**CROP PROTECTION PROGRAMME**

# Development of pheromone trapping for monitoring and control of the legume podborer, *Maruca vitrata* (syn. *testulalis*) by small-holder farmers in West Africa

**R7441 (ZA0311)**

# FINAL TECHNICAL REPORT

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Mark Downham

Natural Resources Institute


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## EXECUTIVE SUMMARY

The legume podborer, *Maruca vitrata* is a major pan-tropical pest of legume crops and particularly of cowpea in West Africa. The specific objectives of this project were to complete optimisation of pheromone traps and lures begun under a previous project; also to integrate their use with other novel IPM technologies to provide improved methods for control by small-holder cowpea farmers in West Africa. The project also aimed to provide a better understanding of the population dynamics, ecology and behaviour of *M. vitrata*, based on long-term monitoring with pheromone traps.

Comparative trapping experiments were conducted to complete optimisation of an effective and practical trapping system for *M. vitrata*. The most effective traps were produced from locally available 5-l plastic jerry-cans. This, and findings in respect of lure dose and longevity, blend ratio and isomeric purity, favoured the practical and economic viability of trapping *M. vitrata*. A commercial source for the lures was identified, lures obtained and verified as being effective. The requirements for registration of the use of pheromone traps within Benin and Ghana were briefly investigated. Presently there appear to be no formal requirements, although the Environmental Protection Agency in Ghana employed an *ad hoc* procedure when approached.

On-farm monitoring studies were conducted in Benin, Ghana and Nigeria through regional PRONAF (*Projet du Niébé pout l'Afrique*) farmer field schools managed by national research and extension bodies, under the direction of IITA. In Benin particularly, these produced good evidence to indicate that trap-catches occur up to 12 days before larval infestations. Thus trap-catches can signal impending infestations. However, some variability in the relative timing of trap-catches and infestations was observed and this could reduce the predictive value of traps. Factors responsible for this were identified and will be taken into account in a future project phase. Although a temporal relationship between trap-catches and larval infestations was found, there was little evidence of a significant quantitative relationship. This is because high infestations seem to occur regardless of trap catch levels. Thus traps will be limited to determining when to begin control measures against *M. vitrata*.

In on-station trials, insecticide spraying based on a trap-threshold approach was more effective than spraying based on crop stage. Results indicated that the best threshold involved spraying 3 days after attainment of a 2-moth per trap threshold. Collectively, the trials showed that while the synthetic insecticide, Decis, clearly provided better control of *M. vitrata* than neem, *Hyptis* and papaya leaf extracts, as well as two formulations of *Metarhizium*, the botanicals and *Metarhizium* all produced significantly lower infestations than the unsprayed control. They did not, however, have any impact on flower thrips infestations.

In on-farm trials, a combined traps and botanicals (T&B) treatment was inferior, in terms of *M. vitrata* infestations and yield, to farmer practice involving several conventional pesticide sprays. However, due to lower input costs it was equivalent in terms of economic returns in two of five villages. Moreover, considerable scope was identified to improve its technical performance. Even if this does not prove possible the combination of traps with synthetic insecticides would still enhance the control of *M. vitrata*.

Monitoring of pheromone traps in Benin has provided useful data concerning seasonal movements of the pest on a national or regional scale. One practical benefit of such information would be to support attempts to avoid infestations by *M. vitrata* by planting outside the normal cropping season. In Nigeria catches in pheromone traps were much lower than in Benin and Ghana. Regional monitoring data may also assist in understanding this.

Project surveys confirmed that farmers in Benin consider *M. vitrata* to be one of the most damaging pests of cowpea and that large majorities in both Ghana and Benin believe pheromone traps could assist in control of the pest. However, most farmers also consider that trap materials may be difficult to obtain. Surveys and trials have shown there is a need to consider other pests, particularly aphids and thrips, in developing T&B treatments. Furthermore, although about half of farmers surveyed already use botanical insecticides, the labour of production will act as a disincentive to uptake.

In conclusion, great progress has been made in developing pheromone traps to assist in the control of *M. vitrata* by acting as predictors of infestations, enabling the timing of control measures to be optimised. There are strong indications that they will prove useful to farmers in Benin and Ghana and that they would be prepared to use them in this way. Trials of the trap-threshold concept, in combination with botanical pesticides, have demonstrated the potential of such an approach, although improvements to the technical and economic efficiency are still required for it to be a practical option for cowpea farmers in West Africa. The scope exists for these improvements.

## BACKGROUND

Cowpea, *Vigna unguiculata* (L.) Walp., is a highly important grain legume crop grown in semi-arid and dry savannah agro-ecological zones of the tropics (Singh & van Emden, 1979). It provides a cheap source of dietary protein for low-income populations (Rachie, 1985) and forms a vital cattle forage crop in many farming systems (Mortimore *et al*., 1997). Africa produces 75% of world production of which the majority comes from West Africa (Coulibaly & Lowenberg-Deboer, 2002, derived from FAOSTAT, 2000).

*Maruca vitrata* Fabricius (syn. *M. testulalis*) (Lepidoptera: Pyralidae), the legume podborer, is a key pest of cowpea (Jackai, 1995) as well as other legume crops. The larvae attack flower buds, flowers and young pods (Singh & Jackai, 1988) and on cowpea yield losses due to *M. vitrata* have been reported in the range 20-80% (Singh *et al*., 1990). In West Africa *M. vitrata* forms one of a complex of insect pests of cowpea, which also includes aphids, *Aphis craccivora*, thrips, *Megalurothrips sjostedti*, several species of heteropteran pod-sucking bugs and the weevil, *Apion varium*. Together, these insect pests are reported as the major production constraints by farmers (Alghali, 1991; Bottenberg, 1995).

Insecticides can control cowpea insect pests and raise yields several-fold (Afun *et al*., 1991; Amatobi, 1995; Asante *et al*., 2001). However in many parts of West Africa expense limits insecticide use by many poor farmers (Alghali, 1991; Bottenberg, 1995). Conversely, in Benin insecticide use is higher and may be excessive in areas in which cotton is grown, due to the availability of subsidised insecticides; as a result serious levels of pesticide-related sickness and death have been reported (Pesticides News, 2000). Resistance in *M. vitrata* to three classes of insecticides has been reported from Nigeria (Ekesi, 1999). To control *M.*

*vitrata* careful timing of application is required because the webs produced by the larvae, and their tendency to bore into flowers and pods, help to protect them from insecticides (Lateef & Reed, 1990). Afun *et al*. (1991) demonstrated effective use of action thresholds, based on flower infestation rates, to time insecticide applications. Potentially, cowpea farmers could use catches in pheromone-baited traps for *M. vitrata* to determine the most effective time to apply insecticides. Such an approach has been developed for pests of other tropical crops such as rice (Kojima *et al*., 1996) and cotton (Reddy & Manjunatha, 2000). For resource-poor farmers this would enable optimal use of limited inputs, whilst in areas of high pesticide use traps could promote a reduction in usage.

Although the basic biology of *M. vitrata* has been studied extensively, there is a lack of information on the behaviour and activity of this pest in the field, particularly in relation to possible migration patterns and off-season occurrence. This has hindered development of IPM strategies in Africa (Singh *et al.*, 1990) and Asia (Shanower *et al*., 1999). Jackai (1995) specifically called for ecological studies to enable the successful implementation of strategies such as manipulation of planting dates to reduce *M. vitrata* damage (Ekesi *et al*., 1996). The use of pheromone traps for monitoring the activity and movements of adult *M. vitrata* could assist researchers in this respect. Bottenberg *et al*. (1997) provided some data on the population dynamics and migration of *M. vitrata* in West Africa, based on light trap catches. However, their data were limited to three sites; pheromone traps could be deployed more easily, cheaply and in greater numbers in order to generate this kind of information. Moreover, pheromone traps are specific to the species of interest.

Okeyo-Owuor & Agwaro (1982) trapped male *M. vitrata* moths in water traps baited with virgin females in Kenya, thus suggesting the production of a sex pheromone by female *M. vitrata*. Later, Adati & Tatsuki (1999) reported (*E,E*)-10,12-hexadecadienal (EE10,12-16:Ald) to be an electroantennogramm-active component of the extract from female *M. vitrata* abdominal tips. Synthetic EE10,12-16:Ald was shown to be attractive to male moths in laboratory bioassays although only at high levels of isomeric purity. The corresponding alcohol, (*E,E*)-10,12-hexadecadienol (EE10,12-16:OH), was found to be present at 3-4% relative to the aldehyde, but not tested. No field-testing was carried out.

The first steps in the practical development of pheromone traps as monitoring tools for *M. vitrata* were taken in previous CPP-funded projects (R5292, R6659). The compounds EE10,12-16:Ald and EE10,12-16:OH were shown to form major and minor components, respectively, of the pheromone blend, confirming the finding of Adati & Tatsuki (1999). The earlier project results suggested the presence of a third pheromone component, which later field trials indicated was (*E*)-10-hexadecenal (E10-16:Ald). Subsequently, the synthetic blend of EE10,12-16:Ald, EE10,12-16:OH and E10-16:Ald in a 100:5:5 ratio was shown to be effective in traps in Benin. Isomeric purity of the conjugated diene compounds tested, EE10,12-16:Ald and EE10,12-16:OH, was greater than 99%. No significant differences in catches using polyethylene vials or rubber septa or between lures containing 0.01 and 0.1 mg of pheromone were found, but 0.1 mg polyethylene vials were adopted due to their greater expected longevity under field. They were changed every two weeks and were shielded from the degradative effects of sunlight by means of aluminium foil wrapped around them. An initial comparison of trap designs showed that one, constructed from a plastic plate and bowl and using water as the trapping agent, caught as many moths as a commercial funnel- or 'Uni-trap' (relying on fumigant insecticide to kill insects) and more than a sticky card based 'delta trap'. However, the water-trap proved difficult to make and was not robust under field conditions. In Benin, preliminary evidence was gathered suggesting that catches of *M. vitrata* moths in pheromone traps might be used to predict subsequent larval infestations. A significant and highly unusual finding was that 5 – 50% of total catches with synthetic lures were of female moths (the exact figure varying between different experiments), and this feature might increase the reliability of the traps in predicting infestations.

The principal partners in this project were NRI and IITA at Cotonou, Benin and Kano, Nigeria together with research, extension and NGO organisations within Benin, Ghana and Nigeria working with IITA in the "PRONAF" (*Projet de Niébé pour l'Afrique*) project. PRONAF (formerly PEDUNE) was established in the late 1990s, by IITA and its partner organisations in nine W. African countries. This was as a result of concern about the negative developmental impact of cowpea crop losses and accompanying risks of poisoning and environmental disturbance due to indiscriminate pesticide use in cowpea and associated crops. PRONAF aims to enable the transfer and implementation of research on cowpea to subsistence farmers in West Africa through the medium of farmer field schools (FFS). PRONAF has a technical objective of reducing the use of toxic pesticides in cowpea through promotion of IPM and a development objective of contributing to food security and poverty reduction within the region. Some of the technologies most commonly adopted through PRONAF FFS have been cowpea varieties resistant to some important pests, use of botanical insecticides, innovative storage practices and pest scouting. Demand for the work described here was expressed primarily by IITA for the reasons articulated in previous paragraphs. It was envisaged that the use of pheromone traps for predicting *M. vitrata* infestations would form another such technology that could be linked to the use of botanical insecticides for control of the pest.

The Swiss Development Corporation and the International Fund for Agricultural Development jointly funded the phase of PRONAF coinciding with the work described in this report.

## PROJECT PURPOSE

The Project Purpose is to develop and promote IPM for cereal-based systems (including cowpea). This Purpose will be achieved by completing optimisation of the design and operation of pheromone traps for *Maruca vitrata* and by integrating their use as monitoring devices with other novel IPM technologies to provide improved methods for control by small-holder cowpea farmers in West Africa. The project also aims to provide a better understanding of the population dynamics, ecology and behaviour of *M. vitrata*, based on long-term monitoring with pheromone traps; this will aid the further development of sustainable control methods.

## RESEARCH ACTIVITIES

### General Issues

Initially, the planned project activities were confined to Benin and Ghana but, following discussions at the World Cowpea Research Conference in September 2000, a proposal was made to the CPP for an 'Add-on' to extend the project to the northern region of Nigeria. Aspects of this work are considered under Outputs 1 and 2.

Approval of a second add-on in November 2002 enabled expansion of the testing of pheromone trap-based thresholds for determining spray timings, both on-station and on-farm in Benin. This work is covered under Output 3.

Statistical analysis of experimental results, where appropriate, was carried out using Genstat 6 for Windows.

## Output 1: Pheromone traps for *M. vitrata* fully optimised

Following on from the previous project the need remained to identify a robust and effective trap design that could be produced cheaply from locally available materials. Various aspects of the lures also needed to be refined. In addition, a pre-requisite for the long-term sustainability of trap use was the existence of at least one commercial supplier of the optimised lures. These aspects of trap and lure optimisation formed Output 1 of the current project.

Trap and lure optimisation experiments in Benin

Experiments were carried out within cowpea fields (local variety Kpodjiguèguè) at the IITA research station near Cotonou, Republic of Benin (6° 25.1’ N, 2° 19.7’ E, 21 m altitude, bimodal rainfall pattern, with a long rainy season from April to July, and a short one from mid-September to November). Fields of cowpea were grown specifically for the trapping experiments. Individual experiments were set out in fields 20 – 30 days after sowing, *i.e.* before flowering, and were continued until after harvesting – a period of 2 to 3 months. Crops were rain-fed and no pesticides were sprayed in the fields.

Traps were suspended from wooden sticks using wire; unless otherwise noted this was at a height of approximately 1.0 – 1.2 m. Lures were normally replaced every two weeks and, unless otherwise indicated, were shielded from sunlight to minimize isomerization by means of aluminium foil. Trap catches were counted daily. Each experiment consisted of between four and six treatments and was carried out to a randomised complete-block design with 5-fold replication. Randomisation was achieved using random number tables. Traps within a replicate block were set out in lines or rectangular formations. Within blocks individual traps were positioned 20 m apart. Blocks were at least 50 m apart, and were usually situated in separate fields.

Following a comparison of rubber septa and polyethylene vial dispensers, lures used in all experiments were of the polyethylene vial type. Unless noted otherwise all contained 0.1 mg of EE10,12-16:Ald, EE10,12-16:OH and E10-16:Ald in a 100:5:5 ratio, plus an equal amount of BHT antioxidant. They were produced NRI as described by Downham et al. (2003a). The EE10,12-16:Ald and EE10,12-16:OH were of >99% isomeric purity, unless otherwise noted, and the E10-16:Ald was of >99% stereochemical purity.

Results were analysed using the “*One- or Two-way ANOVA (in randomised blocks)*” procedure (as appropriate) within Genstat, in terms of the total catches by each trap, appropriately transformed to meet normality and constant variance assumptions (the procedure allowed inspection of various residuals plots). Where analysis of variance indicated statistically significant effects, treatment means were separated using the least significant difference (LSD) at the 5% level. Where not specified, results quoted for the following experiments are for males but trends were generally similar in respect of females. Over all the experiments the proportion of females caught varied from 11 – 50% of the total.

Trap optimisation experiments included a trap height comparison carried out using commercial green, plastic funnel traps (Agrisense-BCS, Pontypridd, UK) positioned such that the trap openings were 20, 70, 120 and 170 cm above ground. DDVP insecticide strips within the funnel traps killed trapped moths in order to facilitate counting. In addition, white sticky, delta traps (Agrisense-BCS, Pontypridd, UK) were compared with three hand-made water-trap designs. These included one made from a 1.5-litre clear plastic bottle (formerly used as a container for mineral water) with two windows cut on opposite sides. The two other water-traps were made from 2-litre white and 5-litre white, plastic jerry-cans (formerly used as vegetable oil containers) of rectangular cross-section (see Figs 1a – d). In each case four windows, one on each side, were cut in the trap. In the delta trap, sticky card inserts served to trap moths. Water, with a little soap powder added to reduce surface tension and improve moth retention, acted as the trapping agent in the remaining other designs.

Four lure optimisation experiments were carried out. In the first, six treatments, *i.e.* the combinations of shielded and unshielded lures with the age ranges 0 – 2, 2 – 4 and 4 – 6 weeks were compared in delta traps. In a second experiment unshielded lures in the age ranges 0 – 1, 1 – 2, 2 – 3 and 3 – 4 weeks were compared in 5-l jerry-can traps. Four levels of isomeric purity of the two diene compounds, EE10,12-16:Ald and EE10,12-16:OH, in lures *i.e.* 73%, 80%, 91% and >99%, were also compared in funnel traps. The respective purity levels reflected those typically achieved after zero, one, two and three serial recrystallizations from the equilibrium mixture of *E,E : Z,E : E,Z : Z,Z* isomers during manufacture of the compounds. The combined effects on catches of lure age and pheromone purity, in unshielded lures, were further investigated in 5-l jerry-can traps. Three types of lure (all unshielded), two produced at NRI of >99% and 80% isomeric purity and a third, commercially produced type[a] (International Pheromone Systems, Ellesmere Port, L65 4EH, UK) of 95% purity were tested. Each was compared in two age ranges, 0 – 2 and 2 – 4 weeks old.

[a] In these lures the initial quantity of pheromone was 0.46 mg and the component ratio (EE10,12-16:Ald; EE10,12-16:OH; E10-16:Ald) was 100:11:6. The figure of 0.46 mg was an inadvertent over-dosing. IPS lures in 2002 contained very close to the intended figure of 0.1 mg of pheromone, and the blend ratio was 100:5:5.

Figure 1a. 1.5 litre bottle trap.

Figure 1b. Two litre jerry-can trap.


Figure 1c. Five litre jerry-can trap showing moths trapped in water and aluminium foil shielding surrounding the pheromone lure.


Figure 1d. Five litre jerry-can trap being installed in a cowpea field.

Pheromone blend experiment in Nigeria

Initial on-station and on-farm observations in Nigeria, in 2001, revealed unexpectedly low trap catches, relative to larval infestations (see Output 2). A possible explanation was thought to be a subtly different optimum pheromone blend to that found to be attractive in Benin. Accordingly an experiment to test blends varying in the relative proportions of the minor components and isomeric purity of the diene components, as well as virgin female *M. vitrata*, was undertaken from July – October 2002 at Abuja under the direction of Dr T. Adati of IITA-Kano (Table 1).

**Table 1.** Lures evaluated in blend experiment at Abuja, Nigeria, July – October 2002 (all lures 0.1 mg dose; 5-l jerry-can traps).

| Treatment/Blend Ratio* | Isomeric purity of major component | Origin of lures |
|---|---|---|
| 100:5:5 (Benin 'standard') | 99% | NRI |
| 100:5:0 | " | " |
| 100:0:5 | " | " |
| 100:0:0 | " | " |
| 100:5:0.5 | " | " |
| 100:0.5:5 | " | " |
| 100:0.5:0.5 | " | " |
| 100:5:5 | 85% | IPS |
| 2 virgin females/trap | - | - |
| blank controls | - | - |

* *i.e.* of EE10,12-16:Ald: EE10,12-16:OH: E10-16:Ald

Identification of potential supplier or manufacturer of pheromone lures

*Supply of ready-made lures*

In September 1999 seven companies (two from the USA, four from the UK and one from the Netherlands) were asked to provide quotations for the supply of pheromone lures for *M. vitrata*. Specifications were for lures of the polyethylene vial dispenser type (captive lid) and contain 100 ug EE10,12-16:Ald, 5 ug EE10,12-16:OH and 5 ug E10-16:Ald, in addition to an equal amount BHT antioxidant. Since no experiments had yet been carried out concerning isomeric purity of the diene components, 99% purity was stipulated. For all of the companies, the blend was a non-standard specification and the lures would have had to be produced to order.

*Supply of pheromone components and local production of lures*

In early 2001 the alternative possibility of buying the raw materials for the pheromone lures and producing them, as an interim measure, at IITA was considered. Two companies, Merlin Synthesis of Wye, UK and Onyx Scientific of Sunderland, UK, were approached to synthesise and supply the pheromone compounds. Detailed discussions followed with Onyx Scientific. Due to the relative instability in long-term storage of the major component, E10,12-16:Ald, Onyx Scientific were asked to quote for the supply of a much larger amount of the more stable EE10,12-16:OH with the intention that this would be the form in which the pheromone would be stored. The final step of conversion to the aldehyde could be made, as an interim measure, at NRI as and when required.

*Investigation of registration issues*

Although not an explicit objective of the project, CPP management asked the project leader to to enquire about the registration requirements for the use of pheromone traps for *M. vitrata* in West Africa.

## Output 2: Trap-catch data interpreted in relation to pest biology and distribution

Successful completion of Output 1 allowed season-long monitoring of *M. vitrata* over a large scale to begin. However, it was also necessary to establish the nature of the relationship, if any, between local catches of adults in traps and larval infestations in cowpea fields. These aspects of the project formed Output 2.

The relationship between trap-catches and infestations of *M. vitrata* in cowpea fields

Based on the results of, and experience gained from, the trapping experiments under Output 1 the 5-l jerry-can trap was adopted as the standard for subsequent work described under Outputs 2 and 3.

*On-farm monitoring studies during 2000 and 2001 in Benin*

Observations to determine the relationship between trap-catches and larval infestations were begun during 2000 at four main sites across Benin: in Mono department (SW Benin), around the towns of Bohicon and Savè in Zou department (central Benin) and near Gogounou, Borgou department (N Benin). Two seasons' observations were possible at Savè, thus there were five data-sets in all. At each site 3 – 4 farmers' fields were selected near each of three villages (56 fields in total), on the basis of previous contact with the PEDUNE/PRONAF project. Fields were 600 $m^2$ in area; they were separated from other fields and were not sprayed with insecticides during the course of the observations, to enable natural population trends to be followed. Two traps per field were checked three times each week by PRONAF technicians in the presence of the farmer. Fresh sets of 20 flowers and 20 pods were sampled twice weekly for the presence of eggs and larvae of *M. vitrata* and, independently, counts of the total numbers of flowers and pods on 10 plants were made, allowing subsequent estimation of infestations on a per plant basis. In each case selection of individual plants for sampling was pseudo-random, with approximately equal distributions of plants across the respective fields.

The quantitative relationship between trap-catches and larval infestation levels was explored using the '*Simple Linear Regression with groups*' procedure of Genstat 6 in which data-sets from the different principal experimental sites formed groups. This was necessary in order to account for quite wide variations in infestation levels between the main sites. Analyses were carried out in respect of cumulative catches seven, 14 and 21 days after the first catch was observed, and of total catches for the season, in the respective fields.

By reference to the analysis of variance for the regressions, and to the value of 't' attached to the parameter estimates it was possible to determine the overall effect of 'site' on infestation levels and whether individual intercept values for each site's data-set departed significantly from zero. Similarly, it was possible to determine whether the slopes of the individual regressions (the relation with trap catches) differed from each other and whether they departed significantly from zero.

Further on-farm studies were undertaken during the first season of 2001 at Savè by Mr D.G. Rurema as part of his M.Sc. thesis studies, while registered at the Université Nationale du Bénin. In this case sampling frequency was greater than in 2000 and all fields were sown simultaneously. Five farmers' fields were selected in the vicinity of Savè, being a locally-representative sample of fields in terms of general characteristics such as surrounding vegetation. Two traps were placed inside each field, and two outside, 50 m from field edges. Trap catches were recorded daily and inspections for larvae were carried out in the fields every two days.

*Monitoring study in Ghana in 2001*

An experiment was set up in July 2001 on the Savannah Agriculture Research Institute (SARI) farm outside Tamale, Northern Region in four cowpea fields. Planting in each field was staged over two periods of 14 – 16 and 28 – 30 July. Four jerry-can traps were set inside each field and two 50 m outside at opposite sides of the field. All were monitored on a daily basis; inspections for larvae were carried out twice weekly.

*Monitoring study in Nigeria in 2001*

A further study was set up at the IITA farm at Minjibir, outside Kano, northern Nigeria in mid-July 2001 under the direction of Dr T. Adati of IITA-Kano. Thirty-eight jerry-can traps were set out on 25 July in fields forming part of separate, but related, population monitoring studies. Twelve traps were placed in one field in plots planted with several different cowpea varieties. No insecticide sprays were made in this field. Twenty-six traps were set out in a second field in plots of a single variety planted as a mono-crop, sprayed (2 times, beginning at flowering) and not sprayed, and as an unsprayed inter-crop with sorghum[b]. Two of the traps were un-baited controls. All traps were checked three times each week and sampling for larvae from flower buds, flowers and pods (minimum of 20 racemes) was carried out 2 – 3 times each week. Organs were randomly selected for sampling using random number tables.

*PRONAF farmer field school activities in 2001*

Since the 2001 season was seen as an introductory phase, trap catch data were not used directly to determine the timing of insecticide applications. The aim was to allow farmers to see for themselves the potential predictive value of the traps through their integration with other activities. Farmers monitored the traps, at the weekly FFS meetings, when they made inspections of the crop for pests, and on two other occasions. Control actions were undertaken in the plots according to the farmers' collective assessment of the pest situation. Traps were included in 18 farmer field schools (FFS).

[b] Intercropping with sorghum or millet is a common practice in northern Nigeria.

In Benin in 2001 FFS activities took place in eight villages: four in Mono dept. and four in Zou dept. There were two sets of similar activities in each village into which trapping was incorporated. One was a comparison of typical farmer practice with an 'IPM' approach, in $100m^2$ plots (2 plots of each treatment per village). The former consisted of 4 – 6 applications of the organophosphate insecticide 'Orthene' (acephate) applied on a calendar basis and the latter of 2 – 3 applications of neem leaf extracts plus 2 – 3 applications of acephate, applied at half recommended rate, on the basis of weekly inspections for cowpea pests. The second set of comparisons, in $20m^2$ plots, was of acephate and botanical insecticides (neem, papaya or African mint[c] leaf extracts) (each six applications) with a no spray control (1 – 2 plots of each treatment per village). Five litre jerry-can traps were placed in one of the IPM plots (farmer practice *vs.* IPM trials) and in the control plot of the botanical/insecticide comparison in each village, and checked three times each week.

The jerry-can traps were also integrated into the FFSs in northern Ghana in 2001. One school, a 'Training -of-Trainers' (ToT) was established by SARI personnel at Yendi, around 60 km SW of Tamale. Farmers trained in the ToT then led FFSs at five nearby villages in Yendi District. In each case traps were checked three times each week, beginning in early September. In Yendi, legume bud thrips, *Megalurothrips sjostedti*, are normally an early-season pest and it was agreed at the outset that monocrotophos, would be applied against them.

Farmer field schools in Nigeria were organised by the Institute of Agricultural Research, Zaria. Four of the FFSs in Kano state were selected for trapping activities. Each took the form of a comparison of an 'IPM' plot with a 'farmer practice' plot. One trap in each plot was checked three times each week, beginning in early September. Five randomly selected plants per plot were inspected for larvae at the weekly FFS meeting. Dates of sowing at the four villages varied from 9 July to 24 August. All IPM plots were treated with one spray of a conventional insecticide and 3 – 4 of neem leaf extract; the farmer practice plots were either untreated or received 1 – 2 sprays of a conventional insecticide.

Regional monitoring of *M. vitrata* with pheromone and light traps

This work was carried out in response to calls by previous workers for ecological studies to enable the successful implementation of strategies involving manipulation of cowpea planting dates and the use of short-season varieties or companion crops to reduce *M. vitrata* damage (see R7441 PMF). Pheromone traps could be deployed more cheaply and easily and in greater numbers than light traps, and would be specific for the pest species.

*Trapping in Benin*

Large-scale monitoring of *M. vitrata* (at farm and non-farm sites) commenced in Benin in 2001. Traps were set up at nine sites on two N – S transects on the eastern and western sides of the country. At each site five traps were placed along an E – W axis with one trap, at the end of the line, in a cowpea field and the others at 500 m intervals into non-cultivated (wooded savannah) areas. The traps were checked three times each week from March – December. In 2002 the same sites were monitored in Benin from May – December. This time five *pairs* of traps were deployed at 500 m intervals at each site. Traps within a pair were 20 m apart.

[c] *Hyptis suaveolens* (Lamiaceae)

The data generated were supplemented by those collected on a daily basis from light traps at Bohicon (7º 10N, 2º 05E) and Kandi (11º 10N, 2º 55E), in the central south and north of the county, respectively. These had been set-up in July – August 2000. In addition daily catch data were available from a light-trap and sticky, delta pheromone traps that had been maintained at IITA, Cotonou (6º 25N, 2º 20E) since 1998. In this case, there were 20 pheromone traps positioned at 150 m intervals around the perimeter of the IITA station. All three light traps were of the same design and employed 500 W mercury vapour bulbs.

*Trapping in Nigeria/Niger*

Six pheromone trap sites were maintained, with five pairs of traps per site, in northern Nigeria and southern Niger from May – December 2002. These sites were (from north to south) at Abuja, Kaduna, Zaria, Kadawa, Minjibir (the site of the IITA-Kano farm) and Zinder (Niger). They formed a line along a SSW - NNE axis, from 9º 00 - 13º 45 N and 7º 10 - 9º 00 E. Additionally light traps were maintained at Abuja, Kaduna, Minjibir and Zinder.

**Output 3: Traps for *M. vitrata* used in development of IPM strategies for control of cowpea pests**

Output 3 made use of the findings of Output 2 to develop and test trap-based thresholds that could be used by farmers as the basis for interventions to control *M. vitrata*. In addition, a socio-economic survey was conducted on farmers' perceptions and knowledge of cowpea pests, including *M. vitrata*, together with current control methods. This was done in order to establish a baseline against which to judge the future impact of traps and of botanically-derived pesticides. Following introduction of traps in some locations, further evaluations of their acceptability to farmers and potential for uptake were made. Economic cost-benefit analyses of the potential for trap use were also carried out.

<u>Evaluation of farmers' perceptions of pests, current control methods and potential for pheromone trap use</u>

*November 2000 survey*

The first of two surveys focussed on farmers' perceptions of cowpea pests and how they deal with these. It involved 190 farm households within the departments of Mono, Zou and Borgou in Benin. These corresponded to the Guinea Savanna (high rainfall) (GSH), Guinea Savanna (low rainfall) (GSL) and Sudan-Savanna (SS) agro-ecological zones, respectively. Four villages in Mono and three in each of the other departments were involved. Twenty heads of farm households per village were interviewed, except for one village in Mono where only 10 could be interviewed due to time constraints. All villages had previously held farmer field schools under the auspices of PRONAF, but a variable number of interviewees had participated. A preliminary survey provided information on gender, socio-economic and FFS participation status and based on these classifications within each village a stratified random sample of farmers was identified for the formal survey, which was carried out through interviews using a structured questionnaire. In order to determine whether farmers' responses regarding the importance of pests and their use of control methods differed between the three agro-ecological zones or between the sexes, $\chi^2$ tests of independence were carried out. To explore the effects of independent variables including agro-ecological and socio-economic characteristics on farmers' awareness of *M. vitrata* larvae, moths and the link between the two and of the adoption of certain pest control practices a multivariate logit (econometric) model was used[d].

*January – February 2002 survey*

The second survey concentrated on farmers' attitudes towards pheromone traps. It was conducted using a similar methodology to that of the earlier survey. In Benin a total of 118 farmers from six villages (three in Mono and three in Zou departments) were surveyed and in Ghana 145 farmers from five villages from Yendi district were included. All villages had previous experience of *M. vitrata* pheromone traps. Villages in Nigeria were not included in the survey due to the previous lack of success in trapping *M. vitrata* there.

