an aluminium tray 32 cm in diameter 3–4 cm in depth, and filled with water to a depth of 2 cm (Fig 10) Four holes 3 mm in diameter (too small to allow the passage of trapped moths) are drilled in the side of the tray 1 cm below the lip to allow rain water to drain away without losing the captured moths from the trap Suspended 2–5 cm above the tray is a lid (21 cm in diameter) which acts to shade the phero mone lure and water surface to reduce evapora tion It also increases the likelihood of moths ap proaching the lure and contacting the water sur face Larger lids appear to inhibit moth entry into the trap, and significantly smaller ones allow the moths to avoid contacting the water The addition of 10–20 mL of standard motor oil (new or used) to the water improves trap catch by reducing the surface tension of the water and also serves to reduce evaporation If motor oil is not available a few milliliters of liquid detergent or a bar of do mestic soap agitated in the water for about 1 min has the same effect on moth captures Vegetable oil is not effective Plastic water trays have a lim ited life in the high light intensity and high tem peratures of the Sahelian zone

Figure 10 A water based pheromone trap for monitoring adult male populations of Coniesta ignefusalis

A stable base greatly improves the reliability of the trap A wooden shelf to hold the water tray, supported on a 5 cm × 2 cm wooden stake driven into the soil is ideal The trap lid is suspended by wire from an arm at the top of the stake and an chored to the trap tray by wire drawn through three holes drilled around the tray

How to Make Lures

Although it is not difficult to make one s own lures (see the list of component suppliers in Ap pendix I) most users will find it simpler to obtain ready made lures from ICRISAT Niamey Niger The technical details of the pheromone and the procedure for making lures are given in Appendix II

The artificial pheromone attractant is a mix ture of three components plus an antioxidant which protects the pheromone from being de graded by heat and light It has been shown that 0 5 mg of the active pheromone ingredient per lure with 0 5 mg of the antioxidant is optimal As with most lepidopteran pheromones the precise proportion of each of the three pheromone compo nents in the mixture is important for optimal attractivity In the case of the millet stem borer the optimal ratio is 100 5 3 3 A solution of the active pheromone ingredient and the antioxidant is injected into a polythene dispenser where it is absorbed into the walls This lure is then hung in the trap to attract male stem borers

How to Use Lures

The lure is suspended from a piece of wire di rectly under the center of the trap lid and above the water Lures can be stored in glass or metal containers (including aluminium foil) in a domes tic refrigerator (4°C) for several months or in a freezer indefinitely There is no health hazard in volved in storing lures

Where and When to Place Traps

Millet stem borer moths fly and mate close to the ground Although trap height is not a critical fac tor a lure height of not more than 0 5 m from the ground appears to be optimal whatever the height of the surrounding crop Larval diapause is broken by the first rains adequate moisture and an appropriate day length Traps should therefore, be placed in the field no later than 10 days after the sowing rains begin If traps are placed in the field before the emergence of the young millet plant and cattle are allowed to graze in the field, care should be taken to ensure that they do not drink the water in the traps

Comparisons of moth densities at different lo cations will be more reliable if traps are located within the crop at least 2 m from the edge of the field Where traps are to be used only for monitor ing a single trap should be placed within the mil let field at least 20 m from the edge

Servicing Traps

The lure continues to release pheromones for at least 6 weeks but the attractiveness decreases significantly after about 4 weeks For consistently high attractivity it is recommended that lures be replaced after 2 weeks The water and soap/oil will need to be replaced more frequently depending on the evaporation rate at the particular site and the time of year Traps should be examined at least twice a week and the catch counted Old lures should either be returned to the supplier for refill ing or disposed of as domestic waste They should not be discarded close to traps where they may in terfere with the trapping efficacy

Identifying Trap Catches

As the pheromone is species specific, the trap catch should almost consist entirely of the millet stem borer Therefore sorting the catch is not a problem as it is with light traps or bait traps Complete illustrated descriptions of all life stages of millet stem borer are given in the NRI publication "Ennemis du Mil au Sahel" and in the ICRISAT Bulletin *Coniesta ignefusalis* a hand book of information" The moth (Fig 11) has a wingspan of 22–30 mm and a wing length of 8–15 mm The female is usually larger than the male The forewings are straw yellow The upper sur face of the hindwings is satin white Occasionally, a very small number of catches of other species may occur Among the other species that might be caught are *Helicoverpa armigera* (Hubner) and *Spodoptera littoralis* (Boisduval) which are much larger and have dark patterned wings The millet head miner moth (*Heliocheilus albipunctella* De Joannis) is of a size and color similar to *Coniesta ignefusalis* but the fringed forewings have