<u>Traps used to test action thresholds in trials of novel IPM approaches</u>

Three trials, two on-station and one on-farm, were carried out with the objectives of testing trap-based action thresholds in conjunction with botanical insecticides. The second on-station trial and the on-farm trial formed the subject of the second project 'add-on' granted in November 2002.

*On-station trials*

Both trials took place at the IITA Cotonou station; the first from May – August 2002 and the second from October – December 2002. Each used a split-plot design, with nine treatments each replicated four times (Fig. 2). The trials each took place in 1.3 ha (100 × 130 m) cowpea fields planted with the local variety Kpodjiguèguè, and fifteen traps were positioned within each field.

For both experiments the trap-based thresholds were defined as the date on which the mean cumulative catches, across all traps, reached pre-determined figures. The first experiment compared treatments in which spraying of neem leaf extracts commenced three and six days, respectively, after the attainment of thresholds of two or five moths per trap (*i.e.* four treatments). In addition, applications of the synthetic insecticide 'Decis' (deltamethrin) were begun 6 days after the attainment of each threshold, forming a further two treatments.

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[d] Under the logit model (Maddala, 1983; Bagi, 1983) co-efficients for the explanatory variables are estimated using the maximum likelihood method. The probability of a farmer's awareness or identification of *M. vitrata* depends on his or her socio-economic attributes and agro-ecological factors, and is defined as:

Y=*f*(**X**,e), where *e* is an error with a logistic distribution. The conceptual model is given as:

$$P(Y_i = 1) = \frac{e^{X_i \beta_i}}{1 + e^{X_i \beta}}$$

Where $Y_i$ is the dependent variable that takes on the value of 1 for the *i*th farmer awareness, P is the probability of awareness of a given farmer, $\beta_i$ = vector of parameters to be estimated on the $i^{th}$ farmer, $X_i$ are explanatory variables related to the awareness of *M. vitrata* of the $i^{th}$ farmer.

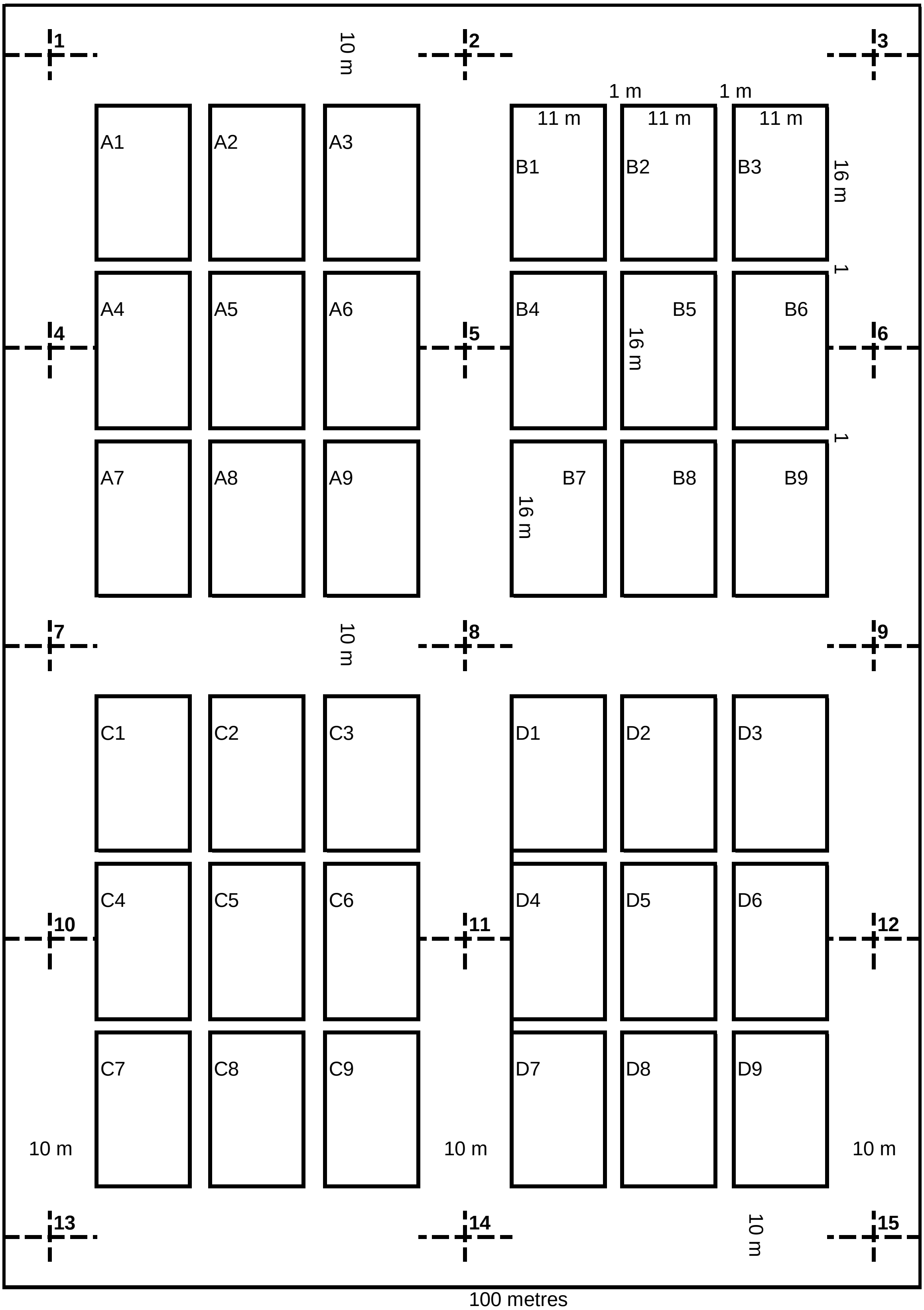



**Figure 2.** Experimental layout used in the two on-station trials of pheromone trap action thresholds. Trap positions are indicated by the dashed crosses in bold, numbered 1 – 15 (5 m from field edges in most cases). Treatments were randomly assigned to sub-plots 1 – 9 within each replicate block A – D (assignments varied between blocks).

Another two treatments consisted of neem leaf extract and 'Decis' sprays commenced as soon as 25% of cowpea plants had one or more flowers, while there was also an unsprayed control. In each of the treatments including neem extracts there was a total of four sprays at 5-day intervals. All treatments involving 'Decis' had two sprays; the second spray of the insecticide was made as soon as 25% of plants had one or more green pods.

No control measures were targeted against pests other than *M. vitrata* during the first trial, but, recognising the problems posed by flower thrips, *M. sjostedti*, treatments in the second trial included a variety of measures specifically to control this pest. These were the fungal entomopathogen *Metarhizium* (two formulations), papaya leaf extracts and an earlier application of 'Decis', made at flower-bud initiation. At the same time the trial tested *Hyptis suavoleons* (African mint) leaf extracts that trials through PRONAF have indicated are of greater effectiveness than neem against *M. vitrata*. Applications of these commenced three days after attainment of a 2-moth/trap threshold or at 25% flowering, and in each case were in conjunction with applications of *Metarhizium* or papaya leaf extracts to control flower thrips. Full details of the treatments are set out in Table 2.

**Table 2.** Details of the control measures against flower thrips and *M. vitrata* in each of the treatments (numbered 1 to 9) of the second on-station trial of pheromone trap thresholds.

| | Thrips control | Trap threshold | *Maruca* control |
|---|---|---|---|
| 1 | Spray 1 time with *Metarhizium* (oil formulation) at flower bud initiation. | 2 moths/trap | Spray *Hyptis* leaf extract 3 days after threshold is reached, then every 5 days for a total of 4 times |
| 2 | Spray 1 time with *Metarhizium* (oil formulation) at flower bud initiation. | - | Spray *Hyptis* leaf extract at 25% flowering, then every 5 days for a total of 4 times |
| 3 | Spray 1 time with papaya leaf extracts at flower bud initiation. | 2 moths/trap | Spray *Hyptis* leaf extract 3 days after threshold is reached, then every 5 days for a total of 4 times |
| 4 | Spray 1 time with papaya leaf extracts at flower bud initiation. | - | Spray *Hyptis* leaf extract at 25% flowering, then every 5 days for a total of 4 times |
| 5 | Spray 5 times with *Metarhizium* (oil formulation), beginning at flower bud initiation, then at 5 day intervals | - | - |
| 6 | Spray 5 times with *Metarhizium* (aqueous formulation), beginning at flower bud initiation, then at 5 day intervals | - | - |
| 7 | Spray 5 times with papaya leaf extracts, beginning at flower bud initiation, then at 5 day intervals | - | - |
| 8 | Spray "Decis" 3 times - at flower bud initiation, 25% flowering and at 25% podding | | |
| 9 | Untreated control – no sprays | | |

During both trials 'Decis' (a recommended insecticide for control of *M. vitrata*) was applied at the standard rate whilst neem and *Hyptis* leaf extracts were made and applied using the standard methods and rates developed by PRONAF. Temporary barriers were erected between neighbouring plots during spraying in order to prevent spray-drift.

Trap monitoring was undertaken on a daily basis commencing three weeks after sowing, and continuing until plots were harvested. The design used was the 5 litre jerry-can trap (bidon) described elsewhere with the standard 3-component, 0.1 mg vial lures replaced every 2 weeks.

Insect sampling was carried out as follows. Twice each week beginning on the sample date following the respective first appearances of flowers and pods in the fields, 20 of each type of organ were sampled from within each sub-plot. Four pods were taken from randomly selected plants within each of five 1 $m^2$ quadrats, one towards each corner and one at the centre of each sub-plot. The flowers were placed directly into 50% alcohol before dissection a few days later. Pods were dissected the same or the next day. All insects found inside the flowers or pods were counted and identified. In cases when scheduled days for sampling and treatment spraying coincided, insect sampling was done first. Yield data from each sub-plot were calculated from five 1 $m^2$ sub-samples.

Yield and infestation data were analysed using the "*One-way ANOVA (in randomised blocks)*" procedure within Genstat. The infestation data used were cumulative, i.e. figures from successive sample dates, for the number of insects per 20 flowers or pods, were summed across the whole trial. In some cases these were transformed to meet normality and constant variance assumptions (the procedure allowed inspection of various residuals plots). In each case the least significant difference (LSD) at the 5% level was calculated.

*On-farm trial*

This trial took place during the second season of 2002 (Aug – Nov). Six farmers' fields were selected in each of five villages participating in PRONAF FFSs. Two of the villages, Dani and Atchakpa, were situated close to Savè in Zou Départment whilst the other three, Gbècotchihoué, Davihoué and Assouhoué, were in Mono Départment. Half of each field was designated a "traps and botanicals" and other half formed a "farmer-practice plot"; each plot was 20 × 20 m in area. One pheromone trap was placed within each pheromone/IPM plot. All fields within each village were sown within one week of each other and were situated within an area 500 × 500 m.

The traps and botanicals treatment was essentially similar to treatment 3 of the second on-station trial (*i.e.* spraying to commence three days after cumulative trap catches reached two moths per trap). However, in the three villages in Mono neem, rather than *Hyptis* extracts were applied against *M. vitrata* due to the non-availability of *Hyptis* at those locations. At the outset it was intended that determination of the threshold date would be based on catches in all six traps within a village. However, in three of the villages, this was varied (see respective section under Outputs).

Control decisions in the farmer practice plots were left to the farmers to decide, but always consisted of 3 – 4 sprays of a range of non-recommended organophosphorus and organochlorine insecticides (mostly acephate, dimethoate, chlorpyrifos and endosulfan).

Pheromone traps were checked three times each week, by PRONAF technicians, but days were chosen such that one coincided with the weekly FFS sessions. Similarly, crop inspections for *M. vitrata* larvae and other pests were carried out in all plots by technicians two times each week with one sample date per week coinciding with the FFS. Twenty flowers and 20 pods were sampled from plot. The total yield per plot was recorded at the appropriate time. Yield and infestation data were analysed using the same methodology as for the on-station trials of the trap-threshold.

Economic analysis of benefits of pheromone technology

A provisional cost-benefit analysis of the use of traps to determine spray dates was carried out in early 2002 using data gathered in Benin during the Jan – Feb 2002 survey of farmers' views concerning traps, mentioned above. This included on-farm yield data from the second season of 2001 in Benin, and known costs (including opportunity costs of labour) of botanical and recommended insecticides and the components of the traps and lures. Data were taken from 56 farmers at PRONAF sites in Mono, Zou and Borgou departments who had had previous experience of *M. vitrata* pheromone traps.

Subsequently, using information and conclusions drawn from this analysis, together with relevant yield data, the respective economic returns were calculated for the 'traps and botanicals' and 'farmer practice' treatments of the on-farm trial conducted in the second season of 2002 (see above).

**Output 4: Project findings demonstrated and disseminated**

Workshop and on-farm demonstration of trap use and IPM technologies

The planned on-farm demonstration of trap use and IPM technologies was considered to be covered by the farmer field school and other on-farm activities described under Outputs 2 and 3.

The planned project workshop was combined with the annual PRONAF planning and evaluation workshop held at IITA, Cotonou in April 2002. This also incorporated related presentations of cowpea research funded by the Bean-Cowpea CRSP project (USAID), which works with IITA and other cowpea researchers in the region. This combination served to maximise the audience at minimum cost, and to best set the work in the context of the rest of the PRONAF project.

Other dissemination

Conference presentations, publications and training are detailed in the Outputs section of this report.

## OUTPUTS

### Output 1: Pheromone traps for *M. vitrata* fully optimised

Trap and lure optimisation experiments in Benin

*Trap optimisation experiments*

Results of a trap height comparison showed that more moths were captured at 120 cm than at 20, 70 or 170 cm. This superiority was statistically significant in respect of 20 and 170 cm, but not 70 cm. In the comparison of trap designs, catches in the 5-l and 2-l jerry-can traps were superior to those by the sticky, delta and the 1.5-l bottle designs (Table 3).

**Table 3.** Mean catches trap$^{-1}$ in different trap designs.

| Trap design | Males | | Females | |
|---|---|---|---|---|
| | Mean | SE | Mean | SE |
| Delta | 4.0 b | 0.8 | 1.4 c | 0.5 |
| 1.5-l bottle | 5.0 b | 1.1 | 2.8 bc | 0.6 |
| 2-l jerry | 10.8 a | 2.0 | 6.0 ab | 1.7 |
| 5-l jerry | 13.0 a | 1.8 | 7.4 a | 1.3 |

Means within a column followed by a common letter were not significantly different (P > 0.05, LSD following ANOVA).

*Lure optimisation experiments.*

In the combined comparison of lure age and shielding (Table 4) 4 – 6 week old lures were significantly less attractive than 0 – 2 and 2 – 4 week old lures, but there was no difference in catches for lures of the two lower age ranges. Shielding did not influence male captures but did affect captures of females. In the second experiment, involving unshielded lures in the age ranges 0 – 1, 1 – 2, 2 – 3 and 3 – 4 weeks lure age had no effect on captures ($P \geq 0.26$, F-ratio, ANOVA).

**Table 4.** Mean catches trap$^{-1}$ in delta traps with lures of different age ranges, shielded or unshielded (6 treatments).

| Lure | Males | | Females | |
|---|---|---|---|---|
| Characteristic | Mean | SE | Mean | SE |
| 0-2 weeks old | 11.9 a | 1.0 | 2.7 a | 0.5 |
| 2-4 weeks old | 10.6 a | 1.1 | 1.2 b | 0.4 |
| 4-6 weeks old | 6.3 b | 0.9 | 0.9 b | 0.3 |
| | | | | |
| Shielded | 9.4 a | 1.0 | 2.2 a | 0.4 |
| Unshielded | 9.8 a | 1.0 | 1.0 b | 0.2 |

Means within a column followed by a common letter were not significantly different (P > 0.05, LSD following ANOVA); means for different age ranges averaged across both shielding classes and *vice versa*.

In the comparison of four levels of isomeric purity of the diene compounds, no effect of purity level was observed upon trap catches ($P \geq 0.39$, F-ratio, ANOVA). In the combined comparison of the effects lure age and pheromone purity, in unshielded lures, results confirmed the earlier findings for these factors individually (Table 5). Neither lure type nor age affected catches, and all six treatments caught very similar numbers of moths.

**Table 5.** Mean catches trap$^{-1}$ in 5-l jerry-can traps with NRI lures of low and high isomeric purity[1] (80% and >99% of the (E,E)-isomer, respectively), and of IPS lures[1] (95% (E,E)-isomer) each of two age ranges (6 treatments).

| Lure | Males | | Females | |
|---|---|---|---|---|
| Characteristic | Mean | SE | Mean | SE |
| 0-2 weeks old | 21.5 | 1.2 | 6.5 | 0.5 |
| 2-4 weeks old | 21.5 | 0.7 | 6.9 | 0.6 |
| | | | | |
| IPS | 21.4 | 1.3 | 6.5 | 0.6 |
| NRI 80% purity | 21.0 | 1.4 | 7.0 | 0.8 |
| NRI >99% purity | 22.1 | 1.1 | 6.7 | 0.7 |

[1]NRI and IPS lures contained 0.1 mg and 0.4 mg, respectively, of the major component, (E,E)-10,12-16:Ald. None of the means within a column were significantly different (P > 0.05, F-ratio, ANOVA); means for different age ranges averaged across lure type and *vice versa*.

Pheromone blend experiment in Nigeria

Traps baited with lures containing blends varying in the relative proportions of the minor components and isomeric purity of the diene components, as well as virgin female *M. vitrata*, were monitored daily from July – October 2002 at Abuja. Unfortunately, up to mid-October no catches took place in any treatment.

Identification of potential supplier or manufacturer of pheromone lures

*Supply of ready-made lures*

Of the seven companies requested to provide quotations for the supply of pheromone lures for *M. vitrata*, three definite responses were received which are summarised in Table 6.

**Table 6.** Responses to the request for quotations to supply *M. vitrata* pheromone lures.

| Company | Address | Response |
|---|---|---|
| Agrisense BCS | Pontypridd, UK | £0.60 - 65 per lure (excl. VAT) on basis of 5000 lures/month (8 month contract), but NRI required to provide minor blend components. |
| International Pheromone Systems | South Wirral, UK | £0.50 per lure, min. order 1000 lures (excl. VAT) |
| Pherobank* | Wageningen, Netherlands | Euro. 1.45 for 1000/month or Euro. 0.98 for 5000/month over 8 month season (excl. VAT) |

*Associated with Dutch Research Institute for Plant Protection

On the basis of the responses, International Pheromone Systems (IPS) was provisionally selected to provide lures for larger-scale, on-farm and season-long monitoring. However, testing of the effect of isomeric purity did not take place until June – August 2000. Following the finding that 99% purity was not necessary, the request to IPS was amended so that the purity level should be approximately 90%. This prompted a reduction in price to the figure of £0.40 per lure, provided at least 1000 lures were ordered.

*Supply of pheromone components and local production of lures*

Details of the quotation from Onyx Scientific, to synthesise and supply the pheromone compounds are given in Table 7.

**Table 7**. Details of a quotation from Onyx Scientific dated 23 February 2001 to supply compounds forming the components of *M. vitrata* pheromone.

| Compound (amount) | Isomeric Purity | Price (excl. VAT) |
|---|---|---|
| EE10,12-16:Ald (1 g) plus EE10,12-16:OH (10 g) | 70 – 80% | £7,500 |
| EE10,12-16:Ald (2 g) plus EE10,12-16:OH (20 g) | 70 – 80% | £9,200 |
| EE10,12-16:Ald (1 g) plus EE10,12-16:OH (10 g) | 99% | £12,000 |
| EE10,12-16:Ald (2 g) plus EE10,12-16:OH (20 g) | 99% | £14,500 |
| E10-16:Ald (1 g) | - | £7,300 |
| E10-16:Ald (2 g) | - | £8,750 |

The figures showed that considerable economies of scale are available: doubling the amount of material ordered would result in a price increase of only 20 – 23%. Furthermore, the 99% isomerically pure diene compounds would be charged at 58 – 60% more than the same amount of 70 – 80% pure compounds. Purchase of the larger amount (20 g) of EE10,12-16:OH, once converted to EE10,12-16:Ald, would be enough to produce 200,000 lures. Based on this and assuming all costs are spread over the production of the first 200,000 lures, the resultant costs per lure could be roughly estimated as in Table 8. As is clear from Table 6 the price per lure would increase if smaller amounts of the pheromone components were purchased.

*Investigation of registration issues*

In April 2002 an opportunity to find out more about the registration requirements for pheromone traps occurred at a workshop on the commercialisation of biopesticides hosted at IITA, attended by relevant parties from Benin and Ghana.

Discussions with representatives from the Institut National des Recherches Agricoles du Bénin (INRAB) indicated that no formal requirements exist in Benin. Similarly, according to a Ghanaian Environmental Protection Agency (EPA) representative there are currently no regulations governing registration of pheromone products in Ghana. Registration protocol is designed around conventional pesticides, rather than pheromone traps. However, to obtain a provisional permit to trap *M. vitrata* for monitoring purposes technical information about the lures was provided in a letter to the EPA in Accra[e]. A further form (designed for synthetic pesticide products) was completed on the understanding that full permission for trap-use could then be given. This was delivered it to the EPA on 5 September and a permit was issued for experimental work to take place during the 2002 season.

**Table 8**. Elements of the estimated cost of pheromone lures if produced at IITA using pheromone compounds purchased from Onyx Scientific.

| Item | Cost per lure (£) |
|---|---|
| Purchase of pheromone compounds sufficient for 200,000 lures – as per table 5. | 0.09 – 0.12 |
| Labour costs for the conversion from EE10,12-16:OH to EE10,12-16:Ald – assume £2000 of NRI staff time | 0.01 |
| Non-recurrent equipment costs (mainly weighing balance) for lure production at IITA, £2000 | 0.01 |
| Cost of polyethylene vials (£300 for 5000) | 0.06 |
| Visit of NRI staff member to train local staff in lure production methods – assume £2000 | 0.01 |
| Costs of consumables for lure production (sealable bags, solvent, BHT, pipette tips), local staff time for dosing of lures | 0.04 |
| **Total** | **0.22 – 0.25** |

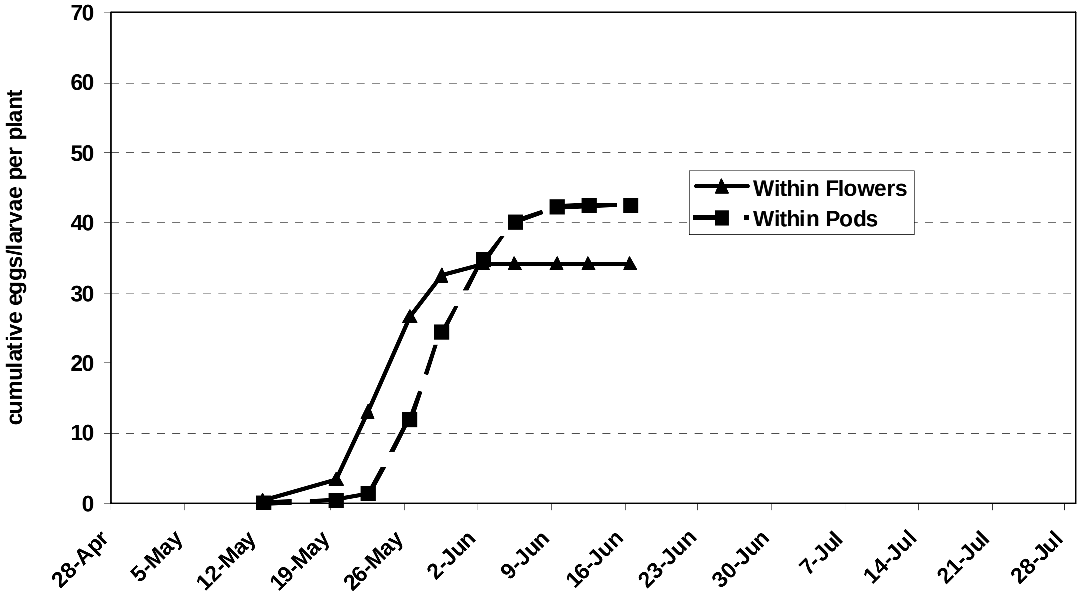
**Output 2: Trap-catch data interpreted in relation to pest biology and distribution**

The relationship between trap-catches and infestations of *M. vitrata* in cowpea fields

*On-farm monitoring studies during 2000 and 2001 in Benin*

Illustrative results are given in Fig. 3 for six early-planted fields from the first season at Savè. These show the first, low infestations occurring 7 days after the initial trap-catches, with somewhat higher infestations observed from 14 days. Over all the fields at this site the mean period between first catches and first infestations was 11 days. This pattern of larval infestations occurring a few days after initial catches in traps was broadly typical of the other sites. Initial catches preceded infestations in 41 of the 56 fields over the five data-sets; in nine fields (all at Gogounou and during the second season at Savè) the reverse was the case, while in the remainder of fields both events were observed on the same date. Table 9 summarises the data.

[e] By comparison, in the UK there are currently no regulations or registration requirements covering the use of insect pheromones for monitoring purposes, although there are EU directives on their use for control purposes which parallel those on conventional pesticides.



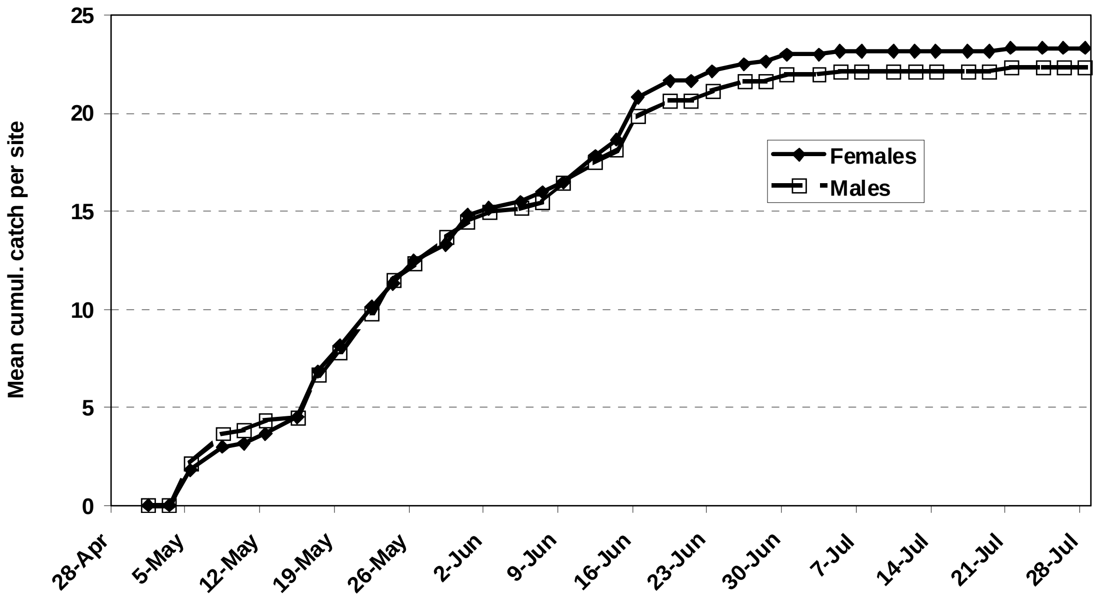




**Figure 3**. Illustrative pooled results of cumulative trap-catches (top) and cumulative infestations of eggs and larvae in flowers and pods (bottom), for six early-planted on-farm sites, first season Savè, 2000.

**Table 9.** Mean dates of first trap captures, first flowering and first larval infestations in flowers, with intervals between them, during on-farm monitoring in Benin, 2000 (standard errors of the means, in days, are given in parentheses).

| Site | Fields | | | First appearance of | | | Periods (days) | |
|---|---|---|---|---|---|---|---|---|
| | Total | 1st catch *before* infestation | 1st catch *after* infestation | trap catches | Flowers | Infestation in flowers | 1st catch to 1st infestation | 1st flower to 1st infestation |
| Mono | 12 | 11 | 0 | 27-Sep (1.2) | 4-Oct (1.9) | 7-Oct (1.3) | 9.6 (1.3) | 2.9 (0.9) |
| Bohicon | 12 | 12 | 0 | 25-Jun (2.7) | 5-Jul (2.0) | 7-Jul (2.3) | 12.5 (2.5) | 1.8 (0.6) |
| Savè (1) | 10 | 9 | 0 | 10-May (2.4) | 18-May (2.9) | 21-May (3.3) | 11.1 (3.1) | 3.4 (2.1) |
| Savè (2) | 10 | 4 | 5 | 5-Oct (2.4) | 1-Oct (2.8) | 4-Oct (2.8) | -0.9 (3.2) | 3.2 (1.4) |
| Gogounou | 12 | 5 | 6 | 9-Sep (2.5) | 10-Sep (1.4) | 11-Sep (1.1) | 1.8 (2.8) | 0.9 (0.5) |

One finding to emerge was that a possible alternative predictive measure, that of the appearance of flowers in the crop[f], tended to give a much shorter warning period of infestations than initial trap captures. This is particularly clear from the data for Mono, Bohicon and Savè (first season) which indicate that infestations commenced only 2 – 3 days after flowering, compared to 9 – 12 days after trap-catches (Table 9).

As regards a quantitative relationship between trap captures and infestations, there was a tendency for both higher catches and higher infestations (expressed as numbers of larvae per plant) at Gogounou and Savè compared to Bohicon and Mono. Linear regressions of log-transformed infestations in flowers on cumulative catches showed, in all cases, that the effect of site was highly significant and the values of the respective intercepts differed from each other (and from zero), reflecting the varying infestation levels observed at each site. Taking into account the effect of 'site' resulted in the percentage of variance accounted for by the model rising to 80 – 85% (from 10 – 20% not including this factor). However, none of the slopes of the regression lines differed significantly from zero (or from each other) irrespective of whether total catches or those after seven, 14 or 21 days were considered (see Table 10 for regression statistics for seven days).

Results of the regression for pod infestations were similar but not identical. The effect of 'site' was always highly significant, and intercept values for each site differed from each other and all were significantly different from zero. Regression models including 'site' as a factor accounted for 80 – 85% of total variance, compared to 10 – 35%, without the factor. An important result, however, was that while slopes of the regression lines for most of the sites did not differ significantly from zero that for Mono was significant over all time periods (see Table 10 for regression statistics for seven days).

**Table 10.** Statistics for the linear regressions with groups of $\log_{10}$-transformed maximum cumulative flower and pod infestations on cumulative catches 7 days after initial captures; on-farm monitoring in Benin, 2000; results for individual monitoring sites (groups).

| Data-set | Intercept | | Slope | |
|---|---|---|---|---|
| | Estimate (SE) | P (t, 46 d.f.)* | Estimate (SE) | P (t, 46 d.f.)* |
| *Flowers* | | | | |
| Mono | 0.69 (0.09) | <0.001 | -0.01 (0.02) | 0.753 |
| Borgou | 2.08 (0.09) | <0.001 | 0.00 (0.01) | 0.591 |
| Savè-1 | 1.47 (0.16) | <0.001 | 0.00 (0.02) | 0.870 |
| Bohicon | 1.17 (0.12) | <0.001 | -0.03 (0.03) | 0.302 |
| Savè-2 | 1.28 (0.25) | <0.001 | 0.00 (0.05) | 0.964 |
| *Pods* | | | | |
| Mono | 0.62 (0.10) | <0.001 | 0.06 (0.02) | 0.006 |
| Borgou | 2.29 (0.10) | <0.001 | 0.00 (0.01) | 0.937 |
| Savè-1 | 1.80 (0.17) | <0.001 | -0.02 (0.02) | 0.171 |
| Bohicon | 1.32 (0.12) | <0.001 | -0.03 (0.03) | 0.360 |
| Savè-2 | 1.37 (0.26) | <0.001 | 0.05 (0.05) | 0.254 |

* Indicates significance/non-significance of departure of estimate value from zero.

The practical implication of these findings are that no useful, quantitative relationship appears to exist between trap catches and infestations in flowers. Generally the same is true

[f] In W. Africa recommendations are normally for spraying to commence when 25 – 50% of cowpea plants are flowering.

for pod infestations, except in Mono department. At this site the slope was significant and positive for all periods over which catch was accumulated. Generally Mono had the lowest pod infestations of all sites. The fact that higher infestations always occurred at the other sites irrespective of adult populations may imply ecological or environmental checks to population growth in the Mono, that are not present at other sites. For the sites other than Mono the indication is that pheromone traps can only signal the timing of the onset of infestations and not their quantity.

The regression results for Mono indicated relationships between pod infestations and catches of the form:

$\text{Log}_{10}$ cumulative infestation = 0.619 + 0.059 (7-day cum. catch)

and,

$\text{Log}_{10}$ cumulative infestation = 0.554 + 0.014 (total catch).

Thus, for example, an economic threshold of 10 infested pods per plant would equate to a cumulative trap catch of 6.3 moths per two traps after seven days, or a total catch over the season of 31.9 moths per two traps. It may be possible to explore the usefulness of these relationships in the next project phase.

Results for the first season of 2001 at Savè (thesis study of Mr D-G. Rurema) broadly confirmed those of the previous year. Initial captures in traps occurred quite uniformly from 31 – 35 days after planting (mean 32.2 DAP). Infestations in flowers were first noted at 39 – 47 DAP (mean 41.4), an average of 9.2 days after initial trap captures. Infestations in pods were first noted between 49 and 55 DAP (mean 51.0), an average of 18.8 days after the start of trap-catches. Temporal trends in catches were very similar for traps within and outside cowpea fields. Thus the precise location of traps does not seem to affect their predictive capability.

*Monitoring study in Ghana in 2001*

Heavy infestations of legume bud thrips, *Megalurothrips sjostedti*, at the SARI farm caused high rates of flower drop during August and occasioned two insecticide sprays, of 'Dursban' (chlorpyrifos) and 'Karate' (cypermethrin) on 8 and 29 August, respectively. The first *M. vitrata* moths were recorded shortly after on 5 September. Subsequent catches were low, totalling 9 – 12 per field over the season, possibly as a result. Larval infestations were negligible.

*Monitoring study in Nigeria in 2001*

Throughout the trapping period a total of 16 males and 2 female *M. vitrata* were caught in the pheromone-baited traps, plus 1 male in an un-baited trap. These captures occurred between 19 August and 24 September. Of the eight pheromone-baited traps within insecticide sprayed plots four caught a total of five moths, while 12 of the 28 traps in unsprayed plots caught 13 moths. Thus the proportion of traps that caught moths did not differ between insecticide sprayed and non-sprayed fields ($\chi^2 = 0.13$, $P = 0.72$, $2 \times 2$ test of independence). Dates of oviposition were estimated, based on the instar of sampled larvae and thermal constants for development. These indicated that oviposition in the plots began around 10 August, before the first trap catches.

*PRONAF farmer field school activities in 2001*

In the Ghanaian FFS it had been foreseen that sprays of monocrotophos would be required for legume bud thrips, *Megalurothrips sjostedti*. Although this is a relatively thrip-selective insecticide, these sprays may partly explain the low trap catches of *M. vitrata* recorded at all six sites (maximum of eight moths during the season in each FFS). In Nigeria, both trap-catches and larval infestations were entirely absent at two FFS sites. At a third, 44 moths were caught in less than a month (which can be considered a relatively high catch level), but sampled larvae were negligible. At a fourth site only 4 moths were trapped in total while infestations peaked at > 2 larvae/plant. Monitoring commenced late at three sites, and finished early at the fourth, which may help to explain these results.

In the Benin FFS, initial trap-catches preceded infestations in only two villages, and were observed on the same day as infestations in three others. The relatively poor prediction of infestations by the traps can be at least partly explained by noting that traps were installed late (40 – 45 DAP), when flowers were already present. Additionally, catch rates were generally low (i.e. < 15 moths per trap, over the reduced period of trapping) in five of the eight villages.

Results of the 'farmer practice' *vs.* 'IPM' and acephate/botanical/no-spray comparisons were not strictly amenable to statistical analysis as no common treatments existed. Between villages the number and type of insecticide/botanical applications and other aspects of the experimental design varied. However, some interesting yield data were produced. These are given in Table 11.

**Table 11.** Cowpea yield data for 'farmer practice' *vs.* 'IPM' and acephate/botanical/no-spray comparisons in FFS, Benin 2001.

| Comparison | Mean yield (± SE) in respective treatments (Kg $ha^{-1}$) | | |
|---|---|---|---|
| | *Farmer Practice – Acephate* | *IPM – Neem + reduced Acephate* | |
| 'Farmer Practice' *vs.* 'IPM' (100 $m^2$ plots) | 1160 (± 170) | 1210 (± 140) | |
| | *Acephate* | *Neem/Papaya/Hyptis* | *No-spray* |
| Acephate/botanical/no-spray (20 $m^2$ plots) | 1440 (± 190) | 950 (± 170) | 470 (± 50) |

The data for the larger plots indicated that 2 – 3 applications each of neem leaf extracts and half-rate acephate are sufficient to achieve good yields of cowpea, and gave equivalent control to that provided by 4 – 6 full-rate applications of acephate.

Data for the smaller plots suggest botanical extracts on their own may not be sufficient to achieve full control of pests and provide yields equivalent to regimens involving multiple applications of acephate. Nevertheless yields in the botanical plots were double those of untreated controls.

<u>Regional monitoring of *M. vitrata* with pheromone and light traps</u>

*Trapping in Benin*

Significant catches in the pheromone traps were concentrated at IITA, Dassa, Savè and Bantè in the centre and south of Benin, and at Malanville in the far north. Few *M. vitrata* were trapped at the other northerly sites (Tables 12a and 12b). On a day-to-day basis, the catches at IITA, Dassa, Savè and Bantè were low to moderate, but distributed through most of the observed period. At Malanville in 2001 catches were confined to the August – October period and were concentrated in September (Fig. 4). In 2002 they mostly occurred during June – July and September. As Figure 4 illustrates, traps within cowpea fields generally only caught moths during the respective cowpea-growing seasons, but catches in traps in the bush areas were spread over a longer period, probably reflecting the flowering period of local leguminous wild-host trees such as *Lonchocarpus* spp. and *Pterocarpus* spp. The reasons for the observed site-to-site variation in overall catch levels are not clear but if a similar phenomenon were to hold elsewhere it could help to explain the low catches observed in Nigeria, and to some extent in Ghana.

A north-south dichotomy was also discernible in the light-trap data (Tables 13a and 13b). In the north at Kandi in both years, successively higher peaks of catches were observed from July – October (see Fig. 5), presumably corresponding to successive generations, whereas at IITA and Bohicon light trap catches were much lower and distributed through a larger part of the year. Comparison of Figs. 4 and 5 suggests that those individuals trapped in the pheromone traps at Malanville corresponded with the third and fourth peaks of the light trap catches a little to the south in Kandi. Since the smaller first and second, and the much larger final peak were not reflected in the pheromone traps (in cowpea or bush), the further indication is that these populations were transient and did not remain in the area to mate.

In West Africa Bottenberg *et al*. (1997) noted that *M. vitrata* persists year round south of 9º N because alternative hosts are more-or-less continuously available, but are only present further north during the wet season. Their light trap data indicated that *M. vitrata* only make short, low-altitude flights and are not long-distance migrants. They advanced the hypothesis that *M. vitrata* populations move from south to north over several generations following the northward progression of rainfall, cowpea planting and alternative host flowering. The different seasonal trends in light and pheromone trap monitoring data between IITA, Dassa, Savè and Bantè in the south and Malanville and Kandi in the north are consistent with this hypothesis.

As Tables 12a – 13b show, females predominated in the light trap catches whereas, as expected, males formed the larger part of the pheromone trap catches. Inter-site variation was observed in the sex ratios for pheromone and light trap catches, but the pattern of this variation was consistent between years. For the light trap data, although the ratio of males to females ranged from 0.5 – 0.9, the values for each site were very similar in 2001 and 2002. For the pheromone trap data the ratios were generally higher in 2002 than in 2001, but the respective trends among sites were similar. The reasons for these patterns are not clear, but it may be speculated that they linked to some aspect of population movement.

**Table 12a.** Summary of pheromone trap data for migration monitoring sites, Benin, 2001.

| Parameter | IITA* 6º 25N, 2º 20E | Dassa 7º 45N, 2º 10E | Savè 8º 00N, 2º 30E | Ina 10º 00N, 2º 40E | Gogounou 10º 50N, 2º 50E | Malanville 11º 50N, 3º 20E | Bantè 8º 25 N, 1º 55E | Bassila 9º 00N, 1º 40E | Djougou 9º 40N, 1º 40E | Natitingou 10º 20N, 1º 20E |
|---|---|---|---|---|---|---|---|---|---|---|
| Trapping days | 269 | 274 | 270 | 268 | 267 | 264 | 264 | 264 | 265 | 265 |
| Main catch period(s) | Jun-Aug, Oct-Nov | Jun-Jul, Oct-Dec | Apr-Dec | Oct | Oct-Nov | Peaks early & late Sept | May-Aug, Oct | May, July | July | - |
| Males caught | 231 | 108 | 453 | 6 | 14 | 558 | 680 | 12 | 3 | 0 |
| Females caught | 38 | 93 | 274 | 1 | 7 | 259 | 112 | 8 | 9 | 0 |
| M/F catch ratio | 6.08 | 1.16 | 1.65 | 6.00 | 2.00 | 2.15 | 6.07 | 1.50 | 0.33 | - |

* At this site 20 sticky, delta traps were employed in contrast to 5 jerry-can traps at all other sites.

**Table 12b.** Summary of pheromone trap data for migration monitoring sites, Benin, 2002.

| Parameter | IITA* 6º 25N, 2º 20E | Dassa 7º 45N, 2º 10E | Savè 8º 00N, 2º 30E | Ina 10º 00N, 2º 40E | Gogounou 10º 50N, 2º 50E | Malanville 11º 50N, 3º 20E | Bantè 8º 25 N, 1º 55E | Bassila 9º 00N, 1º 40E | Djougou 9º 40N, 1º 40E | Natitingou 10º 20N, 1º 20E |
|---|---|---|---|---|---|---|---|---|---|---|
| Trapping days | - | 175 | 176 | 181 | 178 | 178 | 177 | 176 | 177 | 177 |
| Main catch period(s) | - | May-Jul | May-Sept | Jun-Jul, Sept | Jul-Aug, Sept | Jun-Jul, Aug, Sept-Oct | May-Jul, Sept-Oct | May, July | Jun-Jul | Jul, Sept |
| Males caught | - | 116 | 234 | 45 | 88 | 251 | 1818 | 33 | 18 | 21 |
| Females caught | - | 121 | 87 | 7 | 16 | 81 | 125 | 10 | 31 | 8 |
| M/F catch ratio | - | 0.96 | 2.69 | 6.43 | 5.50 | 3.10 | 14.54 | 3.30 | 0.58 | 2.63 |

* At IITA the perimeter trapping with delta traps was discontinued for budgetary reasons after December 2001. NB. 10 jerry-can traps were used at all other sites in 2002.

**Table 13a.** Summary of light trap data at three monitoring sites, Benin, 2001.

| Parameter | | IITA* 6º 25N, 2º 20E | Bohicon 7º 10N, 2º 05E | Kandi 11º 10N, 2º 55E |
|---|---|---|---|---|
| Trapping days | All | 320 | 365 | 340 |
| | Catch M | 98 | 40 | 82 |
| | Catch F | 94 | 46 | 86 |
| Main catch period(s) | | May-Aug, Oct-Nov | June-Aug, Oct-Nov | 4 peaks Jul - Oct |
| Males caught | | 305 | 79 | 857 |
| Females caught | | 348 | 102 | 1771 |
| M/F catch ratio | | 0.88 | 0.77 | 0.48 |

* No data for IITA in December, out of order for 9 nights in Feb. and 5 nights in July. **Out of order 11 April – 4 May.

**Table 13b.** Summary of light trap data at three monitoring sites, Benin, 2002.

| Parameter | | IITA* 6º 25N, 2º 20E | Bohicon** 7º 10N, 2º 05E | Kandi** 11º 10N, 2º 55E |
|---|---|---|---|---|
| Trapping days | All | 321 | 171 | 171 |
| | Catch M | 101 | 51 | 95 |
| | Catch F | 94 | 49 | 106 |
| Main catch period(s) | | June, Oct, Nov, Dec | June, July | 3 peaks Jul – Sept, larger in Oct |
| Males caught | | 1082 | 107 | 7204 |
| Females caught | | 1188 | 140 | 14422 |
| M/F catch ratio | | 0.91 | 0.76 | 0.50 |

* The trap at IITA was run throughout the year, but was out of order from 19 July – 31 August. ** Traps at Bohicon and Kandi were run only from early May to 31 October.

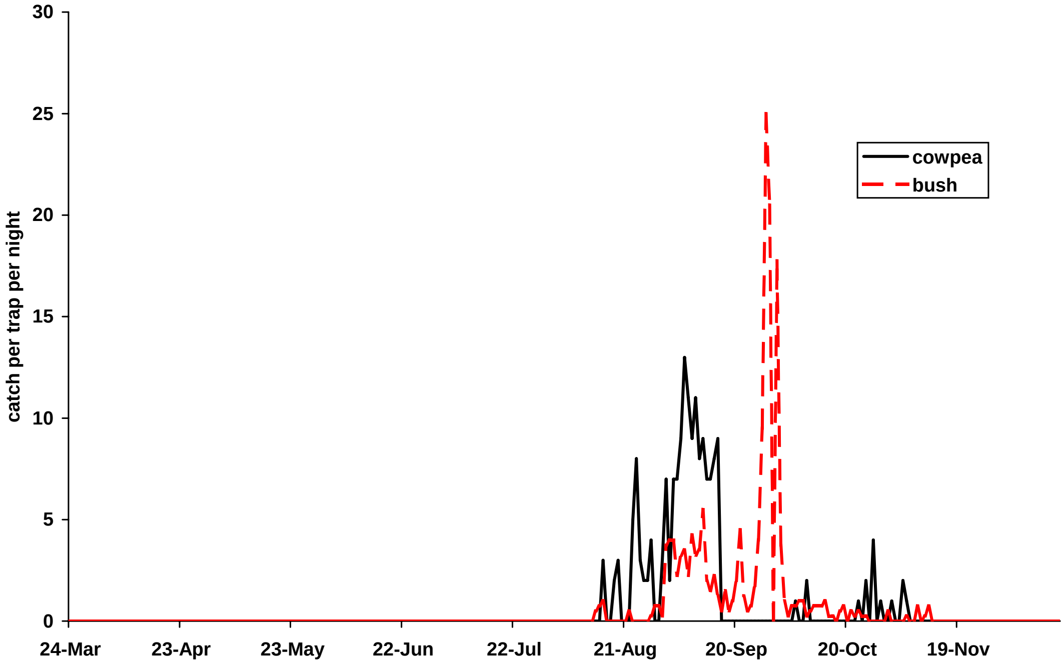



**Figure 4**. Captures in pheromone traps at the migration monitoring site at Malanville during 2001; data for single trap in cowpea field compared with the mean of four traps in the bush (captures of both sexes combined in both cases).

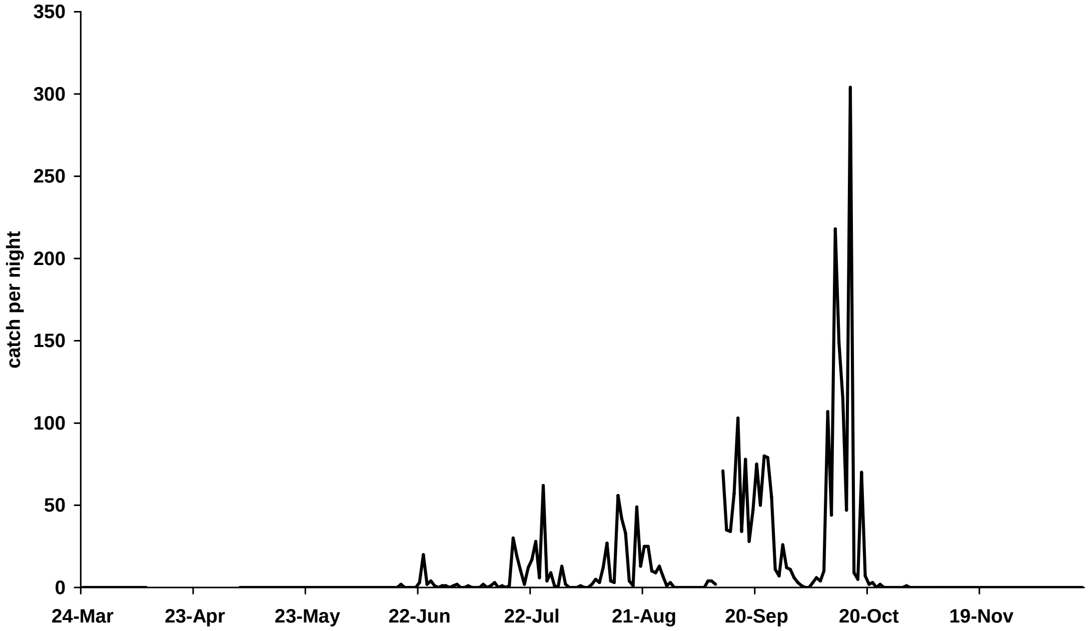



**Figure 5.** Captures in the light trap at Kandi during 2001 (captures of both sexes combined).

*Trapping in Nigeria/Niger*

By the end of the cowpea season, in mid-October, in 2002 less than 10 moths per site were caught in pheromone traps at Minjibir, Kadawa and Zaria. Zero catches were recorded in Abuja, Kaduna or Zinder (Niger). In late-August, mid- and late-September light trap peak catches at Minjibir reached 144, 238 and 598 moths per night, respectively. To the south, the light trap in Abuja recorded consistent, but much lower (< 10 per night), numbers in July - August, but by 10 October had reached 100 per night. The intermediate site at Kaduna, and that at Zinder in Niger, recorded very much lower catches overall (Table 14).

**Table 14.** Summary of light trap data at four monitoring sites, Nigeria and southern Niger, 2002.

| Parameter | Abuja | Kaduna | Minjibir | Zinder |
|---|---|---|---|---|
| Catching days | 133 | 65 | 99 | 15 |
| Males caught | 2373 | 359 | 2510 | 49 |
| Females caught | 1382 | 522 | 3664 | 61 |
| M/F catch ratio | 1.72 | 0.69 | 0.69 | 0.80 |

Analysis by Dr Adati of IITA, Kano of the mated status of females caught by the light traps has shown that in Minjibir 64% of females were mated at the beginning of the trapping period (late August), but subsequently the ratio was gradually decreased to 0 – 2% by the end of November. A similar trend was observed at Abuja, although the highest rate of mating was only around 25%. In Zinder and Kaduna, the mated ratio was very low 15% or below, throughout the trapping period. Although no definite conclusions can be reached on the basis of these limited data the seasonal trends in mated status of females must be a reflection of migration linked with the reproductive behaviour of the insects.

## Output 3: Traps for *M. vitrata* used in development of IPM strategies for control of cowpea pests

Evaluation of farmers' perceptions of pests, current control methods and potential for pheromone trap use

*November 2000 survey*

The results of this survey have been written up in full as a paper for submission to Crop Protection (publication 7). A summary is given below.

When farmers in Benin was asked to list major pest groups, seven were considered as causing significant yield losses. *M. vitrata* was noted by the largest percentage of farmers overall (85%), followed by aphids (*Aphis craccivora*) (79%), then by foliage beetles (*Ootheca mutabilis*) (58%). Thrips, *Megalurothrips sjostedti* (12%), blister beetles, *Mylabris* spp. (Coleoptera: Meloidae) (12%), *Piezotrachelus varius* (Wagner) (Coleoptera: Curculionidae) (21%) and pod bugs, *Clavigralla tomentiscollis* (34%) were only considered serious pests by farmers in one or two zones. In terms of relative importance, *M. vitrata* was generally cited among the top three most significant pests, but the distribution of responses differed between agro-ecological zones and *A. craccivora* was cited slightly more often as being the most important.

These results extend and parallel those of Kossou *et al.* (2001) who surveyed farmers in the Ouémé valley and plateau regions of Benin. They reported that a similar range of cowpea insect pests headed by *A. craccivora* then *M. vitrata* as the most serious. An interesting result was the lack of importance attached to *M. sjostedti* (thrips) by farmers in our study despite the extremely damaging nature of this pest species. The most likely explanation for this is a lack of awareness of the pest, due to its cryptic nature – individuals are tiny and found only within the flowers. Thrips were not mentioned either by farmers in the study by Kossou *et al*. (2001), possibly for the same reason, although the category of 'flower insects' was rated highly as pests in half of the villages surveyed.

Farmers' perceptions of the economic importance of yield losses due to *M. vitrata* are indicated in Table 15. The distribution of responses across zones was significantly different but overall a very high proportion of farmers considered losses to *M. vitrata* as 'Important' or 'Very Important'.

**Table 15.** Farmers' perceptions of the economic importance of *M. vitrata* by agro-ecological zone (%).

| Rating | Zone | | |
|---|---|---|---|
| | GSH | GSL | SS |
| Not important | 1 | 0 | 0 |
| Important | 81 | 2 | 10 |
| Very important | 17 | 98 | 90 |

The distribution of responses differed significantly between zones; $\chi^2$ = 117.5; 4 degrees of freedom; P<0.001

Most farmers (85 – 92%, depending on zone) reported commencing spraying to control insect pests three or four weeks after sowing. This is too early to control *M. vitrata*, since our monitoring studies (this report) indicate that larvae do not appear until at least 5 – 6 weeks after sowing. Instead the early insecticide applications are intended to combat *A. craccivora* infestations which appear earlier in the cropping cycle. In fact, casual remarks by a few (~ 5%) farmers in the GSH zone reported that they spray their crops very early as a preventive measure.

A little over half of farmers reported using synthetic insecticides recommended for cotton and botanical insecticides, respectively, whilst less than a quarter use synthetic insecticides recommended for cowpea. The logit analysis showed that variables significantly influencing farmers' adoption of botanical insecticides for control of *M. vitrata* were gender (women were more likely to use them than men), contact with extension services, agro-ecological zone (uptake was less in the SS zone) and access to roads and cowpea markets. The statistical association of uptake of botanicals and access to markets was negative. This probably relates to the fact that farmers receive no market premium for botanically-grown cowpea, despite the recognised health benefits. Farmers reported that application of botanicals is quite labour intensive. They therefore tend to apply them only to a limited portion of their crop and reserve that for domestic consumption (this was also found by a separate, year-long study of cowpea farmers in Mono dept[g]). Use of recommended insecticides, which are relatively expensive, was only significantly related (positively) with access to credit.

[g] A. Nag (2001). Farmers, beans and agrochemicals; creativity and performance in Beninese farmers where pest management is integrated in complex survival strategies. M.Sc. thesis, University of Copenhagen.

A large majority of farmers in the GSH (99%) and GSL (83%) zones, but only 22% in the SS zone were able to recognize *M. vitrata* larvae. The respective figures for recognition of the adult were 11%, 55% and 22%, while those for knowledge of the link between adults and larvae were 6%, 75% and 12%. Variables affecting ability to recognise the larval and adult stages of *M. vitrata*, and awareness of the link between them included age, contact with extension services, experience in cowpea cropping, and zone.

*January – February 2002 survey*

The most significant findings to emerge from this survey were that more than 90% of farmers in Benin believe that the traps can signal the arrival of *M. vitrata* in cowpea fields and that this information should allow them to target their insecticide spraying activities better. In Ghana only 63% of farmers believed the traps were capable of trapping *M. vitrata* – possibly reflecting the low catches in the Ghanaian FFS in 2001 (Output 2). However, 85% and 61% of farmers in Benin and Ghana, respectively, indicated that it would be difficult for them to find or purchase trap materials such as the plastic jerry-can, wire or soap-powder and this would act as a constraint to future uptake of trap technology.

<u>Traps used to test action thresholds in trials of novel IPM approaches</u>

*First on-station trial*

Treatment 1, to commence spraying neem leaf extracts three days after catches reached 2 moths/trap, was significantly better ($P < 0.05$, LSD) than the untreated control and other treatments involving neem (treatments 2, 4 and 5) in nearly all comparisons of yield and infestations of *M. vitrata* in pods (Table 17). However it did not produce significantly better results than neem extracts applied on the basis of crop stage (treatment 7), possibly because in this instance the respective scheduled spray dates occurred only one day apart (see table).

Treatments involving Decis (3, 6 and 8) performed considerably better in all respects than all the neem treatments, as well as the control ($P < 0.05$, LSD). Furthermore, the Decis treatment made on the basis of the 2 moths per trap threshold (treatment 3) had a statistically higher yield than Decis applied according to crop stage (treatment 8). In this case there was a 4-day difference in the indicated date of first spray.

On the basis of these results the following tentative conclusions were reached:

- A trap-threshold approach could be superior to spraying based on crop stage;
- A 2-moth per trap threshold gives better results than a 5-moth threshold;
- A 3-day delay gives better results than a 6-day delay.

Besides the yield and infestation data, the relative inferiority of a 5-moth/6-day threshold was further demonstrated by the fact treatment 6 dictated a ‘first’ spray on 8 July, whereas the intended second spray, at 25% podding, actually occurred before this – on 6 July (see Table 16). A repetition of at least part of the trial would be advisable to confirm the above conclusions for the following reasons. Additionally, both sets of threshold-based Decis applications were made six days after the threshold was reached, and there was no corresponding treatment involving a 3-day delay, as there were with the neem treatments. It would be useful to remedy this omission.

Moderately high cumulative thrips infestations were noted in flowers – 800 adults per 20 flowers in controls – and these were not controlled by neem extracts. The thrips infestations probably adversely affected yields and could have obscured some treatment differences.

**Table 16.** Summary results from the first on-station test of the trap threshold.

| No. | Threshold | Spray regimen (following attainment of threshold) | Actual spray dates | Mean yield (kg plot$^{-1}$)(±SE) | Mean total cumulative *M. vitrata* infestations per 20 pods (±SE) | Mean total cumulative adult thrips infestations per 20 flowers (±SE) |
|---|---|---|---|---|---|---|
| 1 | 2 moths trap$^{-1}$ | Neem, after 3 days, 4 sprays @ 5 day intervals | 30-Jun, 5-Jul, 10-Jul, 15-Jul | 375 (57) | 15.0 (1.6) | 650 (50) |
| 2 | | Neem, after 6 days, 4 sprays @ 5 day intervals | 3-Jul, 8-Jul, 13-Jul, 18-Jul | 239 (45) | 23.8 (4.3) | 738 (41) |
| 3 | | Decis, after 6 days & 25% pods | 3-Jul, 6-Jul | 602 (57) | 2.8 (1.2) | 252 (20) |
| 4 | 5 moths trap$^{-1}$ | Neem, after 3 days, 4 sprays @ 5 day intervals | 5-Jul, 10-Jul, 15-Jul, 20-Jul | 142 (34) | 18.8 (1.4) | 877 (28) |
| 5 | | Neem, after 6 days, 4 sprays @ 5 day intervals | 8-Jul, 13-Jul, 18-Jul, 23-Jul | 216 (34) | 26.8 (3.6) | 729 (40) |
| 6 | | Decis, after 6 days & 25% pods | 6-Jul, 8-Jul | 557 (97) | 11.0 (1.2) | 330 (15) |
| 7 | Crop stage | Neem @ 25% flowers, 4 sprays @ 5 day intervals | 29-Jun, 4-Jul, 9-Jul, 14-Jul | 278 (40) | 16.3 (3.4) | 738 (60) |
| 8 | | Decis @ 25% flowers & 25% pods | 29-Jun, 6-Jul | 449 (63) | 6.5 (1.0) | 456 (49) |
| 9 | - | Untreated control | - | 210 (34) | 42.8 (6.9) | 807 (66) |
| | | LSD (5%) | | 131 | 8.7 | 123 |

* LSDs calculated following ANOVA of respective data sets.

*Second on-station trial*

Analysis of the results of the second on-station trial (Table 17) indicate that the botanical and *Metarhizium* treatments were all intermediate, in terms of infestations of *M. vitrata*, between untreated controls and the 'Decis' insecticide check ($P < 0.05$, LSD). However, extremely high cumulative infestations of flower thrips were observed (> 3000 adults per 20 flowers in controls) and none of the *Hyptis*, papaya or *Metarhizium* treatments had any noticeable impact on these. This runs counter to previous results (Tamò pers. comm.) suggesting that papaya and *Metarhizium* formulations could be effective in controlling thrips. In contrast, the comparable figure for the Decis treatment (825 thrips per 20 flowers) represented a significant reduction. The high thrips infestations probably explain the low yields in the *Hyptis*, papaya and *Metarhizium* treatments, and why none differed significantly from the no-spray control.

Previous trials conducted at IITA (Tamò pers. comm.) have indicated promise for *Hyptis* leaf extracts in the control of *M. vitrata* and the present trial results are consistent with this insofar as *M. vitrata* infestations in the respective treatments were significantly lower than in the controls.

In this trial the dates indicated for first spraying to control *M. vitrata* were two days later for trap-threshold treatments than the comparable treatments based on spraying at 25% flowering.

*On-farm trial*

Execution of this trial highlighted a few unforeseen practical issues. Among these was the relative timing of sprays against thrips and *M. vitrata* and the effect on these of varying sowing dates. Sowing dates among the six 'traps and botanicals' treatment (T&B) fields in each village varied by 7 – 10 days (Table 18). This meant that the appearance of flower-buds, the trigger for the papaya extract spraying against thrips, varied similarly. In consequence, in four villages, these sprays were not made in all fields simultaneously, but in two groups of three fields each. In three of these villages PRONAF technicians then took the decision to regard the two groups as separate for the purposes of calculating the trap threshold dates for commencing sprays against *M. vitrata*. This was despite the original plan that the trap threshold-based date for commencing spraying would be calculated using all six traps. This would have weakened the reliability of spraying dates determined on the basis of the reduced number of traps.

It was originally anticipated that sprays against thrips would take place before those against *M. vitrata*. However, as defined, the respective thresholds sometimes resulted in sprays against thrips taking place in the middle of the sequence of sprays against *M. vitrata*. In these instances one spray was probably effectively wasted; in future it may be wiser to omit one of the sequence of sprays.

On this occasion, thrips infestations were low or very low at all sites (Table 19) and there was no overall significant difference in their levels between the T&B and FP treatments ($P > 0.05$, LSD). In contrast, compared to that observed in the two on-station trials, *M. vitrata* pest pressure was relatively high at most sites. Except at Assouhoué, infestation rates in both treatments were broadly similar to those seen in the untreated controls of the on-station experiments. Infestations were consistently higher in the T&B treatment and this effect was statistically significant ($P < 0.05$, LSD) (Table 19). However, it was noticeable that the magnitude of this difference was less than between broadly comparable treatments in the on-station trials (cf. Tables 16 and 17). There was considerable variability in yields across sites, but those in the FP treatment were consistently about 25% higher, an effect that was statistically significant ($P < 0.05$, LSD).