Figure 11 Adult Coniesta ignefusalis *female on a pearl millet leaf*

streaks of white and the hindwings are gray rather than white In addition, the forewings of the male have two transparent "windows", absent in *C ignefusalis* In southern and eastern Africa confusion with *Chilo partellus* is also possible, however, there is no evidence of *C ignefusalis* occurrence in these regions

Recording and Reporting Results

Traps should be examined at least twice a week and data recorded on a sheet (Fig 12) In addition to counting and discarding moths, the operator should note whether the trap still has adequate water as this will obviously have influenced trap catch As a guide to changes over time, the best results will be obtained if the traps are not moved within a season and preferably not between seasons Work done elsewhere suggests that results from national trapping systems can be analyzed most reliably if each trap site is coded perhaps by the district, village and trap letter If the trap is moved, a new letter should be allocated as sites can differ in their suitability for trap capture in ways that are not always visually obvious The entomologist based at ICRISAT Niamey, Niger, would be interested to receive trap catch results from across the region Scientists in participating countries are invited to write directly for advice on the most suitable recording format

Interpreting Results

The artificial female pheromone is attractive only to males that are ready to mate Work with other species has shown pheromone traps to be especially sensitive at low population densities perhaps because of the lower number of competing natural females There is therefore rarely a simple relationship between the numbers caught in the traps and the size of the subsequent larval infestation, though some broad correlation will obviously exist As mentioned earlier, traps in slightly different positions within a field can attract significantly differing numbers of moths For practical use in the timing of insecticide or other control measures the operator is most likely to find the dates of the first significant trap catch (e g a mean of at least one moth per trap per night) and the flight peaks which occur some weeks later, the most useful indicators of moth activity In areas not currently suffering from attack by millet stem borer, the pheromone traps provide a simple and reliable method of detecting the first invasion of the species

Research in Progress and Future Prospects

Pheromone traps for monitoring the millet stem borer have proved effective in the eight countries in which they have been used to date This regional monitoring is expected to cover more countries of the West and Central African Millet Research Network Trials have also been undertaken to explore the potential for controlling millet stem borer populations by mass trapping and by mating disruption

Traps arrayed around farmers' granaries have shown that damage in terms of infested hills and percentage of deadhearts can be reduced significantly by trapping close to these storage structures This reduction in infested hills and deadhearts is possibly due to the reduced population of males through mass trapping Granaries made of millet stems infested with diapausing millet stem borer larvae are a major source of infestation of young millet of the succeeding season Further work is in progress to determine whether or not the application of this method is economically viable

Mating disruption was assessed at Sadore near ICRISAT Niamey in 1993 Trap catches in

Record Sheet

Region _____

Country _____

Site (station or farmer's field) _____

Cropping system (mix or sole crop) _____

Operator's name _____

Trap no	Date (of the previous night)	Catches	Remarks

Figure 12 A typical record sheet for monitoring Coniesta ignefusalis *using pheromone baited trap*

treated plots were significantly suppressed, suggesting that sexual communication was being disrupted Further trials with longer lasting dispensers are required before the system can be recommended as being economically viable

Two of the five components of the millet stem borer pheromone inhibit male approaches to traps It may be possible in the future to use these "inhibitors" to disrupt natural sexual communication

The identification and availability of the sex pheromone of the millet stem borer provides a valuable opportunity to monitor insect activity and to time control measures to reduce insect populations and damage In future, it may be possible to use artificial pheromones to control the pest directly in an environmentally desirable way When integrated with the use of tolerant varieties and cultural control practices such as crop residue management, this may finally be the opportunity to practice full and effective integrated management against this key pest of pearl millet in the Sahelian and Sudanian zones

Selected Bibliography

Publications listed here are not cited in the text but they concern aspects of the use of pheromones and the development of the millet stem borer trapping system Further information and an extensive list of references on millet stem borer biology and control can be found in Youm O , Harris, K.M , and Nwanze, K F 1996 *Coniesta ignefusalis* a handbook of information Information Bulletin no 46 Patancheru 502 324, Andhra Pradesh India International Crops Research Institute for the Semi Arid Tropics 60 pp [Part 1 Review pp 1–18, Part 2 Annotated bibliography pp 19–52] ISBN 92 9066 253 0 Order code IBE 046

Most of the publications listed in that bibliography are held at ICRISAT Niamey, BP 12404 Niamey, Niger and ICRISAT Patancheru, Patancheru 502 324, Andhra Pradesh, India

Arn, H , Toth, M , and **Priesner, E** 1992 List of sex pheromones of Lepidoptera and related attractants 2nd edn Montfavet International Organisation for Biological Control