It was clear from these results that the T&B treatment, as used in the trial, is inferior to conventional farmer practice in terms of yield and control of *M. vitrata* infestations. However, it should be remembered that the T&B treatment was only experimental and that the farmer practice treatment consisted of several sprays with conventional pesticides. Of course, economic aspects of the two treatments also need to be considered and this is done in the following section. In terms of improving the efficiency of some form of combined traps and botanicals regimen the main area of improvement may lie in use of more efficacious botanical insecticides. One possibility is the use of neem seed oil, rather than leaf extracts, although the former may be more difficult to obtain. It is known that the concentration of the active ingredient is higher in the oil than in leaves so there would be a high chance of a greater insecticidal or repellent effect. In addition, where the respective thresholds for thrips and *M. vitrata* indicate nearly simultaneous applications it would be logical to omit one of them.

**Table 17.** Summary results from the second on-station test of the trap threshold with dates of the respective spray applications also shown.

| Thrips Treatment | *Maruca* Treatment | Mean yield (kg plot$^{-1}$)(±SE) | Mean $\log_{10}$ cumulative thrips infestation 20 flowers$^{-1}$ (±SE) | Mean cumulative *Maruca* infestation 20 pods$^{-1}$ (±SE) |
|---|---|---|---|---|
| 1 spray *Metarhizium* (oil) on 29-Oct | Threshold-based sprays of *Hyptis* leaf extract on 7, 12, 17, 22-Nov | 270 (77) | 3.42 (0.01) | 15.3 (0.5) |
| | Crop stage based sprays of *Hyptis* extract on (5, 10, 15, 20-Nov | 206 (61) | 3.46 (0.03) | 17.8 (3.6) |
| 1 spray papaya extracts on 29-Oct | Threshold-based sprays of *Hyptis* leaf extract on 7, 12, 17, 22-Nov | 188 (56) | 3.44 (0.03) | 16.0 (3.6) |
| | Crop stage based sprays of *Hyptis* extract on (5, 10, 15, 20-Nov | 346 (17) | 3.49 (0.03) | 11.3 (1.4) |
| 5 sprays *Metarhizium* (oil) on 29-Oct, 3, 8, 13, 18-Nov | - | 250 (87) | 3.50 (0.00) | 15.8 (2.5) |
| 5 sprays *Metarhizium* (aq.) on 29-Oct, 3, 8, 13, 18-Nov | - | 174 (37) | 3.44 (0.02) | 22.3 (0.3) |
| 5 sprays papaya extracts on 29-Oct, 3, 8, 13, 18-Nov | - | 337 (128) | 3.49 (0.03) | 20.8 (3.0) |
| 3 sprays of 'Decis' based on crop stage at 29-Oct, 5-Nov, 13-Nov? | | 1325 (209) | 2.91 (0.05) | 0.3 (0.3) |
| Untreated control – no sprays | | 158 (55) | 3.49 (0.02) | 41.5 (3.9) |
| | LSD (5%)* | 291 | 0.07 | 7.9 |

* LSDs calculated following ANOVA of respective data sets – NB log-transformed in the case of thrips infestations.

**Table 18.** Sowing and treatment details for each village during the on-farm test of the trap threshold.

| Village | Sowing group | Type & dates of treatments for thrips | Date of trap threshold | Type & dates of treatments against *M. vitrata* | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 1st | 2nd | 3rd | 4th |
| Assouhoué (Mono) | 28-Aug | Papaya leaf, 13-Oct | 4-Oct | Neem | 7-Oct | 12-Oct | 17-Oct | 22-Oct |
| | 5-Sep | Papaya leaf, 22-Oct | 16-Oct | Neem | 19-Oct | 24-Oct | 29-Oct | 3-Nov |
| Davihoué (Mono) | 28-Aug | Papaya leaf, 7-Oct | 7-Oct | Neem | 10-Oct | 15-Oct | 20-Oct | 25-Oct |
| | 5-Sep | Papaya leaf, 17-Oct | 21-Oct | Neem | 24-Oct | 29-Oct | 3-Nov | 8-Nov |
| Gbècotchihoué (Mono) | 28-Aug<br>5-Sep | Papaya leaf, 21-Oct | 14-Oct | Neem | 17-Oct | 22-Oct | 27-Oct | 1-Nov |
| Atchapka (Zou) | 1 to 10-Sep | Papaya leaf,<br>8-Oct (fields 2,4,6),<br>24-Oct (fields 1,3,5)* | 3-Oct | Hyptis | 6-Oct | 11-Oct | 16-Oct | 21-Oct |
| Dani (Zou) | 28-Aug | Papaya leaf, 3-Oct | 12-Oct | Hyptis | 15-Oct | 20-Oct | 25-Oct | 30-Oct |
| | 4 to 7-Sep | Papaya leaf, 10-Oct | 10-Oct | Hyptis | 13-Oct | 18-Oct | 23-Oct | 28Oct |

*In this case the papaya leaf applications took place 2 – 3 weeks after flower-buds appeared in the fields (cf. 1 – 3 days in all other cases); the reason for the delay is not known.

**Table 19.** Summary yield and infestation data for each village from the on-farm test of the trap threshold.

| Village | Mean yield ($kg\ ha^{-1}$)(±SE) | | Mean cumulative thrips infestation 20 $flowers^{-1}$ (±SE) | | Mean cumulative *Maruca* infestation 20 $pods^{-1}$ (±SE) | |
|---|---|---|---|---|---|---|
| | T&B* | FP* | T&B | FP | T&B | FP |
| Assouhoué (Mono) | 2273 (305) | 2658 (345) | 48.3 (9.4) | 51.2 (11.9) | 6.2 (0.7) | 3.3 (1.3) |
| Davihoué (Mono) | 803 (128) | 1228 (225) | 5.3 (2.7) | 3.0 (1.2) | 32.0 (15.9) | 20.8 (13.3) |
| Gbècotchihoué (Mono) | 788 (215) | 1258 (115) | 1.0 (0.5) | 1.3 (0.9) | 44.4 (13.1) | 28.0 (7.0) |
| Atchapka (Zou) | 385 (65) | 495 (160) | 68.5 (14.7) | 47.0 (10.5) | 40.0 (4.6) | 27.5 (2.5) |
| Dani (Zou) | 1228 (253) | 1348 (98) | 4.7 (1.3) | 3.3 (1.1) | 28.0 (3.8) | 17.5 (2.3) |
| Actual means | 1095 (79) | 1398 (79) | 25.6 (2.4) | 21.2 (2.4) | 30.1 (3.1) | 19.4 (3.1) |
| ANOVA data transform | Square-root | | $Log_{10}$ | | Square-root | |
| Transformed means | 6.24 | 7.15 | 1.02 | 0.93 | 5.10 | 4.01 |
| LSD (5%)† | 0.68 | | 0.14 | | 0.80 | |

* T&B = traps & botanicals treatment; FP = farmer practice. † LSDs calculated following ANOVA of respective transformed data sets.

Economic analysis of benefits of pheromone technology

For the initial analysis, among the 56 farmers at PRONAF sites in Mono, Zou and Borgou departments eight different production systems were identified. All were shown to be profitable (Annex 7). In the report the question of whether the use of pheromone traps could increase profitability was tackled from the point of view of determining the number of sprays of insecticide that could be saved through trap use.

The full cost of deploying one pheromone trap for a cropping season was shown to be CFA 2730[h] (Table 20). Depending on the type used the cost per ha of one application of insecticide is approximately CFA 8300 – 9100 (including labour and hire of ULV sprayer), while comparable costs for one application of neem leaf extracts were CFA 2265.

**Table 20.** Estimated costs (CFA) of fabrication and maintenance of a 5-l jerry-can pheromone trap over one cropping season.

| | Quantity | Unit price* | Total* |
|---|---|---|---|
| Plastic container | 1 | 550 | 550 |
| Lures | 3 | 440 | 1320 |
| Soap | 1 | 145 | 145 |
| Wire | 1 | 215 | 215 |
| Labour | | 500 | 500 |
| TOTAL | | | 2730 |

* Including transport costs

Assuming six traps $ha^{-1}$ and three lures per trap at full cost (see Output 1), it was determined that the use of traps improves profitability if, compared to previous practice, it enables a reduction of two conventional insecticide sprays, while maintaining yield. The number of neem sprays to be saved for increased profitability is greater – since their cost is less – but the use of other, more effective, botanicals could change the analysis. It was hypothesised that, providing a certain minimum number of traps are used, to ensure accuracy of detection, those traps could be deployed over quite a wide area and thus their density per ha could be relatively low. This point is dealt with further below.

Findings from this first analysis were subsequently applied to the yield data of the on-farm test of the trap threshold to calculate the economic returns of the two treatments under three different scenarios of trap density and lure use (Table 21). These scenarios were:

- 15 traps $ha^{-1}$ using three lures $trap^{-1}$ (the situation in the on-station trials);
- one trap $ha^{-1}$ using three lures $trap^{-1}$;
- six traps $25\text{-}ha^{-1}$ using two lures $trap^{-1}$ (the trap density used in the on-farm trial, if the whole 500 × 500 m trapped area were under cowpea).

Before comparing the economic data for each treatment and village it is first worth considering what the effective trapping density is likely to be in any future application of the trap threshold approach. On the basis of previous experience accumulated during the project (notably on-farm monitoring in 2000), fifteen traps per ha is considered to be a far higher density than would be needed to accurately predict the onset of infestations of *M. vitrata*.

[h] £1 ≈ CFA 1000

Instead, six traps spread around a small village or village community (say, 500 × 500 m = 25 ha in area) is probably the minimum needed (*ie.* 0.24 traps $ha^{-1}$). Of course, in practice, not all of the ground area will be cropped with cowpea, so the effective trapping density would be higher, perhaps lying somewhere in the range 0.24 – 1.0 traps $ha^{-1}$. Concerning the necessary number of lures, on the basis of experience two is almost certain to be the maximum necessary to cover the early period of trap catches until the trap threshold itself is reached. From these considerations the most realistic economic data for the on-farm trial of the trap threshold probably fall between the extremes represented by the two main right-hand columns of Table 21.

Inspection of the data of Table 21 shows that at trapping densities of 1.0 traps $ha^{-1}$ or lower the cost of trapping itself is a relatively small proportion of total costs. It is also clear that the combined costs of the traps and botanical insecticides were much lower than those of the conventional insecticides used in the FP treatments. The resultant difference in total costs means that the net profits of both treatments were similar in Atchakpa and Dani villages, though large differentials remained, in favour of the FP treatment, in the other three villages. Thus, as employed in the trial, the T&B treatment could be considered economically viable in two villages in Zou, but probably not the three villages of Mono. This arises because of the relatively small absolute difference in yield between the treatments in the Zou, as opposed to the Mono. It is tempting to conclude that the use of *Hyptis* in the former, rather than neem leaf extracts, might be responsible for this. However, the infestation data do not support such a conclusion since the differences in *M. vitrata* infestation rates for the two treatments were similar in all villages except Assouhoué.

Overall, these results can be considered encouraging. The T&B treatment regimen was probably deficient in two respects – application of the trap threshold could have been more rigorous (by using all traps to indicate application timings for all fields in concert) and neem leaf extracts may be less effective than neem oil or other botanical insecticides. Despite this economic viability was reached in two of five villages.

Furthermore, the health and environmental benefits associated with the T&B treatment need to be considered. It was clear from surveys of farmers' perceptions of pest problems (see November 2000 survey, above) that they recognise the health advantages of 'botanical cowpea' for their own consumption, although because no market premium exists, this cannot be translated into an economic advantage.

Finally, even if future use of traps with botanical insecticides is not found to be viable, they should be able to enhance the control of *M. vitrata* using synthetic insecticides, relative to a crop-stage approach – as demonstrated by the first on-station trial.

**Table 21.** Summary economic analyses of the on-farm test of the trap threshold - under three different assumed trap densities and costs (monetary figures in CFA; £1 ≈ CFA 1000).

| Village | Treat-Ment* | Gross revenue | Fixed costs | | 15 traps ha$^{-1}$, 3 lures trap$^{-1}$ | | | | 1 trap ha$^{-1}$, 3 lures trap$^{-1}$ | | | | 6 traps 25-ha$^{-1}$, 2 lures trap$^{-1}$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Seeds | Insecticide | Trap cost | Total cost | Net Profit | B/C ratio† | Trap cost | Total cost | Net Profit | B/C ratio† | Trap cost | Total cost | Net Profit | B/C ratio† |
| Assouhoué | T&B | 397833 | 5000 | 11325 | 40950 | 57275 | 340558 | 6.9 | 2730 | 19055 | 378778 | 20.9 | 552 | 16877 | 380956 | 23.6 |
| | FP | 464917 | 5000 | 41625 | 0 | 46625 | 418292 | 10.0 | 0 | 46625 | 418292 | 10.0 | 0 | 46625 | 418292 | 10.0 |
| Davihoué | T&B | 140292 | 5000 | 9438 | 40950 | 55388 | 84904 | 2.5 | 2730 | 17168 | 123124 | 8.2 | 552 | 14990 | 125302 | 9.4 |
| | FP | 214958 | 5000 | 34688 | 0 | 39688 | 175271 | 5.4 | 0 | 39688 | 175271 | 5.4 | 0 | 39688 | 175271 | 5.4 |
| Gbècotch. | T&B | 140569 | 5000 | 9438 | 40950 | 55388 | 85181 | 2.5 | 2730 | 17168 | 123401 | 8.2 | 552 | 14990 | 125579 | 9.4 |
| | FP | 222863 | 5000 | 33300 | 0 | 38300 | 184563 | 5.8 | 0 | 38300 | 184563 | 5.8 | 0 | 38300 | 184563 | 5.8 |
| Atchakpa | T&B | 67448 | 5000 | 7928 | 40950 | 53878 | 13570 | 1.3 | 2730 | 15658 | 51790 | 4.3 | 552 | 13480 | 53968 | 5.0 |
| | FP | 86479 | 5000 | 29138 | 0 | 34138 | 52342 | 2.5 | 0 | 34138 | 52342 | 2.5 | 0 | 34138 | 52342 | 2.5 |
| Dani | T&B | 214958 | 5000 | 8305 | 40950 | 54255 | 160703 | 4.0 | 2730 | 16035 | 198923 | 13.4 | 552 | 13857 | 201101 | 15.5 |
| | FP | 235667 | 5000 | 30525 | 0 | 35525 | 200142 | 6.6 | 0 | 35525 | 200142 | 6.6 | 0 | 35525 | 200142 | 6.6 |

* T&B = traps & botanicals treatment; FP = farmer practice. † B/C ratio = Gross revenue/total cost.

**Output 4: Project findings demonstrated and disseminated**

Joint PRONAF/Bean-Cowpea CRSP/NRI workshop

Around 100 participants attended the workshop. These included representatives of the PRONAF donors, IFAD (Dr A. Meschinelli, Technical Advisory Div.) and SDC (Mr D. Achaire), 3-10 from each of the nine PRONAF countries[i], ~30 IITA staff from the Cotonou, Kano and Ibadan stations and 14 delegates from the Bean-Cowpea CRSP project (from US, Nigerian, Ghanaian and Zimbabwean universities). Additionally there were representatives of some other IFAD-funded projects in Niger and Mali and from World Vision (Accra).

PRONAF country representatives described the cowpea-related activities carried out over the previous year mostly with, or by, weekly farmer field schools in their respective countries. Among many other topics these included:

- On-farm trials/development of botanical insecticides (neem, papaya, *Hyptis*);
- On-farm variety trials/seed multiplication;
- On-farm seed germination tests;
- Farmer training in pest scouting/rational decisions on pesticide use;
- Farmer training in improved cowpea storage techniques;
- Farmer field days (various formats).

Three farmers, two from Benin, one from Burkina Faso, described their experiences of farmer field schools. They confirmed that although many farmers do favour the use of botanical insecticides time and labour in their preparation is a significant constraint to their use.

There were also several research-oriented presentations. Bean-cowpea CRSP project members described biotechnological work on cowpea supported by USAID. IITA staff discussed work on IPM of legume pests and diseases, soybean production and utilization, cowpea/livestock integration and adoption/impact studies – most of these were directly linked to the PRONAF project and last, by Dr Coulibaly, IITA socio-economist, referred to the two evaluation surveys descibed under Output 3. Preliminary analyses of the results of the first of these were distributed to delegates (publications 13 and 14, see below); they will be published in journals as publications 6 and 7. A separate summary of the pheromone trap project (publication 15) was received with interest and several questions – notably from the IFAD rep. and country reps. from Burkina Faso.

A collection of presentations to the workshop has been compiled on CD (see item 16 of list below).

Other Conference Presentations

Four conference presentations were made that were not originally planned. These included an oral summary of the project at the Third, World Cowpea Research Conference, Ibadan, Nigeria, 4 – 7 September 2000 (item 2, see list below) and a poster summarising work on the pheromone blend presented at the International Society of Chemical Ecology, 19th Annual Meeting, University of Hamburg, Germany, 3-7 August 2002 (item 20). In addition, thesis

[i] Benin, Ghana, Nigeria, Cameroon, Mozambique, Burkina Faso, Mali, Senegal and Niger

research on the relationship of trap-catches and infestations was discussed at the Second International Workshop of the African Network of Research on Bruchids held at IITA, Cotonou in November 2001 (item 4). A summary of progress on *M. vitrata* pheromone trap monitoring was also included in an oral presentation to the 15th Conference of the African Association of Insect Scientists and the Entomological Society of Kenya, 9-13 June 2003, at ICIPE, Nairobi, Kenya (item 6).

Publications

An M. Sc. thesis has been completed and five peer-reviewed journal or proceedings papers have been published or are in press. Four more papers are in preparation or planned (see list below).

*Published*

1. Rurema, D.G. (2001). Dynamique des populations de *Maruca vitrata* (Fabricius) (Syn. *Maruca testulalis* Geyer) (Lepidoptre, Pyralidae) dans les cultures de niébé (*Vigna unguiculata*) (L.) Walp.: relations entre infestations larvaires et les vols des adultes sous l'attrait de pheromones. Diplome d'études supérieures specialisées en aménagement et gestion des ressources naturelles, Faculté des Sciences Agronomiques, Université Nationale du Bénin. 68pp. Abstract at Annex 1.

2. Downham, M.C.A.,Tamò, M., Hall, D.R., Datinon, B., Dahounto, D. & Adetonah, J (2002). Development of sex pheromone traps for monitoring the legume podborer, *Maruca vitrata* (F.) (Lepidoptera: Pyralidae). In: Challenges and opportunities for enhancing sustainable cowpea production. Proceedings of the World Cowpea Conference III held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, 4 – 8 September 2000. Fatokun, C.A., Tarawali, S.A., Singh, B.B., Kormawa, P.M. and Tamò, M. (Eds.) IITA, Ibadan, Nigeria. (Peer reviewed). Annex 2.

3. Downham, M.C.A., Hall, D.R., Chamberlain, D.J., Cork, A., Farman, D.I., Tamò, M., Dahounto, D., Datinon, B. and Adetonah, S. (2003). Minor components in the sex pheromone of the legume podborer, *Maruca vitrata* (F.) (Lepidoptera: Pyralidae): development of an attractive blend. Journal of Chemical Ecology 29(4), 989-1011. (Peer reviewed). Annex 3.

*In press*

4. Rurema, D.G., Atachi, P., Tamò, M., Downham, M.C. and Datinon, B. Relation entre les infestations larvaires et les vols des adultes de *Maruca vitrata* (Fabricius) (Syn. : *M. testulalis* Geyer) (Lep : Pyralidae) dans les cultures de niébé (*Vigna unguiculata* (L.) Walp) sous l'attrait des phéromones. Accepted for inclusion in: Proceedings of the Second International Workshop of the African Network of Research on Bruchids: recent developments in crop pre- and post- harvest pest management practices in Africa. November 12-17, 2001 Cotonou, (BENIN). (Editorially reviewed). Annex 4.

5. Downham, M.C.A., Tamò, M., Hall, D.R. , Datinon, B., Adetonah, S. & Farman, D.I. Developing pheromone traps and lures for *Maruca vitrata* (F.) (Lepidoptera: Pyralidae) in Benin, West Africa. Accepted by Entomologia Experimentalis et Applicata. (Peer reviewed). Annex 5.

6. Adati, T., Tamò, M., Yusuf, S.R., Downham, M.C.A., Singh, B.B. and Hammond, W. Integrated Pest Management for Cowpea-Cereal Cropping Systems in the West African Savannah. In: "Integrated Pest and Vector Management in the Tropics: Perspective and Future Strategies." Proceedings of the 15th Conference of the African Association of Insect Scientists and the Entomological Society of Kenya, 9-13 June 2003, International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya. (Editorially reviewed). Annex 6.

*In preparation*

7. Adetonah, S., Coulibaly, O., Downham, M.C.A., Endamana, D., Adéoti, R and Tamò, M. Farmers' perceptions of cowpea yield losses due to insect pests and control methods with particular attention to *M. vitrata* (Fabricus) (Lepidoptera: Pyralidae) in Benin,West Africa. Intended for Crop Protection. (Peer reviewed).

8. Adetonah, S., Coulibaly, O., Downham, M.C.A., Endamana, D., Adéoti, R and Tamò, M. Étude de perceptions paysannes sur les technologies de lutte integrée de *Maruca vitrata* (Fabricus) (Lepidoptera: Pyralidae) au Bénin. Intended for Economie Rurale. (Peer reviewed)

*Planned*

9. Downham, M.C.A., Tamò, M., Rurema, D.G. and Datinon, B. Development of a pheromone-trap based intervention threshold in cowpea for *Maruca vitrata* (F.) (Lepidoptera: Pyralidae). Intended for Crop Protection. (Peer reviewed).

10. Downham, M.C.A., Tamò, M. and Datinon, B. Use of pheromone and light traps to follow seasonal and geographical changes in populations of the cowpea pest *Maruca vitrata* (F.) (Lepidoptera: Pyralidae) in Benin, West Africa. Intended for Bulletin of Entomological Research. (Peer reviewed).

*Internal reports*

11. NRI reports for 11 separate project visits by M.C.A. Downham to Benin, Ghana and Nigeria between August 1999 and September 2002.

12. Étude coût-benefice des pièges à phéromone de *Maruca vitrata* (Cost-benefit study of *Maruca vitrata* pheromone traps). S. Adetonah, O. Coulibaly, C. Aitchedji and B. Datinon. Annex 7.

13. Cost-benefit study of pheromone traps of *Maruca vitrata* in cowpea production in Benin. S. Adetonah, O. Coulibaly, C. Aitchedji and B. Datinon.

*PRONAF/Bean-Cowpea CRSP/NRI workshop*

14. Adetonah, S., Coulibaly, O., Downham, M.C.A., Endamana, D., Adéoti, R and Tamò, M. Farmers' perceptions of cowpea yield losses due to *Maruca vitrata* (Fabricus) (Lepidoptera: Pyralidae) in Benin (West Africa). *(Working paper distributed at workshop in April 2002).*

15. Adetonah, S., Coulibaly, O., Downham, M.C.A., Endamana, D., Adéoti, R and Tamò, M.

Socio-economic factors determining choice of cowpea protection methods from *Maruca vitrata* in Benin: Model Application. *(Working paper distributed at workshop in April 2002).*

16. M.C.A. Downham, M. Tamò, O. Coulibaly, W.N.O. Hammond, B. Datinon, S. Adetonah and D. Dahounto. Enhancing Management of *Maruca vitrata* by using pheromone traps. Oral presentation to the Joint PRONAF/Bean-Cowpea CRSP/Project workshop held 8-11 April 2002, IITA, Cotonou, Republic of Benin (see publication 17).

17. Hammond, W.N.O., Adéoti, R. and Gbaguidi, B. (Eds.). Selected presentations to the joint PRONAF/Bean-Cowpea CRSP/Project workshop held 8-11 April 2002, IITA, Cotonou, Republic of Benin. (*CD compilation*). Annex 8.

*IITA Annual Reports*

18. M. Tamò and M.C.A. Downham. Testing synthetic pheromones for *M. vitrata*. Annual Report 1999, Plant Health Management Division, IITA. Section 8.5.1, pp. 30 – 31. *(See http://www.iita.org/research/amrpt/program8.pdf).*

19. M. Tamò, M.C.A. Downham and D.G. Rurema. Testing synthetic pheromones for *M. vitrata*. Annual Report 2000, Plant Health Management Division, IITA. Section 8.4.3, p. 32. *(See http://www.iita.org/research/program2000/proj8.pdf).*

20. M. Tamò, T. Adati, M.C.A. Downham. Testing synthetic pheromones for *M. vitrata*. Annual Report 2001, Plant Health Management Division, IITA. Section 8.1.13, p. 36.

*Conference presentations:*

21. Mark Downham, David Hall, Alan Cork, Dudley Farman, Manuele Tamò, Didier Dahounto, Benjamin Datinon, Sounkoura Adetonah & David Chamberlain. Developing an attractive pheromone blend for the Legume Podborer, *Maruca vitrata* (F.) (Lepidoptera: Pyralidae). Poster presented at: International Society of Chemical Ecology, 19th Annual Meeting, University of Hamburg, Germany. 3-7 August 2002. (p.139 of programme). *(See http://www.chemecol.org/meetings/hamburg_02.htm).* Annex 9.

In addition, the proceedings publications 2, 4 and 6, above, were originally given as oral presentations at the respective conferences indicated.

Training

Demonstrations of traps and the adult-larva link were made to:

- [In Benin] approximately 200 farmers plus 20 PRONAF facilitator/demonstrators in 17 villages in vicinity of Ouémé valley, Bohicon, Savè and in Mono and Borgou departments as part of on-farm monitoring (2000) and FFS activities (2001-2); plus minimum of 9 farmers and 9 technicians at season-long monitoring sites in 2001-2.
- [In Ghana] 5 SARI staff, approximately 150 farmers plus 10 PRONAF facilitator/demonstrators in 9 village FFS in Yendi and Salvelugu districts in 2001 and 2002.

- [In Nigeria] 5 IAR staff, approximately 80 farmers plus 5 PRONAF facilitator/demonstrators in 5 village FFS in Kano State in 2001 and 2002; plus minimum of 6 farmers and 6 technicians at season-long monitoring sites in 2002.

Testing of pheromone lures by non-project partners

During the course of the project the project leader was approached to provide *M. vitrata* pheromone lures to several non-project partners. These were ICRISAT[j] and Tamil Nadu Agricultural University, AVRDC (Taiwan), MARDI (Malaysia) and ICIPE (Kenya)[k]. In each case, lures and a suggested protocol were sent such that a comparison of different blends could be undertaken. Most testing took place in pigeonpea (*Cajanus cajun*) fields, with the exception of that at AVRDC and MARDI where a variety of bean fields were utilised.

No feedback was obtained from MARDI, but field testing by the other institutions has generally produced zero or single figure catches that have not enabled an evaluation of the relative attractiveness of the different blends. The results echo those found by the author in 1998, during a visit to Sri Lanka as part of a previous project phase. In mitigation of these results, it was not always clear that substantial populations of adult *M. vitrata* were present during the test periods. For example, in some cases traps were placed late in the crop cycle and pesticides were sprayed in the fields, while no independent measure of adult populations (e.g. by light trap) was made in other cases. Nevertheless, overall the results suggest that for reasons not understood pheromone traps do not yet appear to be a viable form of monitoring *M. vitrata* in areas outside W. Africa.

## CONTRIBUTION OF OUTPUTS TO DEVELOPMENTAL IMPACT

### Output 1 – Pheromone traps for *M. vitrata* fully optimised

From the results of the trapping experiments an effective and practical trapping system for *M. vitrata* has been developed for the first time. The four-week longevity of lures under field conditions, the non-criticality of dose, blend ratio and isomeric purity of the diene components all favour the viability of trapping *M. vitrata*. The isomeric purity results were particularly significant because the eventual cost of commercially produced lures will be influenced by the extent of purification required. Another favourable finding was that in respect of trap design. The most effective traps are those produced from locally available 5-l plastic jerry-cans. Not only are these relatively much cheaper than imported, commercial designs – less than £1 compared to £2 or more – they are also easy to construct and robust in use. The 5-l jerry-can trap was adopted as the standard for subsequent work described under Outputs 2 and 3.

From the 2001 season lures purchased from International Pheromone Systems were used for the majority of trapping activities described under Outputs 2 and 3. Within the lifetime of the project the alternative, of purchasing the pheromone compounds and making up the lures subsequently, was rejected due to the high initial financial outlay required. However, if there is sufficient demand for lures, in the longer term it may be a cheaper option, particularly if

[j] In this case fieldwork was carried out by ICRISAT under a small CPP-project, R7821.
[k] In this case the individual responsible was Dr T. Adati (now of IITA, Kano) then working at ICIPE.

conversion of EE10,12-16:OH to EE10,12-16:OH and dosing of lures could be undertaken locally, within W. Africa.

Regarding registration of the use of pheromone traps within Benin and Ghana, presently there appear to be no formal requirements, although an *ad hoc* procedure was employed by the EPA in Ghana when approached. The position will be more closely considered in the following project phase (R8300), and the appropriate steps taken at that time.

The capture of female moths in all of the experiments confirmed our earlier observations of this unexplained phenomenon in the previous project phase. However, investigation of these points was outside the scope of the present project. Whatever the explanation, catches of females may actually improve the predictive power of traps, since mixed male/female catches should more accurately reflect local population events than males alone.

**Output 2 – Trap-catch data interpreted in relation to pest biology and distribution**

In Benin, good evidence was found to indicate that trap-catches occur up to 12 days before larval infestations in flowers and a week or more in advance of flowering within cowpea fields. Thus trap-catches can signal impending infestations and may provide an earlier warning than the appearance of flowers. The exact placement of traps, within or near the edge of the field, does not appear to be critical to the capture of *M. vitrata* adults and should not affect the temporal relationship between catches and infestations.

In a few cases where initial trap captures did not take place significantly in advance of infestations, late installation of traps or insecticide applications against other pests, which reduce trap-catches, may be the explanation. However, several other factors could also produce variability in the relative timing of trap-catches and infestations so as to reduce the predictive value of traps. These could include:

- field-to-field variation in the maturity of the crop within a locality resulting from different varieties and differing sowing dates;
- retarded development of the crop – this appears to extend the period between first catches and infestations;
- sampling frequency will limit the accuracy of detection of the onset of catches and infestations – in most of our studies this would have been ± 2 – 3 days;
- low absolute trap-catch levels in combination with low numbers of traps (one or two per field) will impair detection of the onset of adult immigration into fields.

Consideration of the above points suggested that the detection of the arrival of *M. vitrata* into fields should be most reliable if based upon several traps. These traps could be distributed over several fields within a village providing the planting dates and crop-cycle length of cowpea in the respective fields are similar. These conclusions will influence how traps are used in a practical way in the future project phase.

As well as a temporal relationship between trap-catches and larval infestations, it would clearly be useful if a significant quantitative relationship between trap catches and cumulative infestations existed. This would provide farmers with greater guidance concerning how long, or how many times, they should apply insecticides. However, we found that such a relationship only exists at one site, Mono department, where relatively low, though still damaging, infestations tend to occur. Elsewhere much higher infestations seem to occur irrespective of trap catch levels and so the use of traps must be confined to determining when to begin control measures against *M. vitrata*.

Monitoring of pheromone traps in Benin (and of light traps in Benin and Nigeria) has provided useful data concerning seasonal movements of the pest on a national or regional scale. Data generally support the hypothesis that *M. vitrata* populations persist year round south of 9º N, and only move to the north during the rainy season following the northward progression of rainfall, cowpea planting and alternative host flowering. One practical benefit of such information would be to support attempts to avoid infestations by *M. vitrata* by planting outside the normal cropping season. Such a strategy is beginning to be taken up, with some success, in Kano State, Nigeria, using irrigated dry-season cowpea (*pers. comm.* Director of Kano Agricultural Research and Development Association, Aug. 2002).

Generally in Nigeria low catches in pheromone traps appear to be the norm. None of the pheromone trap observations in 2001 and 2002 produced significant catches (with the exception of one FFS village), while good catches were seen in the light trap at Minjibir in 2002. Thus the behavioural response of *M. vitrata* to pheromone traps appears to vary from that in Benin and Ghana for reasons that are not yet understood. Further large-scale monitoring with pheromone traps may help to resolve this. Some monitoring sites in Benin also experienced low catches in both years' observations. If some environmental, ecological or behavioural correlate of these can be established, by reference to the higher catching sites, it should be possible to at least understand the problems encountered in Nigeria. Work on this is continuing at IITA, Kano under the direction of Dr T. Adati, with the focus being on the mated status of captured females. Resolution of this problem could help to realise the full potential of pheromone traps throughout the huge cowpea-producing sub-sector within Nigeria.

**Output 3 – Traps for *M. vitrata* used in development of IPM strategies for control of cowpea pests**

Project surveys have confirmed that farmers in Benin consider *M. vitrata* to be one of the most damaging pests of cowpea and that large majorities in both Ghana and Benin believe pheromone traps could assist in control of the pest. However, there is clearly a need to consider other pests in future work, particularly those occurring earlier in the cropping season than *M. vitrata*, such as aphids and thrips, because their control may interfere with effective trapping of *M. vitrata* at a time when it is most critical. The project has addressed these difficulties in two ways: by showing that traps just outside cowpea fields could be used to trap *M. vitrata* without loss of efficiency, and by beginning trials involving the biorational control of thrips such that catches in pheromone traps should be only minimally affected.

Another constraint to trap use was identified – that most farmers in Benin and Ghana consider that trap materials may be relatively difficult to obtain (despite their availability in large towns in those countries). Furthermore, although about half of farmers surveyed already use botanical insecticides, the labour of production and the lack of a market premium for 'botanical cowpea' act as disincentives for their full uptake. This could be addressed by encouraging small-scale entrepreneurs to begin local production of botanical insecticides (and traps), such that the labour constraint is no longer an issue for individual farmers.

The first on-station trial of the trap-threshold concept provided evidence of its effectiveness, compared to spraying based on crop stage. This effect was most clearly seen when traps were used in conjunction with the conventional insecticide, Decis. Results also indicated that a 2-moth per trap threshold was better than a 5-moth threshold and a 3-day delay is superior to a 6-day delay. Collectively, the on-station trials showed that while Decis clearly provided better control of *M. vitrata* than neem, *Hyptis* and papaya leaf extracts, as well as two formulations of *Metarhizium*, the botanicals and *Metarhizium* all produced significantly lower infestations than the unsprayed control. They did not, however, have any impact on some rather high flower thrips infestations that were controlled by Decis.

Overall, the results of the on-farm trial can be considered encouraging. Although the traps and botanicals treatment was inferior, in terms of *M. vitrata* infestations and yield, to farmer practice there remains scope for improvement that could close this gap. This scope lies in selection of more efficacious botanical extracts, addressing issues such as relative timing of *M. vitrata* and thrips sprays and more rigorous application of the threshold (*ie.* using all traps to indicate application timings for all fields in concert). Despite the problems economic viability was reached in two of five villages. Farmers are conscious of the health advantages of 'botanical cowpea'. Although no market premium exists for this at present, if such awareness becomes more widespread this could be translated into a real economic advantage.

Finally, even if future use of traps with botanical insecticides is not found to be viable, they should be able to enhance the control of *M. vitrata* using synthetic insecticides, relative to a crop-stage approach – as demonstrated by the first on-station trial.

**Output 4 – Project findings demonstrated and disseminated**

The numerous on-farm monitoring activities carried out, and the threshold-testing trial in Benin, beginning September 2002, demonstrated the traps, and of the link between *M. vitrata* larvae and adults, to a large number of farmers. In all approximately 430 farmers in Benin, Ghana and Nigeria, as well as approximately 80 staff of research and extension organisations associated with the PRONAF project in those countries were trained. This has considerably developed and strengthened institutional and project linkages which will be exploited under the agreed promotional project phase (R8300).

Project findings have been effectively publicised at two well-attended meetings dealing with cowpea research uptake and two more general scientific fora. A range of thesis and peer-reviewed publications has been completed.

**Further Work and Uptake of Outputs**

Great progress has been made in developing pheromone traps to assist in the control of *M. vitrata* by acting as predictors of infestations, enabling the timing of control measures to be optimised. There are strong indications that they will prove useful to farmers in Benin and Ghana and that they would be prepared to use them in this way. Trials of the trap-threshold concept, in combination with botanical pesticides, have demonstrated the potential of such an approach, although improvements to the technical and economic efficiency are still required for it to be a practical option for cowpea farmers in West Africa. The scope exists for these improvements to be made. However, production of botanical insecticides is relatively labour-intensive and has been noted as a constraint to their use by farmers in project surveys and elsewhere. Furthermore, trap materials may be difficult for some farmers to obtain.

To realise the full potential of work undertaken to date it still remains to:
- extend the uptake of the pheromone traps;
- determine their best mode of use by farmers;
- test and refine the use of novel botanicals, and possibly other biorationals, against *M. vitrata* and early season pests such as aphids and thrips;
- find ways to facilitate the manufacture and supply of trap materials, botanical insecticides to farmers.

A follow-on project, R8300, will address these points. It will run April 2003 – March 2005 and will involve staff of NRI, IITA, NGOs, small-scale private sector enterprises and all relevant PRONAF project partners. The project will be strongly associated with the larger, region-wide PRONAF project managed by IITA and funded by IFAD, and activities in Benin will be financially supported by PRONAF. Outputs of the follow-on project will:

- Complete development of an integrated package involving *M. vitrata* pheromone traps and botanical insecticides for control of *M. vitrata*, *A. craccivora* and *M. sjostedti*, through further on-station and on-farm trials.

- Scale-up the uptake of the project's package of technologies and recommendations developed as above through large-scale implementation in farmer field schools. To supplement this there will be assessment of the potential for future transmission outside the FFS framework and dissemination to help ensure further uptake after the project ends.

- Put the means of production and distribution of the technologies in place on a pilot-scale and to determine the requirements for larger scale output of the technologies. There would be investigation of the economic feasibility of supply and distribution from the viewpoint of both producers and consumers. Discussions will be undertaken with the respective regulatory authorities to make them aware of the novel nature of pheromone and botanical products, and thereby assist the future development of formal registration and regulatory procedures.

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CROP PROTECTION PROGRAMME

# Development of pheromone trapping for monitoring and control of the legume podborer, *Maruca vitrata* (syn. testulalis) by small-holder farmers in West Africa

**R7441 (ZA0311)**

# ANNEXES TO THE FINAL TECHNICAL REPORT

**1 July 1999 – 31 March 2003**

Mark Downham

Natural Resources Institute

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## Annex 1 – Abstract of Publication 1

Rurema, D.G. (2001). Dynamique des populations de *Maruca vitrata* (Fabricius) (Syn. *Maruca testulalis* Geyer) (Lepidoptre, Pyralidae) dans les cultures de niébé (*Vigna unguiculata*) (L.) Walp.: relations entre infestations larvaires et les vols des adultes sous l'attrait de pheromones. Diplome d'études supérieures specialisées en aménagement et gestion des ressources naturelles, Faculté des Sciences Agronomiques, Université Nationale du Bénin. 68pp.


# ABSTRACT

The main objective of the study is to investigate the use of pheromone traps to monitor populations of *Maruca vitrata* (Fabricius) and predict field infestations in cowpea fields. For this purpose, five cowpea fields were established at Dani, in the center of Benin. Two pheromone traps were placed inside each field, while two other traps were placed at around 50 meters distance from each field. Adult populations of M. vitrata were monitored from April to June 2001. The first flights were recorded 31 days after planting (DAP), whereas, the first larval infestation in flowers and pods was recorded 10 and 20 days respectively after the first flight. Catches of adult moths in pheromone traps were found to efficiently predict *M. vitrata* infestation in the flowers. However, infestations in the pods could not be related to trap catches. There was no significant difference between the number of adults collected in traps within or outside the fields. Concerning the proportion of the different M. vitrata larval stages, the young instar larvae (first and second) were mainly collected on flowers, whereas later instar larvae (fourth, fifth) and pupae were collected on pods. This finding suggested that *M. vitrata* oviposit mainly on flowers. Then larvae migrate to the pods as third instar larvae.



Kew words: *Maruca vitrata*, *Vigna unguiculata*, Pheromone traps, infestation.

## ANNEX 2 – Publication 2

Downham, M.C.A.,Tamò, M., Hall, D.R., Datinon, B., Dahounto, D. & Adetonah, J (2002). Development of sex pheromone traps for monitoring the legume podborer, *Maruca vitrata* (F.) (Lepidoptera: Pyralidae). In: Challenges and opportunities for enhancing sustainable cowpea production. Proceedings of the World Cowpea Conference III held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, 4 – 8 September 2000. Fatokun, C.A., Tarawali, S.A., Singh, B.B., Kormawa, P.M. and Tamò, M. (Eds.) IITA, Ibadan, Nigeria.

# <u>ANNEX 3 – Publication 3</u>

Downham, M.C.A., Hall, D.R., Chamberlain, D.J., Cork, A., Farman, D.I., Tamò, M., Dahounto, D., Datinon, B. and Adetonah, S. (2003). Minor components in the sex pheromone of the legume podborer, *Maruca vitrata* (F.) (Lepidoptera: Pyralidae): development of an attractive blend. <u>Journal of Chemical Ecology</u> 29(4), 989-1011.

## ANNEX 4 – Publication 4

Rurema, D.G., Atachi, P., Tamò, M., Downham, M.C. and Datinon, B. Relation entre les infestations larvaires et les vols des adultes de *Maruca vitrata* (Fabricius) (Syn. : *M. testulalis* Geyer) (Lep : Pyralidae) dans les cultures de niébé (*Vigna unguiculata* (L.) Walp) sous l'attrait des phéromones. Accepted for inclusion in: Proceedings of the Second International Workshop of the African Network of Research on Bruchids: recent developments in crop pre-and post- harvest pest management practices in Africa. November 12-17, 2001 Cotonou, (BENIN).


## ABSTRACT

An experiment to investigate the use of pheromone traps to monitor the population of *M.vitrata* and predict field infestations was carried out at Savé (Dani), in the center of Benin. For this purpose, five cowpea fields were established. Two pheromone traps were placed inside each field, while two other traps were placed at around 50meters distance from each field. Significant relationships were obtained between the catches of adult months and larval infestations ($R^2$= 64, P= 0.0001: inside; $R^2$= 0.41, P= 0.001:outside). Results suggest catches of adult months in pheromone traps both within and outside the fields were found to efficiently predict *M.vitrata* infestations in the flowers. Pheromone traps would be used to ensure the execution of timely and effective control measures.



Kew words: *Maruca vitrata*, *Vigna unguiculata*, Pheromone traps, infestation.


## INTRODUCTION

Le niébé, *Vigna unguiculata* (L.) Walp, est l'une des principales cultures vivrières des zones écologiques tropicales et équatoriales d'Afrique. En effet, le niébé est une importante source de protéines chez les populations tant rurales qu'urbaines en Afrique (Alghali, 1991). Le rendement potentiel en graines est élevé, 1.5-3.0 t/ha en moyenne. Mais actuellement, le rendement dans les champs des cultivateurs est bas, 0.2-0.3 t/ha en moyenne (Raheja et Hayes, 1975). La contrainte majeure de la production du niébé est la forte pression parasitaire des insectes (ravageurs des fleurs, foreurs et suceurs des gousses) et des maladies (Rachie, 1985; Atachi *et al.*, 1985). Les thrips (*Megalurothrips sjostedti* Trybom), ravageurs floricoles et *Maruca vitrata* (Fabricius), foreur de gousses, sont les plus fréquemment rencontrés et économiquement importants comme déprédateurs du niébé en Afrique tropicale (Jackai et Daoust,1986).

La lutte effective contre ce ravageur a été basée sur l'usage des insecticides (Jackai, 1983; Atachi et Sourokou, l989). En effet, l'application de Décis ( deltaméthrine) les 45$^{è}$ et 65$^{è}$ jours après le semis, alternée avec le systoate (dimethoate) au 55$^{è}$ jour aux doses respectives de 12,45g.m.a/ha et 400 g.m.a/ha, donne des résultats satisfaisants (Atachi et Sourokou, 1989). Mais vu le coût élevé de ces produits chimiques, surtout chez les paysans qui ont de maigres moyens financiers, ainsi que leurs effets au niveau de l'environnement, cette méthode de lutte présente de dangers dans la protection et l'amélioration de la production du niébé. Pour ce faire, une approche de lutte alternative, moins chère, effective, compatible avec la vie des paysans et écologiquement durable doit être une préoccupation de la recherche pour assurer la sécurité alimentaire et réduire la pauvreté de la population.

Des investigations ont été faites notamment au niveau des insecticides micro biologiques tels que les insecticides biologiques (*Bacillus thuringiensis* Berliner), l'usage des insectes bénéfiques (prédateurs et parasitoïdes) (Tamò *et al.*, 1997), l'application des extraits naturels d'origine botanique (neem) (Bottenberg et Singh, 1996; PEDUNE, 1998) ainsi que l'emploi des hormones sexuelles pour l'attraction des insectes (Downham, communications personnelles). Toutes ces stratégies de lutte demandent une parfaite connaissance de la biologie des insectes ravageurs ainsi que de ses ennemis naturels au sein de leur écosystème (Dent, 1991). Bien que la biologie de *M. vitrata* ait été largement exploitée, on ne dispose pas de données renseignant sur le comportement et l'activité des larves en fonction des vols des adultes dans les cultures. Ce qui a retardé le développement d'une stratégie de lutte contre *M. vitrata* en Afrique (Jackai, 1995) et en Asie (Shanower *et al.*,1999).

## MATÉRIEL ET MÉTHODE

Les expérimentations ont été ménées dans cinq champs des paysans à Savé (Dani) au centre du Bénin. Les observations des captures d'adultes ont été effectuées chaque jour tandis que celles des infestations larvaires dans les organes ont eu lieu tous les deux jours.

La méthode adoptée est celle d'échantillonnage aléatoire (sondage). Le hasard s'est situé sur quatre niveaux: 1- le choix au hasard des points d'échantillonnage dans chaque champ, 2- le choix au hasard des plants éparpillés de part et d'autre ces points, 3- le prélèvement au hasard des organes à incuber, 4- le tirage au hasard de 30 organes à incuber.

***Les boîtes d'incubation.***

Il s'agit des boîtes plastiques de 125mm de diamètre sur 90mm de hauteur, au fond desquelles on tapisse le papier torchon lors des prélèvements pour recueillir les larves issues des œufs.

***Pièges à phéromone.***

Les adultes de *M.vitrata* sont attrapés dans des pièges fabriqués à partir des bidons en plastic de cinq litres, de couleur blanche. Des ouvertures sont pratiquées de part et d'autre du bidon pour permettre l'aération. Le bidon est suspendu, à une hauteur de 120cm au dessus du sol, sur un bâton enfoncé dans le sol. L'eau savonneuse est placée dans le bidon à une profondeur de 5cm. Les *M.vitrata* sont attirés par des phéromones contenues dans les capsules placées à l'intérieur des bidons.

***Capsules à phéromones***

Ce sont des cylindres translucides en plastic mesurant approximativement 23mm de long x 9mm de diamètre. Les phéromones sont adsorbées sur les parois des capsules. Deux pièges distants de 20m chacun ont été donc installés aux champs. A la périphérie de chaque champ, deux autres pièges ont été placés à une distance de 50m des champs. Les capsules à phéromones ont été renouvellées tous les 15 jours.

*Méthodes d'analyses statistiques*

Les données de ce travail ont été analysées avec le logiciel SAS (SAS, Institute, 1997). Il s'agit de la détermination des coefficients de corrélation entre les cumuls des captures et les infestations larvaires dans les différents champs. Nous avons appliqué les transformations log(x) pour normaliser les données. Le test d'efficacité des pièges et de leur position a été fait par SAS et GLM. Toutes les moyennes ont été séparées en utilisant SNK (Student Newmann Keuls) au seuil de 5%.

***La conception du modèle de prédiction***

C'est sur la base des données de la bioécologie de l'insecte que nous avons conçu le modèle. La durée de développement des différents stades larvaires de *M.vitrata* a guidé dans sa description.

Selon Odebiyi (1981), Ochieng *et al.*, 1981 et Atachi (1998), l'éclosion des œufs varie de 2 à 5 jours et la durée de développement de chaque stade larvaire est de deux jours sauf au stade L5 qui dure 3 jours. Le stade prépupe dure également 2 jours, selon Jackai *et al.*, (1990).

Si on désigne par $I_n$, le nombre total de larves collectées au jour n, les cumuls de captures des jours allant de n-i à n-j ont été utilisés pour prédire les infestations In du jour n ( i étant le nombre total de jours qu'il faut pour passer du stade L1 au stade supérieur, et j étant la durée d'éclosion)

Si $I_n$ comporte une pupe, i=13 et j = 3

Si $I_n$ comporte L5, i=11 et j = 3

Si $I_n$ comporte L4, i=8 et j = 3

Si $I_n$ comporte L3, i=6 et j = 3

Si $I_n$ comporte L2, i=4 et j = 3

Si $I_n$ comporte L1, i=2 et j = 3

Les infestations $I_n$ du jour n seront corrélées avec les cumuls de captures d'adultes dont la formule est la suivante:

In est corrélée avec $\sum_{n-i}^{n-j} cap$ ,

celles des jours n+1 jusqu'au jour n+p sont corréllées comme suit :

$I_{n+1}$ est corrélée avec $\sum_{n-i-1}^{n-j-1} cap$

$I_{n+2}$ est corrélée avec $\sum_{n-i-2}^{n-j-2} cap$

$I_{n+3}$ est corrélée avec $\sum_{n-i-3}^{n-j-3} cap$

. .

. .

$I_{n+p}$ est corrélée avec $\sum_{n-i-p}^{n-j-p} cap$

(p étant une date donnée).

# RESULTATS

## 3.1 Dynamique des populations de *M. vitrata* dans les champs de niébé.

### 3.1.1 Efficacité des pièges (interne et externe) et évolution des proportions pré-imaginales de *M.vitrata* dans les champs

Les courbes des captures d'adultes de *M. vitrata* dans les pièges placés tant à l'intérieur des champs qu'à l'extérieur de ces derniers montrent présentent trois grandes parties.

1. Une phase d'installation de la population de *M. vitrata* allant du 29 au 51$^{è}$ JAS.

2. Une phase d'abondance de la population de *M. vitrata*. Elle se situe entre les 53 et 67$^{è}$ JAS. Le pic s'est localisé le 55$^{è}$ et le 65$^{è}$ JAS (3,6 adultes) pour les pièges du périmètre et le 61$^{è}$ JAS (3,8 adultes) pour les pièges du champ.

3. Une phase de stabilisation de la population de *M. vitrata* couvrant la période du 73 au 81$^{è}$ JAS (Fig. 1a).

La courbe d'infestation des fleurs qui a commencé le 39$^{è}$ JAS (0,66 larve), présente un pic le 43$^{è}$ JAS (6,7 larves) puis au déclin le 45$^{è}$ JAS ( 2,75 larves). Un pallier a été observé au 53$^{è}$ JAS (6,5 larves en moyenne), puis le déclin est noté le 63$^{è}$ JAS (2,4 larves) puis la population s'est stabilisée. (**Fig.** 1a).

Les infestations des gousses ont présenté le premier pic et le déclin respectivement au 53$^{è}$ JAS (11,5 larves) et au 57$^{è}$ JAS (2,2 larves). Un second pic et déclin ont été notés respectivement le 65$^{è}$ JAS (8,4 larves) et le 75$^{è}$ JAS (1,2 larves) (Fig. 1a).

Les résultats ont montré que la période allant du 51$^{è}$ au 63$^{è}$ s'est révélée celle d'infestations sévères. En effet tous les pics (gousses) et le pallier (fleurs) d'infestation sont contenus dans cet intervalle de temps.

Les captures d'adultes sont significativement corrélées avec les infestations larvaires dans les fleurs et non dans les gousses d'une part et d'autre part les captures des champs et de la périphérie sont significativement corrélées .

Dans la population des larves totales collectées aux champs, les proportions varient de la manière suivante. Dans les fleurs, les larves de stades L1, L2, L3 ont été observées au début des infestations, puis L4, L5 et les pupes au fur et à mesure du temps (**Fig**. 1b). Les infestations dans les gousses ont été exclusivement des larves de stades âgés (L4, L5 et pupes) (Fig. 1c).

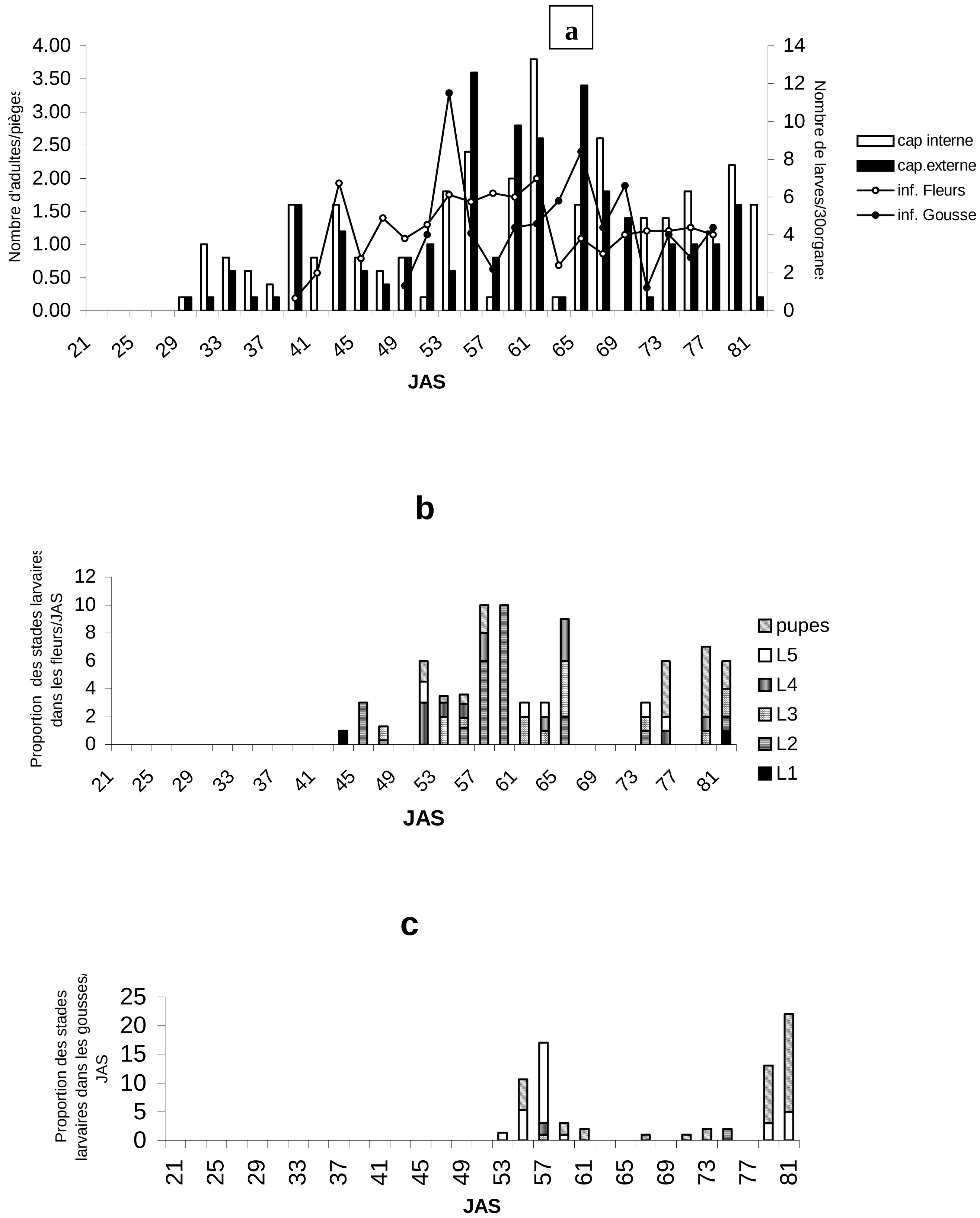


**Fig.1.** Evolution des populations de *M. vitrata* dans la localité de Dani

Tableau 8: Corrélation entre les cumuls de capture et les infestations sur les différents organes, en relation avec la position des pièges dans les champs.

| Position des pièges | Organes | $R^2$ | P |
|---|---|---|---|
| A l'intérieur du champ | Fleurs | 0,64 | 0,0001 |
| | Gousses | 0,22 | 0,12 |
| A la périphérie du champ | Fleurs | 0,41 | 0,001 |
| | Gousses | 0,11 | 0,34 |

**3. 2. Etude comparée de l'efficacité des pièges placés à l'intérieur des champs et ceux placés à la périphérie des champs**.

A l'exception du champ 2 et 3, le nombre d'adultes capturé dans les pièges placés à l'intérieur du champ est positivement et significativement corrélé au nombre d'adultes capturé dans les pièges de la périphérie (Tableau 2).

Tableau 2. Coefficients de corrélation entre les captures des pièges à l'intérieur et à la périphérie des champs

| Champ | $R^2$ | P |
|---|---|---|
| 1 | 0,75 | 0,007 |
| 2 | (-) 0.086 | 0,811 |
| 3 | 0,66 | 0,07 |
| 4 | 0,86 | 0,002 |
| 5 | 0,79 | 0,03 |
| confondus | 0,33 | 0,02 |

## DISCUSSION

### 4.1. Infestations larvaires.

Au vu des résultats du présent travail, des traits importants sur les infestations larvaires d'une part et sur les captures d'adultes de *M. vitrata* d'autre part ont pu être dégagés.

Les valeurs de pics d'infestation dans les fleurs varient en fonction des champs. Elles se situent entre 7 à 15 larves sur 30 fleurs incubées et de 9 à 17 larvessur 30 gousses. Cette densité larvaire semblerait être faible dans les organes échantillonnés. Cette situation est tout à fait normal compte tenu de la biologie du ravageur. En effet selon Atachi et Ahohuendo (1989), une seule larve en moyenne par fleur de niébé suffit pour causer des dégâts économiquement importants estimés entre 30-86%. *M. vitrata* est donc un insecte de grande voracité et n'a alors pas besoin d'être abondant dans les champs pour causer des dégâts qui entraînent des pertes de rendements.

Les courbes d'évolution de *M. vitrata* dans les champs ont montré les infestations larvaires dès le début d'observations et ont augmenté rapidement que ce soit au niveau des fleurs ou de gousses. Ceci est expliqué par le fait que cet insecte n'entre jamais en diapause durant les saisons défavorables comme le font d'autres insectes pour échapper à l'atrocité du climat. Ainsi il se maintient dans l'écosystème grâce à la présence d'une gamme importante de plantes hôtes (Akinfenwa, 1975; Taylor, 1978; Jackai et Singh, 1981, 1983; Atachi et Djihou, 1994; Arodokoun, 1996).

Les stades larvaires avancés présents dans les fleurs au fur et à mesure du temps et dans les gousses, sont le résultat de la migration des larves des boutons floraux aux fleurs puis aux gousses. Atachi & Gnanvossou (1989) stipulent que les jeunes larves ($1^{er}$, $2^{e}$, $3^{e}$ stades) endommagent surtout les boutons floraux tandis que les stades avancés ($4^{e}$ et $5^{e}$ stades) concentrent plutôt leurs dégâts sur les fleurs épanouies et les gousses immatures, ce qui est en accord avec nos résultats.

Selon Jackai ( 1982), les œufs sont préférentiellement pondus sur les boutons floraux, une moindre quantité sur les fleurs et rarement ou exceptionnellement déposés sur les gousses. Nos travaux ont confirmé cette conclusion. Les œufs pondus sur les gros boutons floraux continueront leur développement dans les fleurs. C'est la raison pour laquelle les Fig. **1b** montrent les jeunes stades larvaires au début des infestations dans les fleurs puis un mélange de stades avec le temps. Les œufs pondus dans les fleurs continueront leur développement sur les gousses.

### 4.2. Captures d'adultes dans les pièges à phéromones.

La dynamique de la population d'adultes étudiés à base des pièges à phéromones a connu des fluctuations dans le temps. Plusieurs raisons seraient à la base de ce phénomène entre autres les conditions climatiques et l'évolution phénologique des organes. A la floraison, les adultes sont stimulés par les fleurs pour venir déposer les œufs dans les champs de niébé (Jackai, 1982). La densité d'adultes serait donc susceptibles de fluctuer en fonction de l'apparition des fleurs.

L’analyse statistique a révélé une corrélation positive et significative entre les captures d'adultes dans les pièges à phéromones et les infestations larvaires aux champs. Ceci suggère qu’une augmentation du nombre d’adultes à l’extérieur et à l’intérieur des champs s’accompagne d’une augmentation des infestations des champs. Les larves sont issues des œufs pondus par les adultes qui volent d’où il y a eu une migration de *M.vitrata* de l’extérieur vers les cultures de niébé.

Le modèle que nous avons conçu est en accord avec Jackai (1982), Arodokoun (1996) et Atachi (1998) qui stipulent que les fleurs du niébé jouent un grand rôle dans le processus d’infestation larvaire de *M. vitrata*.

**4.3. Efficacité des pièges vis à vis de leur position.**

L’analyse statistique a révélé partout dans les champs une corrélation positive et significative entre les vols des pièges des champs et ceux de la périphérie (Tableau 2). Cela suggère qu’une augmentation du nombre des adultes à l’extérieur des champs entraînerait une augmentation du nombre des adultes dans les champs. Ces résultats montrent donc qu’il est probable de prédire la migration de *M. vitrata* des plantes hôtes non cultivées vers le niébé en plaçant les pièges soit à l’intérieur du champ soit à l’extérieur de celui-ci.

## CONCLUSION

Les résultats du présent travail apportent une contribution à l’étude de la dynamique quantitative des populations de *M. vitrata* dans un écosystème donné. L’étude a révélé une corrélation significative entre les captures et les infestations larvaires de *M. vitrata* dans les fleurs. Le résultat de ce travail fournit donc un élément d’indicateurs pour la prévision de l’apparition de *M. vitrata* sur la culture du niébé. Le modèle conçu sera basé sur les fleurs et non sur les gousses.

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## ANNEX 5 – Publication 5

Downham, M.C.A., Tamò, M., Hall, D.R. , Datinon, B., Adetonah, S. & Farman, D.I. Developing pheromone traps and lures for *Maruca vitrata* (F.) (Lepidoptera: Pyralidae) in Benin, West Africa. Accepted by Entomologia Experimentalis et Applicata.