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Youm, O , McVeigh, L J , Toure, K , and **Mahamadou, C I** 1995 Regional monitoring of *Coniesta ignefusalis* (Hampson) using pheromone traps Partial results obtained in Niger and Mali in 1993 and 1994 Quarterly Bulletin West and Central African Millet Research Network (7) 12–13

Appendix I. List of Suppliers and Sources of Information

Pheromone Lures

ICRISAT Niamey
BP 12404 Niamey
Niger
Fax (227) 734 329

Agrisense BCS Ltd
Treforest Industrial Estate
Pontypridd
Mid Glamorgan CF37 5SU
United Kingdom
Fax (44) 1443 841152

International Pheromone Systems Ltd
Units 12 and 13 Meadow Lane
Ellesmere Port
South Wirral L65 4EH, United Kingdom
Fax (44) 151 355 0299

Chemicals

Shin Etsu Chemical Co Ltd
Fine Chemicals Department
6 1, Ohtemachi 2 chome Chiyoda ku,
Tokyo, Japan
Fax (81) 3 3246 5371

Aldrich Chemical Company
The Old Brickyard
New Road
Gillingham, Dorset SP8 4JL
United Kingdom
Fax (44) 1747 823779

Pipetting Equipment

Fisher Scientific UK
Bishop Meadow Road
Loughborough
Leicestershire LE11 ORG
United Kingdom
Fax (44) 1509 616121

Jencons Scientific Ltd
Chettycourt Way Industrial Estate
Stanbridge Road
Leighton Buzzard LU7 8UA
United Kingdom
Fax (44) 1525 379547

Technical Advice on Pheromones

Chemical Ecology Group
Natural Resources Institute
Chatham Maritime
Chatham, Kent ME4 4TB
United Kingdom
Fax (44) 01634 880066

Appendix II. Technical Details of Pheromone and Lure Production

A standard lure contains the following ingredients

Pheromone

1 *(Z)*-7 dodecen 1 ol	500 µg
2 *(Z)* 5 decen 1 ol	25 µg
3 *(Z)* 7 dodecenal	16 5 µg

Antioxidant

4 Butylated hydroxy toluene (BHT)	542 µg

The isomeric purity of the pheromone components has been shown not to be critical down to at least 90%

Lure Manufacture

The best dispenser is a capped polythene vial (32 × 15 × 2 mm thick) into which the pheromone is impregnated in a small suitable amount of nonpolar, rapidly evaporating solvent Hexane or 60/80 petroleum spirit are ideal, while ethanol and methanol are not The release rate characteristics of the particular polythene used are important (see list of suppliers)

To make 1000 lures mix 500 mg of component (1) 25 mg of component (2) and 16 5 mg of component (3) in 99 mL of solvent To this is added 542 mg of antioxidant and the components are thoroughly mixed A reliable dispensing pipette (RePette or Eppendorf are ideal, see suppliers' list) is then used to inject 0 1 mL of the resulting mixture into each lure Where large numbers of lures are being made they should be prepared in a fume cupboard or an extremely well ventilated room The solvent is left to evaporate (only a few minutes at ambient tropical temperatures) before the vials are capped Ideally, lures are then sealed in aluminium foil and marked with the name of the species date of manufacture, and batch number If this is not possible, they should be stored in airtight glass or metal (not plastic) containers In this form, they can be stored in a domestic refrigerator for a season (indefinitely in the freezer compartment) However under ambient tropical temperatures lures should be used within 3 months of manufacture if not kept refrigerated When the foil seal is broken, lures should be placed in traps within 24 hours as the pheromone will start to be released immediately

About ICRISAT

The semi arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub Saharan Africa, much of southern and eastern Africa and parts of Latin America Many of these countries are among the poorest in the world Approximately one sixth of the world's population lives in the SAT, which is typified by unpredictable weather limited and erratic rainfall, and nutrient poor soils

ICRISAT's mandate crops are sorghum pearl millet finger millet, chickpea pigeonpea, and groundnut these six crops are vital to life for the ever increasing populations of the semi arid tropics ICRISAT s mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT ICRISAT communicates informa tion on technologies as they are developed through workshops, networks, training, library services, and publishing

ICRISAT was established in 1972 It is one of 16 nonprofit research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR) The CGIAR is an informal association of approximately 50 public and private sector donors it is co sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP) the United Nations Environment Programme (UNEP), and the World Bank

About NRI

The Natural Resources Institute (NRI) is a scientific institute within the University of Greenwich, and is an internationally recognized center of expertise in research and consultancy in the environment and natural resources sector Its principal aim is to increase the productivity of renewable natural resources in developing countries in a sustainable way by promoting development through science