# DEVELOPING PHEROMONE TRAPS AND LURES FOR *MARUCA VITRATA* FABRICIUS (LEPIDOPTERA: PYRALIDAE) IN BENIN, WEST AFRICA

**M.C.A. Downham[1], M. Tamò[2], D.R. Hall[1], B. Datinon[2], S. Adetonah[2] and D.I. Farman[1]**

[1] Natural Resources Institute, University of Greenwich, Central Avenue, Chatham Maritime, Chatham ME4 4TB, United Kingdom

[2] International Institute of Tropical Agriculture, Biological Control Center for Africa, 08 BP 0932, Tri Postal, Cotonou, Republic of Benin

## Abstract

In previous work successful trapping of the legume podborer, *Maruca vitrata* Fabricius (Lepidoptera: Pyralidae) was accomplished using a synthetic pheromone blend consisting of (*E,E*)-10,12-hexadecadienal, (*E,E*)-10,12-hexadecadienol and (*E*)-10-hexadecenal in a 100:5:5 ratio. In the present work experiments were conducted in cowpea fields in Benin to compare different trap designs, and other aspects of the lures. A water-trap made from a plastic jerry-can was found to be superior to commercial funnel- and sticky-trap designs and 120 cm was the optimum height for captures. Generally, lures consisted of polyethylene vials containing 0.1 mg of pheromone. Results showed that shielding of lures from the adverse effects of sunlight, by means of aluminium foil, did not increase trap catches of *M. vitrata*. The degree of isomeric purity of the (*E,E*)-10,12-hexadecadienal and (*E,E*)-10,12-hexadecadienol blend components, in the range 73 – 99%, had no significant effect on captures, while lures of 80% isomeric purity showed no loss of effectiveness for up to four weeks. Similar results were observed with lures from a commercial source containing 0.46 mg of pheromone in the blend ratio 100:11:6 and 95% isomeric purity. Residue analysis showed that vial lures exposed for two weeks in the field still contained 73% of the initial amount of (*E,E*)-10,12-hexadecadienal, in contrast to rubber septa dispensers which only retained 22%. Females comprised 11 – 50% of total catches confirming earlier, unexpected results for synthetic lures. The observations that effective traps can be made from locally available plastic containers and that pheromone blend composition and purity are not critical, should reduce costs and improve the feasibility of traps as practical monitoring tools for *M. vitrata*.

**Keywords -** trap design, blend purity, monitoring, (*E,E*)-10,12-hexadecadienal, (*E,E*)-10,12-hexadecadienol, (*E*)-10-hexadecenal.

## Introduction

Cowpea, *Vigna unguiculata* (L.) Walp., is a highly important grain legume crop grown in semi-arid and dry savannah agro-ecological zones of the tropics (Singh & van Emden, 1979). It provides a cheap source of dietary protein for low-income populations (Rachie, 1985) and forms a vital cattle forage crop in many farming systems (Mortimore *et al*., 1997). Africa produces 75% of world production of which the majority comes from West Africa (Coulibaly & Lowenberg-Deboer, 2002, derived from FAOSTAT, 2000).

*Maruca vitrata* Fabricius (syn. *M. testulalis*) (Lepidoptera: Pyralidae), the legume podborer, is a key pest of cowpea (Jackai, 1995) as well as other legume crops. The larvae attack flower buds, flowers and young pods (Singh & Jackai, 1988) and on cowpea yield losses due to *M. vitrata* have been reported in the range 20-80% (Singh *et al*., 1990).

Insecticides can control cowpea insect pests and raise yields several-fold (Afun *et al*., 1991; Amatobi, 1995; Asante *et al*., 2001). However in West Africa expense limits insecticide use by many poor farmers (Alghali, 1991; Bottenberg, 1995). Careful timing of application is required because the webs produced by young *M. vitrata* larvae, and their tendency to bore into flowers and pods, help to protect them from insecticides (Lateef & Reed, 1990). Afun *et al*. (1991) demonstrated effective use of action thresholds, based on flower infestation rates, to time insecticide applications. Potentially, catches in pheromone-baited traps for *M. vitrata* could be used by cowpea farmers to determine the most effective time to treat their crops. Such an approach has been developed for pests of other tropical crops such as rice (Kojima *et al*., 1996) and cotton (Reddy & Manjunatha, 2000).

The use of pheromone traps for monitoring the activity and movements of adult *M. vitrata* could also assist researchers to develop new pest management strategies. Bottenberg *et al*. (1997) provided some data on the population dynamics and migration of *M. vitrata* in West Africa, based on light trap catches. However, pheromone traps could be deployed more easily, cheaply and in greater numbers in order to generate this kind of information. Moreover, pheromone traps are specific to the species of interest.

Okeyo-Owuor & Agwaro (1982) trapped male *M. vitrata* moths in water traps baited with virgin females in Kenya, thus suggesting the production of a sex pheromone by female *M. vitrata*. Later, Adati & Tatsuki (1999) reported (*E*,*E*)-10,12-hexadecadienal (EE10,12-16:Ald) to be an electroantennogramm-active component of the extract from female *M. vitrata* abdominal tips. Synthetic EE10,12-16:Ald was shown to be attractive to male moths in laboratory bioassays although only at high levels of isomeric purity. The corresponding alcohol, (*E*,*E*)-10,12-hexadecadienol (EE10,12-16:OH), was found to be present at 3-4% relative to the aldehyde, but not tested. No field testing was carried out. Recently Downham *et al*. (2003) confirmed the presence of EE10,12-16:Ald and EE10,12-16:OH as major and minor blend components, respectively, together with a third component that laboratory and field bioassays suggested was probably (*E*)-10-hexadecenal (E10-16:Ald). In field experiments in Benin, traps baited with a blend of EE10,12-16:Ald, EE10,12-16:OH and E10-16:Ald in a 100:5:5 ratio caught significantly more males than traps baited with the major component alone, either two-component blend or virgin female moths. In an almost unprecedented finding, significant numbers of female *M. vitrata* moths, in variable proportions up to 50% of total catches, were trapped with synthetic blends but not with virgin females. All laboratory and field experiments employed blends in which the isomeric purity of the EE10,12-16:Ald major component was >99%. Downham *et al*. (2003) found no significant differences in catches using polyethylene vials or rubber septa, or between lures containing 0.01 and 0.1 mg of pheromone, but considered 0.1 mg polyethylene vials to be the lures of choice due to their greater expected longevity under field conditions.

This paper reports experiments to develop an effective trap for *M. vitrata* and to explore the effects of lure age and blend purity on catches of both sexes, with a view to the sustainable use of traps by poor farmers in West Africa for optimising control of *M. vitrata*. We also report some analysis of pheromone lures exposed under field conditions.

## Materials and Methods

*Experimental sites.* Experiments were carried out between 1998 and 2001 within cowpea fields planted with the local variety Kpodjiguèguè (Tamò & Baumgaertner, 1993) at the IITA research station near Cotonou, Republic of Benin (6° 25.1’ N, 2° 19.7’ E, 21 m altitude). At this location rainfall is bimodal in pattern, with a long rainy season from April to July, and a short one from mid-September to November. Cowpea may be cultivated at any time from May – December. *M. vitrata* may be present at any time during this period, depending on the flowering of its wild hosts (leguminous tree species such as *Lonchocarpus* spp. and *Pterocarpus* spp), but normally appears most strongly during the latter half of the cropping cycle. All the trapping experiments were conducted over 2 – 3 months within the period June – December. Fields of cowpea were grown specifically for the experiments. Traps were set out in fields 20 – 30 days after sowing, *i.e.* before flowering, and were continued until after harvesting. Crops were rain-fed and no pesticides were sprayed in the fields.

*General trapping methods.* Traps were suspended from wooden sticks using wire; unless otherwise noted this was at a height of approximately 1.0 – 1.2 m. Lures were replaced every two weeks and were shielded from sunlight to minimize isomerization by wrapping aluminium foil around them to leave only the lower-most surface exposed. Trap catches were counted daily and trapped moths discarded at that time.

Each experiment was carried out to a randomised complete-block design with 5 replications. Traps within a replicate block were set out in lines or rectangular formations, the exact layout depending on the number of treatments being compared. Individual traps were positioned 20 m apart. Blocks were at least 50 m apart, and were usually situated in separate fields. With this arrangement it is possible that some interactions between traps occurred as individual pheromone plumes overlapped and moths, initially attracted by the plume of one trap, passed on to the plumes of others nearby. This would have acted to blur treatment differences. However, the random positioning of treatments within blocks and variation in wind direction would have greatly reduced, if not eliminated, any systematic biases.

*Trap optimisation experiments.* Six trap designs were used during the course of two experiments. The first compared two commercially available designs with a water-pan trap made from a green plastic bowl (5 cm depth × 20 cm diameter) and an up-turned plate (20 cm diameter) held 5 cm apart with steel wire, with the plate uppermost. The commercial traps (Agrisense-BCS, Pontypridd, UK) were white sticky, delta traps (28 cm long × 20 cm floor width × 14 cm sloping side) and green plastic funnel-traps (22 cm high × 15 cm outside diameter). In the delta trap, sticky card inserts that were replaced on a weekly basis served to trap moths; in the funnel trap DDVP insecticide strips inside killed any trapped moths. Delta traps were fixed in such a way as to prevent them turning in the wind. Dilute detergent solution was placed in the water-pan traps to 1 – 2 cm below the trap openings. A little vegetable oil was added to this to reduce evaporation. The detergent solution was topped-up or entirely replaced 2 – 3 times each week as necessary.

The second experiment compared the same delta trap with three more water-trap designs. These included one from a 1.5-litre clear plastic bottle (formerly used as a container for mineral water - 30 x 8 cm) in which two windows (6 × 4 cm) were cut on opposite sides, with the lower edge of the window being 9.5 cm from the bottom of the bottle. The two other water-traps were made from 2-litre yellow and 5-litre white, plastic jerry-cans (formerly used as vegetable oil containers, 26 x 17 x 13 cm) of rectangular cross-section. These designs were very similar to those described by Smit *et al*. (1997). Four windows, one on each side, each positioned with the lower edge 8 cm above the bottom of the trap, were cut in each trap (two each of 8 × 9 cm and 8 × 6 cm for the 5-l trap; four of 4 × 6.5 cm for the 2-l trap). As in the water-pan trap, dilute detergent solution acted as the trapping agent in the bottle and jerry-can traps.

In addition a trap height comparison was carried out using funnel traps suspended so that the trap openings were at 20, 70, 120 and 170 cm above ground.

Previous observations have consistently noted zero catches for un-baited control traps where delta and funnel trap designs were used (Downham *et al*., 2003). In the case of the water-trap designs occasional control catches have been noted, but these have not exceeded one individual per trap over a cropping season (Adati & Downham unpub. data). In consequence, un-baited control traps were not included in any of the present experiments.

*Lure optimisation experiments.* Lures used in all the trapping experiments consisted of polyethylene vial dispensers (23 mm × 9 mm × 1.5 mm thick; Just Plastics, London E10 7PY, U.K.). White rubber septa (Aldrich Chemical Co. Ltd., Gillingham, Dorset UK; catalogue number Z10,072-2) were additionally used in the quantitative residue experiment. Unless noted otherwise all lures contained 0.1 mg of EE10,12-16:Ald, EE10,12-16:OH and E10-16:Ald in a 100:5:5 ratio. They were produced at the Natural Resources Institute, UK by adding the pheromone, and an equal weight of 2,6-di-*tert*-butyl-4-methylphenol (BHT) as antioxidant, dissolved in 0.1 ml petroleum spirit (b.p. 40 – 60ºC) and allowing the solvent to evaporate. The pheromone components were prepared as described by Downham *et al*. (2003). The EE10,12-16:Ald and EE10,12-16:OH were of >99% isomeric purity, unless otherwise noted, and the E10-16:Ald was of >99% stereochemical purity. Lures were suspended within the centre of each trap using a small wire paper-clip.

Rubber septa and polyethylene vial dispensers initially containing EE10,12-16:Ald alone or with one of both of the EE10,12-16:OH and E10-16:Ald minor components were exposed under field conditions for two weeks in sticky delta traps during August 1998. Duplicate samples of each of the eight blend/dispenser combinations were retrieved, wrapped in aluminium foil and stored in a refrigerator at 4º C prior to determination of the residual amount of EE10,12-16:Ald remaining. Lures were extracted individually overnight at room temperature in hexane (5 ml) containing 0.1 mg of pentadecyl acetate as internal standard. The resultant solutions were analysed by gas chromatography using a fused silica capillary column (30 m x 0.32 mm i.d.) coated with CP Wax52CB (Carbowax equivalent; Chrompack, London, UK). Carrier gas was helium (0.5 kg/$cm^2$) and the oven temperature was programmed at 60°C for 2 min then at 6°C/min to 230°C. Injection was in splitless mode (1 μl; 200°C) and data were captured and processed with EZChrom 6.0 (Aston Scientific, UK) hardware and software. Under these conditions, good separation was obtained for E10-16:Ald and the four isomers each of EE10,12-16:Ald and EE10,12-16:OH, and these were quantified by direct comparison of peak area with that of the internal standard without applying a response factor.

Four trapping experiments were carried out concerned with age and blend purity. In the first, six treatments, *i.e.* the combinations of shielded and unshielded lures with the age ranges 0 – 2, 2 – 4 and 4 – 6 weeks, were compared in delta traps. The older two ranges were produced by pre-ageing lures for 2 or 4 weeks in delta traps situated at least 100 m from the experimental fields. These, together with fresh lures were placed in the respective traps at the start of each two-week lure replacement period. In a second experiment unshielded lures in the age ranges 0 – 1, 1 – 2, 2 – 3 and 3 – 4 weeks were compared in 5-l jerry-can traps. In this case the older lures were produced by pre-ageing for one, two and three weeks, using a similar procedure to that for the age/shielding experiment. In this experiment lures were changed on a weekly basis.

The effect of isomeric purity of the two diene compounds, EE10,12-16:Ald and EE10,12-16:OH was determined in a further experiment using funnel traps. The four purity levels tested were 73%, 80%, 91% and >99%. These levels of purity reflected those typically achieved after zero, one, two and three serial recrystallizations from the equilibrium mixture of *E,E : Z,E : E,Z : Z,Z* isomers during manufacture of the compounds (see Downham *et al*., 2003).

The combined effects on catches of lure age and pheromone purity, in unshielded lures, were further investigated in 5-l jerry-can traps. Three lure types were compared: two produced at NRI of >99% and 80% isomeric purity with respect to the diene components and a third, commercially produced type (International Pheromone Systems, Ellesmere Port, L65 4EH, UK), hereafter termed IPS lures. In these lures the initial quantity of pheromone was 0.46 mg and the component ratio (EE10,12-16:Ald; EE10,12-16:OH; E10-16:Ald) was 100:11:6, while the isomeric purity of the diene components was 95 – 96%. These three lures were each compared in two age ranges, 0 – 2 and 2 – 4 weeks old (the latter produced by an appropriate pre-ageing procedure as described above) to produce six treatments in all.

*Statistical analysis.* For statistical analysis of the trapping experiments, total catches by each trap during the respective trapping periods were used. Before statistical analysis, data were transformed to square-root (trap height experiment) or $\log_{10}(x)$ (trap design, lure age, blend purity and age/purity experiments). Analysis of variance was carried out using Genstat 5 for Windows© (release 4.1). Where this indicated statistically significant effects, treatment means were separated using the least significant difference (LSD) at the 5% level.

## Results

*General observations.* Rates of capture of *M. vitrata* moths, males and females combined, were low in absolute terms, ranging from less than 10 to almost 30 individuals per trap throughout an experiment (less than 1 individual $trap^{-1}$ $night^{-1}$). The proportion of females caught varied from 11 – 50% of the total.

*Trap optimisation experiments.* Significant treatment effects were observed in both the trap design experiments ($P < 0.05$, F-ratio, ANOVA). In the first, the delta trap attracted the fewest moths of both sexes (Table 1). The Agrisense-BCS funnel trap captured most males, but the locally-constructed water-pan trap was most effective in capturing females. However, the different capture rates of the water-pan and funnel traps were not significant for either sex ($P > 0.05$, LSD). In the second experiment the 5-l and 2-l jerry-can designs captured significantly more males than both the delta trap and the 1.5-l bottle design ($P < 0.05$, LSD) (Table 2). A similar trend was evident in captures of females; the 5-l jerry-can caught significantly more females than the delta trap and the 1.5-l bottle design, but the difference between 2-l jerry-can and the 1.5-l bottle design was not significant. The overall percentage captures of females in the two experiments were 46% and 35%.

During the trap height experiment more males were captured at 120 cm than the other heights (Table 3). Mean catches of males at this height were significantly greater than at 20 and 170 cm ($P < 0.05$, LSD), though not at 70 cm. Catches of females were relatively low in this experiment (11% of the total) and there were no significant differences in respect of trap height.

*Lure optimisation experiments.* Results of the quantitative residue experiment were that the amounts of EE10,12-16:Ald remaining in the polyethylene vials averaged 73% of the initial value compared to 22% in the rubber septa. There was some variation in the amount of EE10,12-16:Ald remaining with pheromone blend, particularly in the polyethylene vials but this may reflect the low replication at the level of individual blends. These results were reflected in a two-way analysis of variance showing the effect of dispenser type to be highly statistically significant ($P < 0.001$, ANOVA, 1 d.f.). Pheromone blend was not a significant factor ($P = 0.08$, ANOVA, 3 d.f.), but the interaction of blend and dispenser type was ($P = 0.04$, ANOVA, 3 d.f.).

Results of the age and shielding experiment (Table 4) showed highly significant effects of lure age upon captures of both sexes ($P < 0.01$, ANOVA, 2 d.f.). Four to six week old lures were significantly less attractive to males than 0 – 2 and 2 – 4 week old lures ($P < 0.05$, LSD), but there was no difference in catches for lures of the two lower age ranges. Zero to two week old lures were significantly more attractive to females than both older sets of lures ($P < 0.05$, LSD). Male captures were not influenced by shielding of the lures ($P = 0.75$, ANOVA, 1 d.f.), but this factor did affect captures of females ($P < 0.01$, ANOVA, 1 d.f.), catches being higher with shielded lures. The interaction of age lure and shielding was not significant for males or females ($P > 0.38$, ANOVA, 2 d.f.). Captures of female moths made up 14% of the total in this experiment. In the comparison of unshielded lures up to four weeks old, lure age had no effect on captures of males or females ($P \geq 0.26$, ANOVA, 3 d.f.). Mean captures were in the range 4 – 6 individuals per trap for each age range, for both males and females. Females comprised 50% of captures.

For the experiment on the effect of isomeric purity of the diene components using shielded lures, there was also no effect of treatment for males or females ($P \geq 0.39$, ANOVA, 3 d.f.). Mean captures were in the range 4 – 8 individuals per trap for each purity level, for both males and females.  Females made up 47% of total captures in this case.

The experiment on the combined effect of lure age and blend purity (unshielded lures) confirmed the earlier results for these factors individually. Lure age, up to 4 weeks, did not affect catches of males or females ($P \geq 0.64$, ANOVA, 1 d.f.), neither did the type of lure (NRI, high or low blend purity or IPS) ($P \geq 0.85$, ANOVA, 2 d.f.).  There was no interaction of the two factors for either sex ($P \geq 0.14$, ANOVA, 2 d.f.). Captures of males and females for each treatment were 21 – 22 and 6 – 7 individuals per trap, respectively.  Thus 24% of catches were of females during this experiment.

## Discussion

Our results are similar to many previous reports with other species in showing significant effects of trap-design and height on insect captures (*e.g.* Bradshaw *et al*., 1983; Smit *et al*., 1997).  Earlier work shows that trap design can affect capture rates through its effect on pheromone plume structure (Lewis & Macaulay, 1976) and hence on the approach behaviour of insects (Foster *et al.*, 1991, 1995). Diffuse plumes reduce the number and accuracy of approaches by diminishing the insects' ability to orient upwind. For radially asymmetric designs such as the delta trap a cross-wind orientation tends to reduce approaches and captures at least partly for this reason.  Visual cues and physical accessibility of the trap interior are also probably important as well as the ability of the trap to retain insects that have entered (Foster *et al*., 1991, 1995). Thus we can speculate that the delta trap performed relatively poorly during our own comparisons (Tables 1 & 2) because it was inappropriately oriented with respect to the wind for much of the time or because approaching *M. vitrata* found it difficult to locate the trap entrances. Although the 1.5-l bottle was cylindrical in cross-section, a similar argument can be made for this, as it only had two entry windows and often these may have been mis-aligned with the wind. In contrast, the 2-l and 5-l jerry-can designs, with four windows each, were similar to the funnel trap in being almost omni-directional.

In general, an optimal trap height can reflect the preferred natural activity zone of a species, but height may also affect catch in other ways. For example, Gregg & Wilson (1990) reported that traps for *Heliothis* spp. (Lepidoptera: Noctuidae) should be just above crop height in order to prevent obstruction of the plume. In our experiments (Table 3) the crop canopy would have been well above 20 cm for most of the trapping period, thus plumes from traps at this height would not have carried far. The optimal trap height of 120 cm corresponds roughly to a distance of 60-90 cm above canopy, depending on phenological stage of the plant and season. Traps at 170 cm were presumably too far above the crop for their plumes to be encountered frequently by flying *M. vitrata*.

The lure age and shielding experiment showed male catches were unaffected by shielding of the lures from direct sunlight with aluminium foil or by lure age up to four weeks (Table 4). We considered that the design of the delta trap might have provided some protection of the lures, but similar results in respect of lure age were obtained with unshielded lures in two later experiments which used the 5-l jerry-can trap. In this design lures are more exposed to sunlight due to the larger trap entrances and the translucent nature of the trap's walls. Results in respect of females were somewhat conflicting. In the lure age and shielding experiment captures were significantly lower with successive lure age groups and were also affected by lure shielding. However, there was no effect of lure age up to four weeks in 5-l jerry-can traps in the other two experiments in which this factor was investigated.

The first purity experiment showed no effect on trap catches of isomeric purity of the diene components, in the range 73% – 99%, for lures up to 2 weeks old. The combined purity and age experiment confirmed this for lures of 80% and 99% purity up to 4 weeks old. These are slightly surprising results as incomplete or 'off' blends typically greatly reduce attraction of moths to sources (*e.g.* Willis & Baker, 1988; Witzgall, 1990). They run contrary to those of Adati & Tatsuki (1999) for *M. vitrata* in which EE10,12-16:Ald of even 92% isomeric purity failed to attract males of Ghanaian origin in laboratory bioassays, in contrast to material of 99% purity. The reported results were obtained with EE10,12-16:Ald alone, although it was noted without supporting data that attraction rates to the pure EE10,12-16:Ald were not improved by the addition of EE10,12-16:OH. Our results can only be reconciled with those of Adati & Tatsuki (1999) if it is supposed that deficiencies in the isomeric purity of the major component can be off-set by the presence of both minor blend components.

Generally, trap-catches decline with age of lure as a result of a falling release-rate or a shift away from the optimal pheromone blend caused by the isomerisation or other reaction of one or more components. It is now possible to say that, within quite wide limits, catches of *M. vitrata* are relatively unaffected by several factors relating to blend quality and lure dose or release-rate. Downham *et al.* (2003) found no effect of varying the proportions of the two minor blend components together over the range 1% – 50% and the present work indicates that wide variation in the isomeric purity of the main component similarly has no effect. Downham *et al.* (2003), observed no differences in catches with lures containing 0.01 or

0.1 mg, at least up to two weeks of age, or between polyethylene vial or rubber septa dispensers (despite the large difference in pheromone longevity within these dispensers shown by the quantitative residue experiment). From the present work we note that catches with IPS lures (containing 0.46 mg pheromone) in the combined purity and lure age experiment were very similar to those with NRI lures (0.1 mg). It may be argued that the IPS lures also differed in the blend ratio (100:11:6) and isomeric purity of the main component (95%) and therefore the comparison is not strictly valid. However, the previous findings with respect to these factors (above) suggest that these would not have affected catches, and thus a comparison can reasonably be made in terms of lure dose. In any event results with the IPS lures indicate that the commercially produced lures were as effective as those produced at NRI.

From the results of the trap and lure optimisation experiments an effective and practical trapping system for *M. vitrata* has now been developed for the first time. The 0.1 mg polyethylene vials showed no loss of attractiveness for up to 4 weeks under field conditions, although the precise dose, blend ratio or isomeric purity of the EE10,12-16:Ald and EE10,12-16:OH components are not critical in achieving catches in the field. The isomeric purity results are significant from the practical view-point because the eventual cost of commercially produced lures would be heavily determined by the extent of purification required. If, as appears possible, a lower level of purity can be used without a marked loss of attractiveness, this will help to ensure the economic viability of pheromone trap monitoring of *M. vitrata* by farmers and extension workers. The best trap height is 120 cm and the most effective traps are those produced from locally available plastic jerry-cans. Not only are these relatively much cheaper than imported, commercial designs (less than US$1.00 compared to US$3.00 or more), they are easy to construct and robust in use as Smit *et al*. (1997) also found for traps for sweetpotato weevils. To utilise traps at a practical level some quantitative or qualitative relation now needs to be established between trap-catches of adults and the incidence of larval attack in cowpea fields. This is the subject of on-going work, initial results of which are positive (Downham unpub. data; Rurema, 2001) and indicate that larval infestations generally commence several days after the first trap captures.

The capture of female moths in all of the experiments confirmed our earlier observations of this phenomenon (Downham *et al*., 2003). Possible explanations include incomplete identification of the natural pheromone and direct attraction of females to the synthetic lures or to previously trapped males. We consider the first of these unlikely, partly because of the extensive identification work done with strains of *M. vitrata* of several different geographical origins (Downham *et al*., 2003), but particularly because incomplete pheromone blends generally produce lower catches of males, rather than co-attraction of both sexes. The latter two possibilities were tested in the laboratory by Mondhe (2001) and appeared unlikely, although further work would be merited. We now see, from the present results, variability in the proportion of females captured that also needs to be explained.

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# Tables

**Table 1.** Mean catches/trap of *Maruca vitrata* in the first trap design experiment at IITA, Cotonou, Benin using lures containing 0.1 mg of EE10,12-16:Ald, EE10,12-16:OH and E10-16:Ald in a 100:5:5 ratio (5 replicates; October - December 1998).

| Trap design | Males | | Females | |
|---|---|---|---|---|
| | Mean | SE | Mean | SE |
| Delta | 3.0 b | 1.6 | 3.2 b | 1.5 |
| Water-pan | 7.6 ab | 3.4 | 9.0 a | 3.5 |
| Funnel | 11.0 a | 4.0 | 6.4 ab | 2.7 |

Means within a column followed by a common letter were not significantly different (P > 0.05, LSD following ANOVA).

**Table 2.** Mean catches/trap of *Maruca vitrata* in the second trap design experiment, at IITA, Cotonou, Benin using lures containing 0.1 mg of EE10,12-16:Ald, EE10,12-16:OH and E10-16:Ald in a 100:5:5 ratio (5 replicates; September - November 1999).

| Trap design | Males | | Females | |
|---|---|---|---|---|
| | Mean | SE | Mean | SE |
| Delta | 4.0 b | 0.8 | 1.4 c | 0.5 |
| 1.5-l bottle | 5.0 b | 1.1 | 2.8 bc | 0.6 |
| 2-l jerry | 10.8 a | 2.0 | 6.0 ab | 1.7 |
| 5-l jerry | 13.0 a | 1.8 | 7.4 a | 1.3 |

Means within a column followed by a common letter were not significantly different (P > 0.05, LSD following ANOVA).

**Table 3.** Mean catches/trap of *Maruca vitrata* in funnel traps at different heights above ground, at IITA, Cotonou, Benin using lures containing 0.1 mg of EE10,12-16:Ald, EE10,12-16:OH and E10-16:Ald in a 100:5:5 ratio (5 replicates; July - October 1999).

| *Height* | Males | | Females | |
|---|---|---|---|---|
| | Mean | SE | Mean | SE |
| 20 cm | 5.6 bc | 1.2 | 0.2 a | 0.2 |
| 70 cm | 6.8 ab | 0.6 | 1.4 a | 0.4 |
| 120 cm | 10.4 a | 1.4 | 0.6 a | 0.4 |
| 170 cm | 3.4 c | 1.3 | 1.2 a | 1.0 |

Means within a column followed by a common letter were not significantly different (P > 0.05, LSD following ANOVA).

**Table 4.** Mean catches/trap of *Maruca vitrata* in delta traps with lures of different age ranges and shielded or unshielded from sunlight, at IITA, Cotonou, Benin using lures containing 0.1 mg of EE10,12-16:Ald, EE10,12-16:OH and E10-16:Ald in a 100:5:5 ratio (5 replicates; August - November 1999).

| Lure | Males | | Females | |
|---|---|---|---|---|
| Characteristic | Mean | SE | Mean | SE |
| 0-2 weeks old | 11.9 a | 1.0 | 2.7 a | 0.5 |
| 2-4 weeks old | 10.6 a | 1.1 | 1.2 b | 0.4 |
| 4-6 weeks old | 6.3 b | 0.9 | 0.9 b | 0.3 |
| | | | | |
| Shielded | 9.4 a | 1.0 | 2.2 a | 0.4 |
| Unshielded | 9.8 a | 1.0 | 1.0 b | 0.2 |

Means within a column followed by a common letter were not significantly different ($P > 0.05$, LSD following ANOVA); means for different age ranges averaged across both shielding classes and *vice versa*.

## ANNEX 6 – Publication 6

Adati, T., Tamò, M., Yusuf, S.R., Downham, M.C.A., Singh, B.B. and Hammond, W. Integrated Pest Management for Cowpea-Cereal Cropping Systems in the West African Savannah. In: “Integrated Pest and Vector Management in the Tropics: Perspective and Future Strategies.” Proceedings of the 15th Conference of the African Association of Insect Scientists and the Entomological Society of Kenya, 9-13 June 2003, International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya.

# INTEGRATED PEST MANAGEMENT FOR COWPEA-CEREAL CROPPING SYSTEMS IN THE WEST AFRICAN SAVANNA

**T. ADATI[1], M. TAMÒ[2], S. R. YUSUF[3], M. C. A. DOWNHAM[4], B. B. SINGH[1] AND W. HAMMOND[2, †]**

[1] International Institute of Tropical Agriculture, Kano Station, Sabo Bakin Zuwo Road, PMB 3112, Kano, Nigeria;

[2] International Institute of Tropical Agriculture, Benin Reserch Station, 08 BP 0932 Tri Postal, Cotonou, Bénin;

[3] Crop Production Programme, School of Agriculture, Abubakar Tawafa Balewa University, PMB 0248, Bauchi, Nigeria;

[4] Natural Resources Institute, University of Greenwich, Central Avenue, Chatham Maritime, Chatham, ME4 4TB, UK

Running title: IPM for cowpea cropping systems in West African savanna

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Corresponding author: TA.

[†] Present address:

**Abstract—**Cowpea (*Vigna unguiculata* (L.) Walp.) is an important crop as a component in the mixed cropping systems, which conform with the agroecological characteristics of the West African savanna. However, the contribution of cowpea to overall productivity for the systems is small because insect pests are the serious constraints to its production. Compared with the humid zone, the features of insect pests in the savanna region are: 1) a higher concentration of pest incidence during the limited cultivation period, 2) a more advantageous situation for generalist and migratory pests in the scanty and unstable vegetation, and 3) lower parasitism rates of parasitoids in the pest population. Among those pests, the key pests which are currently important in West African savanna are the legume flower thrips, *Megalurothrips sjostedti* (Trybom) (Thysanoptera: Thripidae), the legume pod borer, *Maruca vitrata* (Fabricius) (Lepidoptera: Pyralidae), and the pod sucking bug, *Clavigralla tomentosicollis* Stål (Hemiptera: Coreidae). To control these insects, the pest management practices including resistant cowpea varieties, cropping systems, botanical insecticides, biological control and pest monitoring, have been developed. Nevertheless the knowledge accumulated so far suggests that there is no single component that is effective by itself, but specific combinations could work synergistically. This paper highlights recent progress in integrated pest management (IPM) strategies in cowpea-cereal based systems in the West African savanna.

***Key Words*:** cowpea, IPM, West Africa, *Megalurothrips sjostedti*, *Maruca vitrata*, *Clavigralla tomentosicollis*, resistant variety, botanical insecticide, biological control, pest monitoring

**Résumé—**Le niébé (*Vigna unguiculata* (L.) Walp.), composante dans le système de culture associée conforme aux caractéristique agroécologique de la savanne Ouest Africaine, est une plante importante. Cependant, la contribution du niébé à la productivité du système dans son ensemble n’est pas significative à cause de l’infuluence des ravageurs, contrainte sérieuse à cette productivité. Comparer à la zone humide, les caractéristiques des ravageurs dans cette region de la savanne sont: 1) une grande concentration de l’incidence des ravageurs pendant la période très limitée de culture, 2) une situation plus avantageuse et généralisée pour les ravageurs migratoires au sein de la végétation mince et instable, et 3) le taux bas du parasitisme des parasitoïdes au sein de la population. Parmi les ravageurs, les plus courant en Afrique de l’Ouest sont les thrips, *Megalurothrips sjostedti* (Trybom) (Thysanoptera: Thripidae), les pineuses, *Maruca vitrata* (Fabricius) (Lepidoptera: Pyralidae), et les suceuses, *Clavigralla tomentosicollis* Stål (Hemiptera: Coreidae). Concernant le control, la gestion des ravageurs y compris la séléction des variétés résistantes, le systeme de culture, les insecticides botaniques, le control biologique, et la supervision des ravageurs ont été developpés. Néanmoins, malgré les connaissances acquises, il n’y a pas de pratique qui marche seule. Cependant, des combinaisons de pratiques marchent en synergie de manière effective. Ce papier met en lumière les stratégies de la lutte intégrée des ravageurs (IPM) dans le système basé sur l’association mil-niébé en Afrique de l’Ouest.

***Mots Clés*****:** niébé, IPM, Afrique de l’Ouest, *Megalurothrips sjostedti*, *Maruca vitrata*, *Clavigralla tomentosicollis*, variété résistante, insecticide botanique, control biologique, supervision des ravageurs

## INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp.) is an important legume of the tropics and subtropics with various uses. Grains are used for main meal dishes and snacks, while fresh leaves, pods and peas are used as vegetables. The haulm is also a great source of livestock feed. Since all edible parts of the plant are nutritious, providing protein, vitamins and minerals, cowpea is of great value to human and livestock health. Cowpea is grown throughout West Africa from moist to dry savanna zones in a variety of crop mixtures. Due to its drought tolerance and unique ability to fix nitrogen, the importance of cowpea as a component crop is greater towards the northern areas, where rainfall is less and soils are poor. It is also shade-tolerant and, therefore, suitable for the mixed cropping systems with cereals and root crops. Subsistence farmers in West African savanna usually intercrop their cowpea with maize, sorghum, millet, and cassava.

Although cowpea is an important component in the cereal-based cropping systems, the contribution of cowpea to overall productivity is small (Mortimore et al., 1997). This yield gap is principally due to both abiotic (e.g. drought, poor soil fertility) and biotic (e.g. arthropod pests, diseases, birds and rodents) factors. In most of West Africa, insect pests are reported to be the single most important constraint to cowpea production (Singh et al., 1990). Since the late 1970s, extensive studies on insect pests of cowpea in West African savanna have been lead by the entomologists from International Institute of Tropical Agriculture (IITA) (Singh and Taylor, 1978; Jackai et al., 1985; Bottenberg et al., 1997; Tamò et al., 2002). This stream of studies have hailed the global trend of integrated pest management (IPM), which intended to reduce harmful influences on the environment. However in West Africa, apart from environmental and human health concerns, there are also socio-economic implications that make the use of synthetic insecticides problematic. Among these are low level of farmers’ education, lack of capital, high prices of insecticides, lack of input market and access to recommended insecticides (Coulibaly et al., 2002, in press). As advocated by Jackai and Adalla (1997), pest control practices in cowpea should rely on IPM, where synthetic insecticides are used when all other measures fail to keep pests below acceptable levels.

This paper firstly summarizes the features of insect pests in savanna regions and some key pests in the cowpea-cereal cropping systems, and then highlights recent progress of IPM strategies for some key pests in the West African savanna.

## FEATURES OF INSECT PESTS IN WEST AFRICAN SAVANNA

Compared with the humid zone, the features of insect pests in the savanna region are: 1) a higher concentration of pest incidence during the limited cultivation period, 2) a more advantageous situation for generalist and migratory pests in the scanty and unstable vegetation, and 3) lower parasitism rates of parasitoids in the pest population.

In the moist savanna, the rainfall pattern is bimodal and cowpea can produce two crops, the first rainy season lasts from April to July, and the second from mid-September to November. Meanwhile in the dry savanna, the beginning and length of monomodal rainy season depend on the latitude. As shown in Fig. 1, high pest incidence is observed throughout only one rainy season without interruption in Kano located in the dry savanna, while the pest occurrence is relatively low and sporadic during two rainy seasons in Cotonou in the moist savanna.

Apart from their target crop as a main host, some insect pests have alternative hosts, depending on the host range of the pests. In the dry savanna, however, it is not rare that host plants entirely disappears in the periods other than the cropping season. To such a harsh environment, some insects have adapted with some specific traits such as broader host range and the ability to diapause and/or migrate seasonally. In savanna and sahelian regions of West Africa, the legume pod borer, *Maruca vitrata* (Fabricius) (Lepidoptera: Pyralidae) and the Senegalese grasshopper, *Oedaleus senegalensis* Krauss (Orthoptera: Acrididae) are known as the species which conduct seasonal migration (Launois and Launois-Luong, 1989; Bottenberg, et al., 1997).

In terms of natural enemies, their abundance seems to depend on vegetation of the region rather than the host insect population. Arodokoun (1996) reported that the parasitism level in *M. vitrata* collected from cowpea was lower than those in the pest collected from other alternative hosts. This fact suggests that the parasitism rates in the pests would be low in the dry savanna where the vegetation including host plants of the pests is poor and unstable. In fact, the overall parasitism rate in Kano fluctuated between 4 and 9 % year by year (Bottenberg et al., 1997; Adati et al., unpublished data).

## KEY PESTS OF COWPEA

The polyphagous and/or migratory pest species, which are adaptable to the difficult condition in the savanna, as mentioned in the previous section, can be the key pests in this region. Among a large number of cowpea pest species, the common key pests which distribute in the West African savanna are: the cowpea aphid, *Aphis craccivora* Koch (Homoptera: Aphididae), the legume flower thrips, *Megalurothrips sjostedti* (Trybom) (Thysanoptera: Thiripidae), the legume pod borer, *M. vitrata* and the brown pod sucking bug, *Clavigralla tomentosicollis* Stål (Hemiptera, Coreidae), and the cowpea bruchid, *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae). Of these, considerable attention has been devoted to *M. sjostedti*, *M. vitrata,* and *C. tomentosicollis* as the target pests in the cowpea-cereal cropping systems in West African savanna**.**

## COMPONENTS OF IPM STRATEGIES

There are a large number of conceptual definitions of IPM. The historical change of the definitions of IPM was summarized by Bajwa and Kogan (2002). According to them, nowadays IPM is commonly referred to as a "crop protection/pest management system" with implication for both methodological and disciplinary integration in the socioeconomic context of farming systems.

Based on the above definition, as components of the strategies for cowpea-cereal cropping systems in the West African savanna, this section contains resistant cowpea varieties, cropping systems, botanical insecticides, biological control, and pest monitoring.

**Resistant cowpea varieties**

Cowpea varieties which have resistance to insect pests have been developed after evaluating hundreds of germplasm accessions from the gene bank at IITA. A number of varieties which combine resistance to aphid, thrips and bruchid have been developed (Singh et al., 1996; 2002). Among the new varieties, IT97K-207-15, IT95K-398-14, and IT98K-506-1 have a high level of bruchid resistance (Singh, 1999). Nkansah and Hodgeson (1995) confirmed resistance of TVu 801 and Tvu 3000 to a Nigerian strain of aphid. However, only low levels of resistance have been observed for *M. vitrata* and pod sucking bugs, which cause severe damage and grain yield reduction in cowpea. Several studies have suggested mechanisms of varietal resistance to *M. vitrata*. Veeranna and Hussain (1997) found TVx 7 to be resistant and it has a high density of trichomes. Veerappa (1998) reported that the tolerant lines screened out of 45 breeding lines had higher phenol and tannin contents compared to susceptible lines. Singh et al. (2002) suggested that cowpea varieties with pigmented calyx, petioles, pods and pod tips suffer less damage due to *M. vitrata*.

Genes conferring resistance to *M. vitrata* and pod sucking bugs were found to exist in the genomes of some wild *Vigna* species such as *V. vexillata* and *V. oblongifolia*, but the efforts to transfer these genes from the wild *Vigna* spp. to cowpea have not been successful (Fatokun, 2002). Recently, Koona et al. (2002) reported antibiotic effects of the wild cowpea subspecies, *V. ungiculata dekinditiana* to *C. tomentosicollis*.

Laboratory screening techniques for resistant varieties have been developed. Jackai (1991) used dual-choice arena test, provided a choice of the pods from two cowpea varieties to the *M. vitrata* larva for 72 h. In this test, two wild cowpea relatives TVNu 72 and TVNu 73 were identified with high levels of resistance.

Field screening is often difficult due to low or unknown level or different timing of insect infestation. Adati et al. (unpublished data) demonstrated that the larval incidence of *M. vitrata* differed with maturing period of cowpea varieties although the stage-specific mortalities throughout the larval stages were not significantly different between the varieties. This suggests that the temporal relationship between the oviposition and the cowpea phenology greatly influenced the pest incidence.

To avoid the effect of crop phenology and timing of pest immigration on the pest incidence, 121 breeding lines were classified into five groups by maturing period and the lines in each group were planted at the same time in Kano, northern Nigeria (Yusuf, et al., unpublished data). Within each of the groups, the breeding lines were compared for *M. vitrata* resistance. As a result, significant difference in the pod borer incidence was seen among the varieties in the groups I (extra early maturing) and II (early maturing). The least incidence of *M. vitrata* was observed in extra-early maturing IT93K-452-1 (1.2 larvae/flower) and early maturing IT86D-719 (48% pod damage).

**Cropping systems**

The traditional farming practice in Africa is that crops are often cultivated in mixtures, such as various patterns of mixed cropping or intercropping. This was with a view to ensure food security, optimal use of soil and space, maintenance of soil fertility, erosion control, reduction of the need for weeding, and the possible reduction in the incidence of insect pests and diseases. But given the susceptible nature of cowpea to disease and insect attack, several studies have been conducted to determine the best option in a cowpea-cereal based systems. Singh and Emechebe (1998) screened ten cowpea varieties under sole cropping and intercropping with millet with and without insecticide application. They reported that the grain yield of intercropped cowpea was generally higher than that from the sole crop when no insecticide was applied, indicating less insect damage under intercropping. Mensah (1997) reported lower incidence of *M. vitrata* and pod sucking bugs, but higher incidence of *M. sjostedti* in a cropping system with one row of sorghum alternated with two rows of cowpea. However, several trials have demonstrated that there was insufficient evidence to suggest intercropping reduces infestations on cowpea by *M. vitrata* in a consistent and predictable manner (Ezueh and Taylor, 1984; Lawson and Jackai, 1987; Oghiakhe et al., 1991). It has been suggested that certain crop arrangement probably predisposes crops in a mixture to a higher infestation by certain insect pest. Such contradictory reports on the effects of intercropping on pest attack could probably be attributed to the difficulty of teasing out the ecological factors that can affect insect plant relations. Andow (1991) analyzed 209 studies involving 287 pest species. Compared with monocultures, the population of insect pests in intercrops was lower in 52 % of the studies (149 species) and higher in 15 % (44 species). Of the 149 pest species with lower populations in intercrops, 59 % were monophagous and 28 % polyphagous.

To make a further elucidation on the implication of pest incidence to cowpea yield in cowpea-cereal based systems, the effect of cropping system, cowpea variety and insecticide application on pest incidence and grain yield was investigated in Kano (Yusuf et al., unpublished data). As shown in Table 2, the grain yield was significantly higher in sole cropping among others with and without insecticide application than that in intercropping (a row of sorghum and a row of cowpea alternately planted) and strip cropping (two rows of sorghum and four rows of cowpea alternately planted). No significant difference was observed in the incidence of *M. vitrata* and thrips between the cropping systems. However, the resistance of the cowpea varieties to the legume pod borer differed within the cropping systems. For example, significantly higher incidence of *M. vitrata* occurred on IT90K-277-2 than other varieties under sole cropping with insecticide application, while no significant difference was observed between the varieties under strip cropping and intercropping (Table 2).

Although there have been more cases that mixed cropping reduce pest population rather than sole cropping, its effect seems to depend on combination of crops or varieties in the cropping system, host range of the pest insects, and fauna of natural enemies, as well as the schedule of insecticide application. The present result suggests that grain productivity from intercropping and strip cropping could be further enhanced by two applications of insecticide on the cowpea crop (Table 2). Further studies are needed to clarify the best options combined with cropping system, cowpea varieties, and insecticide application, according to regional circumstances.

**Botanical insecticides**

In these days when it is well understood that the misuse of synthetic insecticides causes costly environmental pollution and disruption of the balance of nature, development of environment-friendly insecticides is to be desired. Since old times it has been known that several plants have insecticidal and repellent effects. Among them, neem, *Azadirachta indica* A. Juss (Meliaceae) was introduced from India to West Africa in 1920s, and subsequently neem has been studied for its inhibitory effects on insect pests. Even during the golden days of synthetic insecticides in other parts of the world, inaccessibility to the products in Africa spurred the studies on botanical insecticides. Jackai (1993) reviewed extensive studies on the use of neem in controlling cowpea pests. In the late 1990s, IITA and national agricultural research and extension systems (NARES) initiated a collaborative research and technology dissemination project for cowpea production in several West African countries. In this project, the effects of botanical insecticides, the leaf extracts of neem, papaya, *Carica papaya* L. (Caricaceae) and the African mint, *Hyptis suaveolens* Poit. (Lamiaceae) have been evaluated.

In 2002, at Sekou in the southern moist savanna zone of Benin, leaf extracts of neem, papaya and *Hyptis* were tested with applications at 5-day intervals on the cowpea variety, KVx61-1 till pod maturity (Hammond et al., unpublished data). As shown in Table 3, significantly higher grain yield was obtained when *Hyptis* extract was applied. This application simultaneously reduced the population of thrips. Although neem and papaya applications gave 170–610 kg/ha of gains in grain yield, no statistically significant effects were observed in the pest incidence and yield. Meanwhile at Kano in the dry savanna , neem leaf extract was tested with 13 applications in total at 7-day intervals on the cowpea variety, IT90K-277-2 (Adati et al., unpublished data). The grain yield for the plots with neem application was significantly higher than that for no application plots, but it was not significantly different from the yield for plots with the soap solution, which was added as a sticker in the neem extract preparation (Table 4). Therefore, no clear effect of neem leaf extract on the pest incidence and grain yield was confirmed in this experiment. In both of the above cases, neem leaves were collected from the nearby fields. Thus, regional variation in quality of the extracts should be considered. In respect of neem, apart from leaf extract, the aqueous seed (kernel) extract and kernel oil were reported to be effective for the control of crop and vegetable pests in northern Nigeria (Anaso and Lale, 2001a; 2001b). Generally, the use of botanical insecticides is more labour intensive than synthetic insecticides, as the number of applications shown in the above experiment. Further studies on the labour cost for the practice are necessary.

**Biological control**

During the 1980s and early 1990s, researches on biological control against cowpea pests had mainly focused on exploiting the naturally occurring interactions between pests and their locally available antagonist (Jackai and Daoust, 1986; Tamò et al., 1993a). In most of these cases, however, the overall level of pest control exerted by the indigenous antagonist was observed to be inadequate for controlling the intended pest population. Presently, research at the IITA and other centres like the International Centre of Insect Physiology and Ecology (ICIPE) is continuing to develop longer lasting solutions to the cowpea pest problem, of which biological control is one of the pillars.

In West Africa, *Ceranisus menes* Walker (Hymenoptera: Eulophidae) was known to be a larval endoparasitoid for the legume flower thrips, *M. sjostedti* (Tamò et al., 1993b). But subsequent studies revealed poor field parasitism rate on cowpea (Table 5), averaging below 1 % (Tamò et al., 1997) and physiological incompatibility in parasitizing *M. sjostedti* (Diop, 2000). In 1998, *C. femoratus* Gahan collected from flowers of *Centrosema pubescens* Benth. and *Millettia* sp. (Fabaceae) in southern Cameroon was identified as a parasitoid for *M. sjostedti*. This newly discovered parasitoid was then introduced in to the IITA Benin Research Station and experimental releases were carried out in the coastal savanna in Benin and Ghana. In Benin, during the first 1.5 years following release, the monthly average of parasitism by *C. femoratus* remained substantial (Tamò et al., 2003). The parasitsm was, however, subjected to seasonal variation, largely influenced by the flowering phenology of the available host plant. Furthermore, several studies suggested that some of the released parasitoids eventually became established, but their potential impact might still be masked by the continuous and inappropriate use of insecticides.

Natural enemies of the legume pod borer, *M. vitrata* in Africa were summarized by Tamò et al. (1997). From West Africa, the larval parasitoids such as *Phanerotoma leucobasis* Kriechbaumer (Hymenoptera: Braconidae) and *Braunsia kriegeri* Enderlein (Hymenoptera: Braconidae) and the egg parasitoids, *Trichogrammatoidea ?eldanae* Viggiani (Hymenoptera: Trichogrammatidae) have been reported (Arodokoun, 1996; Tamò et al., 1997; Zenz, 1999). However, the available quantitative data indicate that overall parasitism rates on cowpea are low. In Kano, for instance, the annual parasitism rate fluctuated in the low level as shown in Table 1 (Bottenberg et al., 1997; Adati et al., unpublished data).

In 1998, a cypovirus (CPV) was found in southern Benin infecting larvae of *M. vitrata* on wild leguminous plants (Tamò et al., 2003). Disruption of the midgut of the host insect by CPV infection leads to nutritional deficiencies and a reduction in feeding, and CPV-infected pupae and adults are malformed, thus reducing survival and longevity as well as their mating ability and fecundity. Furthermore, as CPV is usually transmitted vertically to the next generation, the viability of offspring may be compromised (Belloncik, 1996). In laboratory studies at IITA, at least some of these characteristics have already been demonstrated in *M. vitrata* larvae infected with indigenous CPV (Tamò et al., 2003).

The pod sucking bug, *C. tomentosicollis* has become the target of investigations into the potential of entomopathogenic fungi as a pest management option. Isolates of *Beauveria bassiana* (Balsamo) and *Metarhizium anisopliae* (Metschnikoff) from Nigeria with good activity against eggs, nymphs and adult *C. tomentosicollis* were identified by Ekesi (1999) and Ekesi et al. (2002). More recently, *M. anisopliae* isolate ICIPE 69 has been found to be active against adult *C. tomentosicollis* in Benin (Tamò et al., 2003). Egg parasitoids such as *Gryon fulviventris* Crawford (Hymenoptera: Scelionidae) are very common and have been observed inflicting high mortality to *C. tomentosicollis* egg batches (Asante et al., 2000). However, in most of the cases, they cannot prevent feeding damage by *C. tomentosicollis* in the field, which is caused by migrating adults before oviposition.

**Pest monitoring**

A recent interesting development in the area of pest monitoring concerns pheromone traps for *M. vitrata*. Laboratory studies by Adati and Tatsuki (1999) indicated that (*E*,*E*)-10,12-hexadecadienal (EE10,12-16:Ald) and (*E*,*E*)-10,12-hexadecadienol (EE10,12-16:OH), were major and minor components, respectively, of the *M. vitrata* sex pheromone. But they also reported the antagonistic effect of isomeric impurities in the synthetic pheromone on its attraction. Downham et al. (2003) extended this work by demonstrating that in field experiments in Benin, traps baited with polythene vials containing 0.1 mg of a blend of EE10,12-16:Ald, EE10,12-16:OH and E10-16:Ald in a 100:5:5 ratio caught significantly more males than traps baited with the major component alone, either two-component blend or virgin female moths. Furthermore, the precise dose, blend ratio or isomeric purity of the EE10,12-16:Ald and EE10,12-16:OH components have been found not to be critical in achieving catches in the field (Downham et al., unpublished data). These lures remain attractive for at least four weeks under field conditions, and the most effective design for traps is one produced from 5-litre plastic jerry-cans as shown in Fig. 2 (Downham et al., 2002). These are also easy to construct and robust in use. The cost of fabrication, installation and maintenance of one such trap over a season, including lures and manpower, is approximately US$ 4.00 (O. Coulibaly, pers. comm.).

In contrast to southern Benin, the pheromone traps were ineffective in the northern region of West Africa. The efficacy of the pheromone traps was compared between different locations in Benin, Niger and Nigeria (Adati et al., unpublished data). Subsequently, at all the locations to the south of latitude 9º N, the maximum daily catches in the pheromone traps were 2.0–5.0 moths per trap. However, at the most of locations to the north of the same latitude, the maximum daily catches were very few (0–0.4 moths per trap) although there were large number of catches in the light trap at some locations in the same region. A marked exception was observed in Malanville (11º 52' N) on the Niger River, where the maximum daily catch was 20 moths per trap. A likely explanation appears to be a lowered responsiveness to the lures due to altered physiological or behavioural characteristics in the different geographical regions, including the migrating pattern, mated status, and host plant vegetation. Continuing investigations should resolve the issue and may indicate some ways in which traps can be made more effective in the dry savanna.

Of greatest practical significance was the finding that pheromone trap-catches occur up to 12 days before larval infestations in flowers and a week or more in advance of flowering within cowpea fields (Rurema, 2001; Downham, unpublished data). Thus, trap catches can signal impending infestations and provide an earlier warning than the appearance of flowers. Follow-up research in Benin and Ghana, led by Natural Resources Institute and IITA, is presently focussing on the development of a trap-based threshold. Afun et al. (1991) has shown previously that action thresholds based on larval-flower infestation rates could be used to improve the effectiveness of insecticide applications in cowpea. Preliminary trials of the trap-threshold concept in conjunction with botanical insecticides have provided evidence of its effectiveness, in terms of infestation rates and yield, compared to spraying based on crop stage. Results indicate superiority for spraying based on the trap threshold compared to that based on crop stage. A 3-day delay between attainment of the threshold and the commencement of spraying appears to be better than a 6-day delay, while a threshold of 2 moths per trap is better than 5 moths per trap (Fig. 3).

## PROSPECTS OF IPM IN WEST AFRICAN SAVANNA

The above sections summarized the recent progress in pest control strategies, giving a number of examples for various components. Nevertheless, the knowledge accumulated so far suggests that there is no single component that is effective by itself. For instance, the choice of a resistant cowpea variety or a cropping system alone will not be able to control in pest populations in a vast expanse of the West African savanna. However, if combined with applications of botanical and/or synthetic insecticides, of which appropriate dose and timing based on pest monitoring, it will definitely contribute to a sustainable solution for insect pest problem in the cowpea-cereal cropping systems.

As mentioned in the above section about resistant varieties, we have been getting some promising resistant breeding lines for the key pests. Constant efforts to screen the new varieties should be necessary. A problem if the use of resistant varieties is widespread would be the possible development of insect biotypes. Biotypes are insect populations that have undergone genetic changes which allow them to survive on a host plant that was previously resistant to them. A possible solution to this problem is to reduce selection pressure on the pest population. To avoid monoculture in large area and to introduce mosaic or rotation farming with a mixture of resistant and susceptible varieties would be effective. Recently, transgenic crops which are resistant to insect pests have been developed, and this technology can be applied to cowpea as well. But we should take notice that insect pests can develop their resistance to the toxin produced by the transgenic crops, as they can develop it against synthetic insecticides and conventional resistant varieties.

Compared to resistant varieties and cropping systems, biological control has been behind in research and development particularly in the dry savanna of West Africa. However, recent progress in the use of egg parasitoids and entomopathogenic viruses promises well for the future. To utilize these control agents effectively, it is particularly important that all other pest interventions remain compatible with biological control. Although never to use synthetic insecticides would not be realistic in the dry savanna, where the incidence of specific insect pests is very high, yet it would be possible to keep the amount of insecticide application at minimum levels by applying the practice of pest monitoring.

Large scale pest monitoring, using light traps, organized by national or regional agricultural research and extension systems would contribute to establish a regional pest management program. Meanwhile, small scale monitoring with pheromone traps or visual scouting for pest population in the field would be very helpful in decision making for farmers to time the application of control measures. In this respect, implementation of pest monitoring provides a potential for farmers to understand the concept and strategies of IPM.

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**Table 1. Annual parasitism rate (%) of parasitoids in *Maruca vitrata* collected from cowpea field in Kano, Nigeria[a]**

| Parasitoid | 1992 | 1993 | 1994 | 2001 | 2002 |
|---|---|---|---|---|---|
| *Phanerotoma leucobasis* | 0.6 | 1.2 | 0.3 | 2.0 | 6.4 |
| *Braunsia kriegeri* | 7.7 | 3.3 | 0.0 | 2.4 | 1.7 |
| Tachinidae | 0.0 | 1.8 | 5.8 | 0.0 | 1.2 |
| Total | 8.2 | 6.3 | 6.1 | 4.3 | 9.3 |

[a] Source for 1992–1994: Bottenberg et al. (1997); 2001–2002: Adati et al., unpublished data.

**Table 2. Insect pest incidence on four cowpea varieties under three cropping systems with and without insecticide application (Yusuf et al., unpublished data)[a, b]**

| Treatment | Thrips/20 flower buds | | *M. vitrata* /20 flower buds | | Pod damage (%) | | Grain yield (kg/ha) | |
|---|---|---|---|---|---|---|---|---|
| | NA | AP | NA | AP | NA | AP | NA | AP |
| **Sole cropping** | | | | | | | | |
| IT90K-277-2 | 16.2 | 6.4 | 3.6 a | 1.1 a | 22.5 a | 5.3 a | 236 bc | 2281 b |
| IT93K-452-1 | 17.1 | 3.2 | 1.3 b | 0.3 b | 16.0 a | 5.5 a | 1242 ab | 1801 b |
| IT97K-499-38 | 19.9 | 2.1 | 3.7 a | 0.5 b | 20.8 a | 3.8 ab | 1560 a | 3337 a |
| Dan Ila | 8.4 | 6.7 | 0.7 b | 0.2 b | 2.2 b | 0.3 b | 0 c | 0 c |
| *F* LSD ($p$ <0.05) | *ns* | *ns* | 1.4 | 0.6 | 9.9 | 3.7 | 1161 | 703 |
| **Strip cropping** | | | | | | | | |
| IT90K-277-2 | 20.6 a | 5.1 | 3.7 a | 1.1 | 23.7 a | 8.8 a | 196 c | 1290 b |
| IT93K-452-1 | 21.2 a | 1.8 | 2.0 b | 0.3 | 15.0 b | 4.3 ab | 676 b | 1127 b |
| IT97K-499-38 | 29.3 a | 2.7 | 4.0 a | 1.1 | 18.5 ab | 6.8 a | 1165 a | 1776 a |
| Dan Ila | 2.6 b | 2.1 | 0.4 b | 0.8 | 2.8 c | 0.3 b | 0 c | 0 c |
| *F* LSD ($p$ <0.05) | 14.7 | *ns* | 1.6 | *ns* | 8.6 | 4.5 | 241 | 444 |
| **Intercropping** | | | | | | | | |
| IT90K-277-2 | 12.6 a | 3.0 | 3.4 ab | 0.9 | 27.6 a | 10.2 a | 184 c | 866 b |
| IT93K-452-1 | 23.2 a | 1.6 | 2.5 b | 0.4 | 18.9 a | 7.3 ab | 403 b | 690 b |
| IT97K-499-38 | 30.1 a | 2.7 | 5.0 ab | 0.7 | 23.1 a | 5.0 bc | 595 a | 1447 a |
| Dan Ila | 2.1 b | 0.9 | 0.5 c | 0.5 | 2.8 b | 0.9 c | 0 d | 0 c |
| *F* LSD ($p$ <0.05) | 15.8 | *ns* | 1.9 | *ns* | 10.9 | 5.2 | 140 | 326 |
| **Cropping systems** | | | | | | | | |
| Solecropping | 15.4 | 3.9 | 2.3 | 0.5 | 15.4 | 3.7 | 760 a | 1855 a |
| Stripcropping | 18.4 | 2.9 | 2.5 | 0.8 | 15.0 | 5.1 | 509 ab | 1048 b |
| Intercropping | 19.3 | 2.0 | 2.8 | 0.6 | 18.1 | 5.9 | 295 b | 751 c |
| *F* LSD ($p$ <0.05) | *ns* | *ns* | *ns* | *ns* | *ns* | *ns* | 321 | 240 |
| **Varieties** | | | | | | | | |
| IT90K-277-2 | 19.5 a | 4.8 a | 3.6 a | 1.1 a | 24.6 a | 8.1 a | 206 b | 1479 b |
| IT93K-452-1 | 20.5 a | 2.2 b | 1.9 b | 0.4 c | 16.6 b | 5.7 ab | 774 a | 1206 b |
| IT97K-499-38 | 26.4 a | 2.5 b | 4.2 a | 0.8 ab | 20.8 ab | 5.2 b | 1107 a | 2187 a |
| Dan Ila | 4.4 b | 2.2 b | 0.5 c | 0.5 bc | 2.6 c | 0.5 c | 0 b | 0 c |
| *F* LSD ($p$ <0.05) | 7.5 | 1.9 | 1.0 | 0.4 | 5.6 | 2.6 | 371 | 277 |

[a] For every sub-set of the data within the same column followed by the same letter are not significantly different ($p$ >0.05) by Fisher's protected LSD following ANOVA ($p$ < 0.05, *ns* : not significant) . Before analysis, data for insect numbers and pod damage proportion were square root and arcsine transformed, respectively.

[b] NA: no insectiside application; AP: insecticide applications at flowering and podding time.

**Table 3. Field trial of neem, papaya, and *Hyptis* leaf extract on pest incidence and grain yield in Sekou, Benin in 2002 (Hammond, et al., unpublished data)[a]**

| Treatment | No. of thrips (/flower) | No. of *M. vitrata* larvae (/10 flowers) | No. of pod sucking bugs observed (/plot) | Grain yield (kg/ha) |
|---|---|---|---|---|
| Neem | 5.1 b | 1.7 ab | 3.1 *ns* | 1133 b |
| Papaya | 5.2 b | 1.5 ab | 2.8 | 1572 ab |
| *Hyptis* | 4.7 b | 1.6 ab | 2.0 | 2102 a |
| Synthetic insecticide | 4.0 b | 1.0 b | 2.3 | 1867 a |
| No application | 7.3 a | 3.0 a | 4.6 | 960 b |

[a] Figures in the same column followed by the same letter are not significantly different ($p > 0.05$) by Tukey's test following ANOVA ($p < 0.05$, *ns* : not significant).

**Table 4. Field trial of neem leaf extract on pest incidence and grain yield in Kano, Nigeria in 2002 (Adati et al., unpublished data)[a]**

| Treatment | Aphid incidence (rating scale)[b] | No. of thrips (/flower bud) | No. of *M. vitrata* larvae (/10 flower buds) | No. of pod sucking bugs (/10 hills) | Pod damage (%) | Grain yield (kg/ha) |
|---|---|---|---|---|---|---|
| Neem | 5.2 a | 2.1 ab | 4.8 a | 5.0 ab | 26.7 bc | 510 c |
| Soap (control)[c] | 4.8 ab | 2.3 a | 5.4 a | 4.7 ab | 35.0 ab | 361 c |
| 2 SI applications[d] | 1.7 c | 1.6 ab | 3.7 ab | 4.5 ab | 20.2 c | 516 b |
| 3 SI applications[d] | (1 application only) | 0.2 b | 1.0 b | 2.8 b | 7.1 d | 1352 a |
| No application | 3.5 b | 2.9 a | 5.1 a | 8.1 a | 40.6 a | 2430 c |

[a] Figures in the same column followed by the same letter are not significantly different ($p > 0.05$) by Tukey-Kramer's test (except for aphid number grouped by Tukey's test) following ANOVA ($p < 0.05$). Before analysis, data for pod damage proportion were arcsine transformed.

[b] Rating scale: 0: no aphid/plant; 1: 1–4 aphids/plant; 3: 5–20 aphids/plant; 5: 21–100 aphids/plant; 7; 101–500 aphids/plant; 9: more than 500 aphids/plant.

[c] 0.1 % soap solution, which was added to neem extract as a sticker, was applied alone as control.

[d] SI (syntetic insecticide) was applied at 14-day intervals.

**Table 5. Assesment of parasitism inflicted by *Ceranisus menes* on larvae of *Megalurothrips sjostedti* collected from different host plants in Benin (adapted from Tamò et al., 2002)**

| Host plant | Viable *M. sjostedti* collected | Larvae parasitized | Parasitism (%) |
|---|---|---|---|
| *Cajanus cajan* (pigeonpea) | 694 | 3 | 0.4 |
| *Cochlospermum planchoni* | 235 | 45 | 19.1 |
| *Centrosema pubescens* | 2694 | 36 | 1.3 |
| *Dolichos africanus* | 374 | 30 | 8.0 |
| *Erythrinia senegalensis* | 558 | 81 | 14.5 |
| *Lonchocarpus cyanescens* | 5670 | 217 | 3.8 |
| *Lonchocarpus sericeus* | 8357 | 95 | 1.1 |
| *Pterocarpus santalinoides* | 7590 | 30 | 0.4 |
| *Tephrosia bracteolata* | 1750 | 102 | 5.8 |
| *Tephrosia candida* | 8220 | 361 | 4.4 |
| *Tephrosia platycarpa* | 1142 | 52 | 4.6 |
| *Vigna unguiculata* (cowpea) | 3822 | 5 | 0.1 |

Fig. 1. Adati et al.

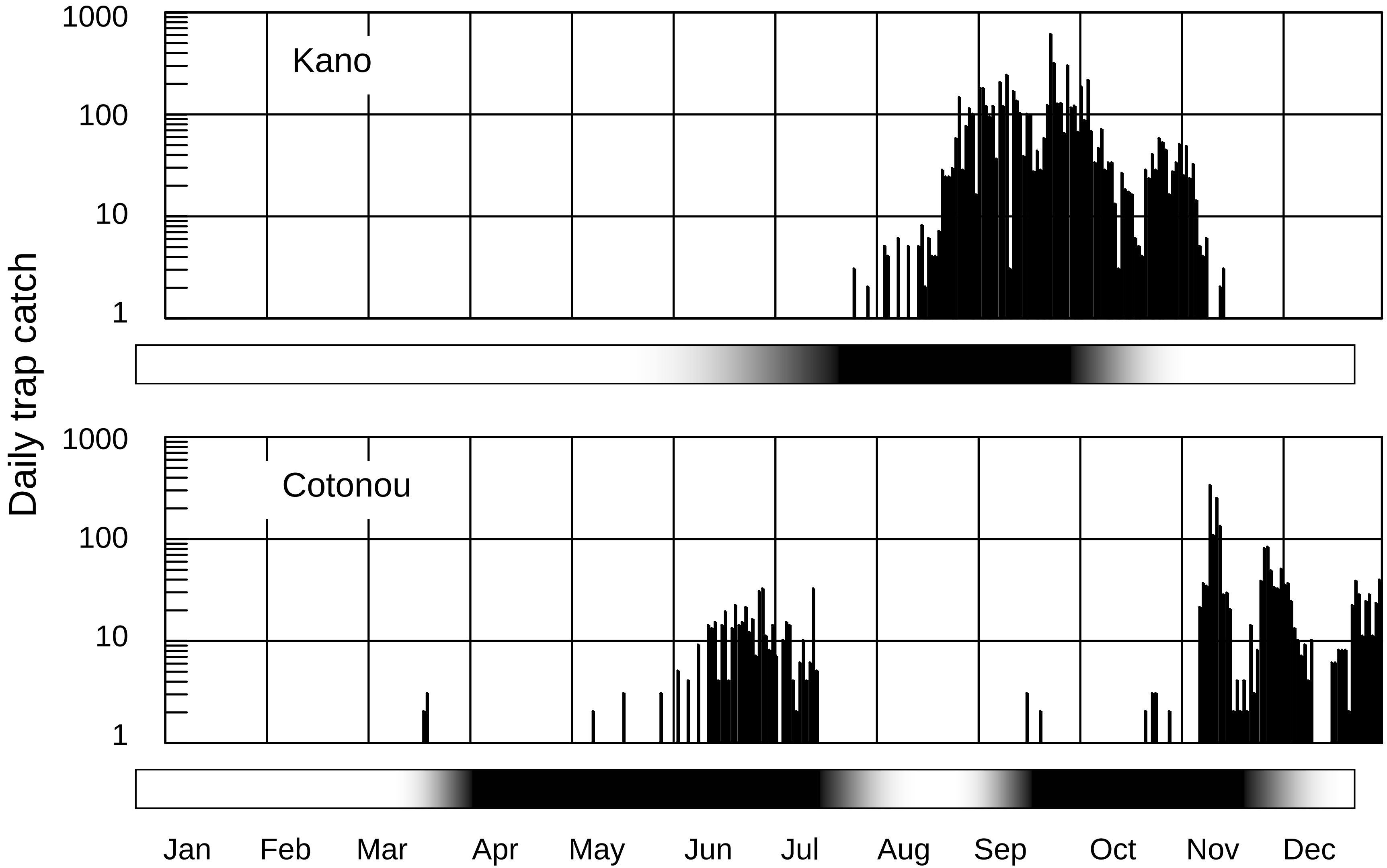


Fig. 2. Adati et al.

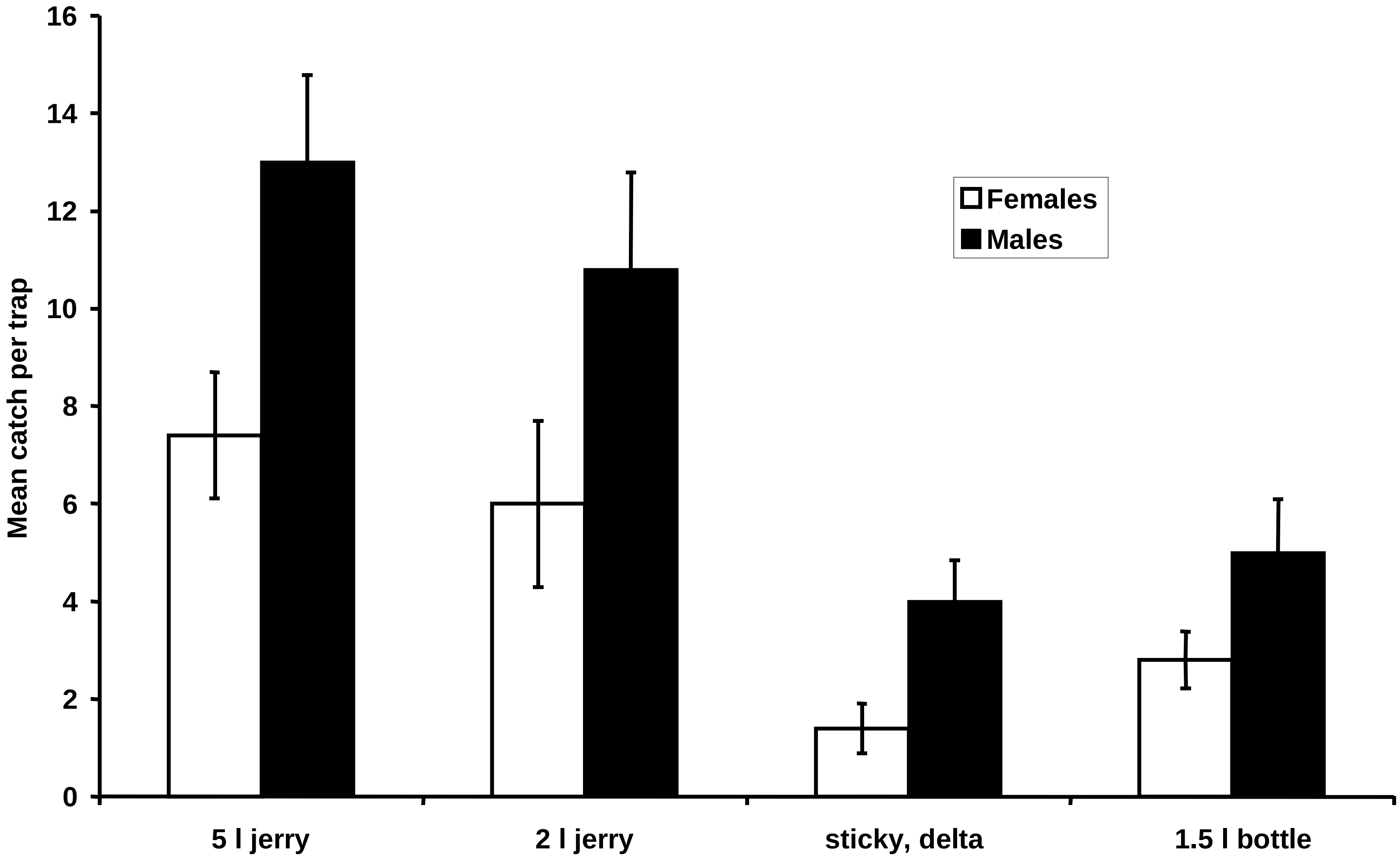
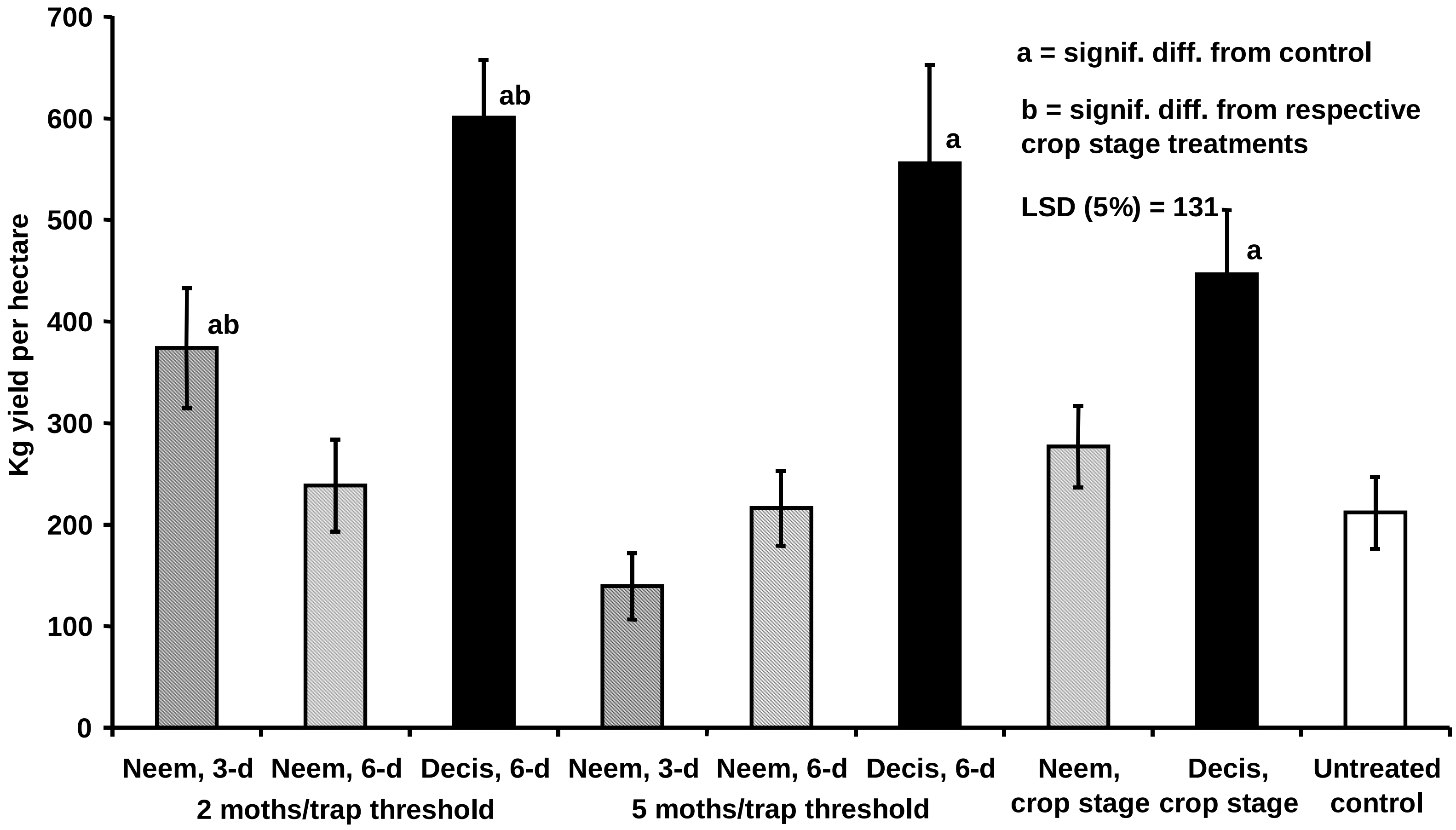


Fig. 3. Adati et al.



## Figure Legends

Fig. 1. Daily light trap catch of *Maruca vitrata* moth at Kano in the dry savanna and Cotonou in the moist savanna in 2002. Dark zones in the horizontal bars under the abscissas indicate rainy seasons. Source: Adati et al., unpublished data (Kano) and Downham et al., unpublished data (Cotonou).

Fig. 2. Mean catches/trap of *Maruca vitrata* in a trap design experiment, at IITA, Cotonou, Benin, September – November 1999 (adapted from Downham et al., 2002). Vertical bars indicate standard errors.

Fig. 3. Cowpea yields recorded in a test of the pheromone trap threshold concept (Downham, unpublished data). 3-d = 3 day delay between attainment of the threshold and spraying; 6-d = 6 day delay; ‘crop stage’ refers to spraying beginning at 25% flowering; Neem = neem leaf extracts; Decis = deltamethrin.

## ANNEX 7 – Publication 12

Étude coût-benefice des pièges à phéromone de *Maruca vitrata* (Cost-benefit study of *Maruca vitrata* pheromone traps). S. Adetonah, O. Coulibaly, C. Aitchedji and B. Datinon. Unpublished Report.

# ETUDE COUT-BENENFICE DES PIEGES A PHEROMONE DE *MARUCA VITRATA*

### Justification

Le niébé *Vigna unguiculata* est une légumineuse la plus cultivé au Bénin. Il joue un role important dans la sécurité alimentaire des populations rurales et du point de vue économique il est une source génératrice de revenus en milieu rural.

Cependant, il est affrontée à de nombreux problèmes qui limitent sa production ; ce sont les attaques des insectes, de maladies, le problème de stockage et le manque d'organisation du marché.à savoir les insectes et les maladies.

Beaucoup de méthodes de lutte ont été préconisées telle que la lutte biologique, les techniques culturales, les variétés améliorées et la lutte chimique. Parmi La lutte chimique s'avère efficace mais son danger sur la santé et l'environnement n'est pas négligeable.

Beaucoup de décès ont été enregistrés dans ses deux dernières années dans le Borgou et dans le Zou nord due à l'utilisation anarchique des insecticides coton précisément l'Endosulfan.

C'est pourquoi le projet de l'Institut des Ressources Naturelles en collaboration avec l'IITA, a initié un projet "Maruca phéromone Trap" dont le but est la gestion de la lutte intégrée en utilisant les pièges à phéromone qui signalent l'arrivée de la foreuse de gousses et de fleurs au champ. Cela permet de réduire les coûts et les périodes de traitements au champ du paysan.

### Objectifs

L'objectif principal de cette étude est d'analyser la rentabilité des pièges à phéromone permettant de réduire les coûts et les périodes de traitements.

Les objectifs spécifiques sont :

- évaluer la rentabilité financière des différents systèmes de production avec et sans piège à phéromone
- ressortir l'effet du changement du prix du phéromone
- montrer les avantages tangibles et intangibles de l'installation des pièges à phéromone en milieu rural.

**Méthodologie**

A) Echantillonnage

L'étude de perception sur les pièges à phéromone après le FFS de cette année a servi de base pour notre échantillonnage pour cette étude. Elle a pris compte les trois zones agro-écologiques (soudano-guinéenne à fotre pluviométrie(Couffo) ; soudano-guinéenne à faible pluviométrie(Colline) ; soudano sahélienne (Alibori)) avec un total de 118 producteurs de niébé enquêtées à Davihoué, Gbècochihoué, Assouhoué, Atchakpa, Gobé, Dani, Kantakpara, Sori, et Gounarou.

Au sein des 118 exploitations nous avons considéré les producteurs ayant utilisés au moins une fois les pièges dans leur champ ou ayant participés au moins à l'école paysanne (FFS) où les pièges ont été déjà instaurés dans le programme de formation des paysans.

Ainsi 56 exploitations ont été identifiées et sur lesquelles des enquêtes ont été conduites au milieu paysan.

La combinaison des différentes technologies a donné 21 systèmes de production dont seulement 8 sont rencontrés et retenues dans notre cas

Tableau 1 : Répartition de l'échantillon par système de production

| No | Systèmes de production | Effectif |
|---|---|---|
| 1 | Variété locale + sans insecticide + sans traitement + avec piège | 5 |
| 2 | Variété locale + insecticide recommandé et neem + 4 traitements + avec piège | 20 |
| 3 | Variété améliorée + insecticide recommandé (Décis)et neem + 6 traitements + avec piège | 2 |
| 4 | Variété améliorée + insecticide recommandé (orthène) et neem + 6 traitements + avec piège | 3 |
| 5 | Variété améliorée + insecticide recommamdé (orthène) + 6 traitements + sans piège | 7 |
| 6 | Variété locale + extrait neem/papayer + 6 traitements + sans piège | 10 |
| 7 | Variété locale + insecticide recommandé (orthène) et neem + 6 traitements + sans piège | 7 |
| 8 | Variété améliorée + extrait neem/papayer + 6 traitements + sans piège | 2 |

B) Collecte des données

Au premier niveau, les données primaires ont été collectées par le biais d'un questionnaire administré. à passage unique sur les 56 exploitations au cours du deuxième campagne de 2001

Au deuxième niveau porte sur la recherche des données secondaires auprès des structures impliquées dans le domaine de l'agriculture et des données prises dans la thèse de Casimir AITCHEDJI.

Au troisième niveau porte sur les interviews des personnes pour recueillir des informations complémentaires nécessaires pour les analyses coût/bénéfice.

Les coûts concernent essentiellement les intrants, la main d'œuvre familiale et salariée, et le matériel (équipements).

Les intrants sont seulement les insecticides recommandés, les insecticides coton, et les extraits aqueux de neem et de papayer

La main d'œuvre est évaluée en nombre d'hommes jours de travail par hectare. Elle constitue le temps mis pour chaque activité de l'installation des pièges.

Le matériel est évalué par le prix sur le marché du bâton, de bidon, de leurre, du savon du fil de fer, etc …

La production est estimée en terme de rendement et évaluée en hectare (avec piège et sans piège)

C) Méthode d'analyse

Les données ont été principalement traitées avec le logiciel Excel et SPSS et un budget financier partiel a été estimé pour chaque système de production qui contribue aux ressources.

Les prix financiers sont ceux que les paysans paient ou reçoivent réellement.

Les quantités physiques des intrants, de la main d'œuvre et du matériel sont utilisés pour le piège et exprimés dans le tableau 2 (voir annexe)

## Resultats et Discussion

Cette section présente les résultats de l'étude. L'analyse est faite en deux parties complémentaires. La première partie présente la rentabilité financière des différents systèmes de production avec ou sans piège à pheromone. Cette partie a été complétée par une analyse de sensibilité pour ressortir l'effet du changement du prix du pheromorne. Tandis que la deuxième partie montre les avantages tangibles et intangibles de l'installation des pièges a pheromorne. A ce niveau, nous avons fait la comparaison entre le coût de l'installation des pièges et ce que le producteur gagne en terme de réduction du nombre de traitements phytosanitaires.

***Première partie :***

Les tableaux 5 présentent les résultats de l'analyse coût-bénéfice des systèmes de production du niébé utilisant des pièges ou sans piège. Huit (8) systèmes production ont été identifiés dont quatre (4) systèmes dans lesquels les producteurs ont introduit la technique du piège à pheromorne et quatre systèmes sans pièges. A ce niveau de l'analyse, nous avons distingué 4 scénarios en faisant varier le prix d'achat au producteur du pheromone (prix unitaire du pheromone : cas1=200, cas2=250, cas3=300, cas4=430 FCFA). Mais, les résultats obtenus n'ont pas montré une différence très significative au niveau de la rentabilité des systèmes étudiés.

A travers ces résultats, nous constatons que tous les huit (8) systèmes (avec piège et sans piège) étudiés sont financièrement rentables (Marge brute positive ou Ratio B/C financier >1). Ceci signifie que l'activité de production du niébé est toujours rentable au producteur quelle que soit l'option choisie: utilisation ou non utilisation des pièges des Nous pouvons ressortir ici quelques résultats. Notamment, ceux des 4 systèmes de production dans lesquels on a installé des pièges :

- Variété Locale + sans traitement + avec piège (ratio B/C financier = 2.3)
- Variété Locale + Insecticides recommandés (orthène et neem) + 4 Traitements + avec piège (ratio B/C financier = 1.19)
- Variété Améliorée + Insecticides recommandés (Decis et neem) + 6 Traitements + avec piège (ratio B/C financier = 2.02) ; (Zone 1 : Davihoué)

- Variété Améliorée + Insecticides recommandés (orthène et neem) + 6 Traitements + avec piège (ratio B/C financier = 2.99) ; (Zone 2 : Gobé)

Du fait que tous les systèmes étudiés sont profitables au producteur qu'il installe de piège ou pas, une question fondamentale se pose : où se trouve l'intérêt économique du producteur de niébé à adopter les pièges à pheromone ?

C'est la réponse à cette question qui nous a amenés à considérer les types de traitements phytosanitaires utilisés et le nombre de traitements effectués. Le détail est présenté dans la partie 2.

***Deuxième partie :***

Il importe ici de rappeler l'objectif de l'installation des pièges à pheromone. En effet, les pièges signalent l'arrivée de *Maruca* dans le champ du paysan. A cette alerte, ce dernier prend la décision de traiter son champ au moment juste et sans gaspillage. En d'autres termes, les pièges permettent aux paysans de rationaliser les traitements phytosanitaires en vue d'une production rentable et durable. Ainsi, avec la technique des pièges, le paysan peut réduire le nombre de traitement phytosanitaire par rapport à sa pratique habituelle (pratique paysanne sans piège).

Pour cela, nous avons cherché à comparer le coût des traitements phytosanitaires réduits au coût lié à l'installation des pièges. Si le coût des traitements phytosanitaires réduits est supérieur au coût lié à l'installation des pièges, alors le paysan gagne financièrement et contribue à la protection de l'environnement. Dans ce premier cas, il est très bénéfique pour le paysan d'installer les pièges et de bien les surveiller. Mais, si le coût des traitements phytosanitaires réduits est inférieur au coût lié à l'installation des pièges, alors le paysan perd financièrement. Ici, l'installation des pièges devient alors une charge supplémentaire au paysan. Dans ce deuxième cas de figure, il va falloir trouver des mécanismes de diffusion qui vont permettre aux paysans d'accéder aux pièges à moindre coût. Ces résultats dépendent du type de traitement phytosanitaire appliqué (extraits aqueux, insecticides recommandés, insecticides non recommandés) et du nombre de pièges installés par unité de superficie.

Tableau : Gains tangibles bruts des paysans suivant le Nombre de traitements réduits et par type de traitement effectué (FCFA/HA)

| **Types de traitement phytosanitaire** | **Gains du paysan suivant le Nombre de traitements réduits : (Brut)** | | | |
|---|---|---|---|---|
| | **1 traitement réduit** | **2 traitements réduits** | **3 traitements réduits** | **4* traitements réduits** |
| Extrait aqueux | 2265 | 4530 | 6795 | 9060 |
| insecticide recommande | 8325 | 16650 | 24975 | 33300 |
| insecticide non recommande | 9075 | 18150 | 27225 | 36300 |

*Selon la réalité sur le terrain, le paysan peut réduire au minimum 1 traitement et au maximum 4 traitements selon le type de traitements phytosanitaires (sans toucher à l'efficacité des produits utilisés)

Dans cette deuxième partie, plusieurs scénarios sont considérés. Les résultats de ces différents scénarios sont présentés dans le tableau 6. Nous avons fait une simulation suivant les critères ci-après :

- Le prix du 'leure' : 200, 250, 300, 430 FCFA/unité,
- L'unité de superficie considérée est 1ha,
- Le nombre de pièges à pheromone par hectare : 15, 12, 10, 8 et 6 pièges par hectare.
- Pour chaque prix de 'leure' fixé, nous avons considéré cinq (5) scénarios en fonction du nombre de pièges installés par hectare soit au total vingt (20) cas. Les tableaux 6A, 6B, 6C et 6D présentent les résultats obtenus cas par cas.

L'adoption de la technique des pièges à pheromone entraîne chez le paysan la réduction du nombre de traitements phytosanitaires. Ainsi, les paysans peuvent économiser de l'argent en réduisant le nombre de traitements phytosanitaires. Cet argent dépend du nombre de traitements réduits et du type de traitements (extraits aqueux, insecticides recommandés, insecticides non recommandés). C'est ce que nous avons essayé de ressortir au niveau des tableaux 6A, 6B, 6C et 6D :

- **Le prix du ‘leure’ est fixé à 200 FCFA (tableau 6A)**

- **Cas 1 : 15 pièges/ha**

Les seuils de rentabilité sont de 14 traitements aux extraits aqueux, 5 traitements aux insecticides chimiques recommandés et non recommandés. C’est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 14 traitements pour que l’installation des pièges lui soit profitable. S’il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 5 traitements pour que l’installation des pièges lui soit profitable. Dans les deux situations, ces seuils sont impossibles à atteindre car les paysans font au plus 8 traitements aux extraits aqueux et 4 traitements au insecticides recommandés ou non recommandés. L’installation des pièges à pheromone est non rentable au paysan.

- **Cas 2 : 12 pièges/ha**

Les seuils de rentabilité sont de 11 traitements aux extraits aqueux, 3 traitements aux insecticides chimiques recommandés et non recommandés. C’est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 11 traitements pour que l’installation des pièges lui soit profitable. Ce seuil est impossible à atteindre car les paysans font au plus 8 traitements aux extraits aqueux. S’il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 3 traitements pour que l’installation des pièges lui soit profitable. Dans ce cas, ce seuil peut être atteint car les paysans font habituellement 4 traitements au insecticides recommandés ou non recommandés. Ceci signifie qu’ils vont traiter leur champ **une seule fois sur les quatre**. Mais, est-ce qu’un seul traitement serait efficace? A quelle période faudrait-il le faire ? **L’installation des pièges à pheromone est non rentable au paysan**.

- **Cas 3 : 10 pièges/ha**

Les seuils de rentabilité sont de 9 traitements aux extraits aqueux, 3 traitements aux insecticides chimiques recommandés et non recommandés. C’est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 9 traitements pour que l'installation des pièges lui soit profitable. Ce seuil est impossible à atteindre car les paysans font au plus 8 traitements aux extraits aqueux. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 3 traitements pour que l'installation des pièges lui soit profitable. Dans cette situation, ce seuil peut impossibles à atteindre car les paysans font au plus 8 traitements aux extraits aqueux. Ceci signifie qu'ils vont traiter leur champ **une seule fois sur les quatre**. Mais, est-ce qu'un seul traitement serait efficace? A quelle période faudrait-il le faire ? **L'installation des pièges à pheromone est non rentable au paysan.**

- **Cas 4 : 8 pièges/ha**

Les seuils de rentabilité sont de 7 traitements aux extraits aqueux, 2 traitements aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 7 traitements pour que l'installation des pièges lui soit profitable. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 2 traitements pour que l'installation des pièges lui soit profitable. Dans les deux situations, ces seuils peuvent être atteints car les paysans font au plus 8 traitements aux extraits aqueux et 4 traitements au insecticides recommandés ou non recommandés. Mais, il ne serait pas efficace de faire un seul traitement aux extraits aqueux. **En conclusion, l'installation des pièges à pheromone serait rentable au paysan s'il traite 2 fois avec des insecticides chimiques recommandés ou non.**

- **Cas 5 : 6 pièges/ha**

Les seuils de rentabilité sont de 5 traitements aux extraits aqueux, 2 traitements aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 5 traitements pour que l'installation des pièges lui soit profitable. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 2 traitements pour que l'installation des pièges lui soit profitable. Dans les deux situations, ces seuils peuvent être atteints car les paysans font au plus 8 traitements aux extraits aqueux et 4 traitements au insecticides recommandés ou non recommandés. Mais, est-que 3 traitements aux extraits aqueux (par rapport 8 traitements) seraient efficace ? **L'installation des pièges à pheromone serait rentable au paysan s'il fait :**

*** 2 traitements aux insecticides recommandés au lieu de 4 traitements**

*** 3 traitements aux extraits aqueux au lieu de 8 traitements**

- **Le prix du 'leure' est fixé à 250 FCFA**

- **Cas 1 : 15 pièges/ha**

Les seuils de rentabilité sont de 15 traitements aux extraits aqueux, 4 traitements aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 15 traitements pour que l'installation des pièges lui soit profitable. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 4 traitements pour que l'installation des pièges lui soit profitable. Dans les deux situations, ces seuils sont impossibles à atteindre car les paysans font au plus 8 traitements aux extraits aqueux et 4 traitements au insecticides recommandés ou non recommandés. **L'installation des pièges à pheromone est non rentable au paysan.**

- **Cas 2 : 12 pièges/ha**

Les seuils de rentabilité sont de 12 traitements aux extraits aqueux, 4 et 3 traitements respectivement aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 12 traitements pour que l'installation des pièges lui soit profitable. Ce seuil est impossible à atteindre car les paysans font au plus 8 traitements aux extraits aqueux. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 4 traitements aux insecticides recommandés et de 3 pour les insecticides non recommandés pour que l'installation des pièges lui soit profitable. Ces seuils peuvent être atteints car les paysans font habituellement 4 traitements au insecticides recommandés ou non recommandés. Ceci signifie que le paysan va traiter son champ une seule fois au lieu de quatre traitements (insecticide non recommandé) ou ne pas traiter du tout (insecticide recommandé). **L'installation des pièges à pheromone est non rentable au paysan**.

- **Cas 3 : 10 pièges/ha**

Les seuils de rentabilité sont de 10 traitements aux extraits aqueux, 3 traitements aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 10 traitements pour que l'installation des pièges lui soit profitable. Ce seuil est impossible à atteindre car les paysans font au plus 8 traitements aux extraits aqueux. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 3 traitements pour que l'installation des pièges lui soit profitable. Dans cette situation, ce seuil peut être atteint car les paysans font au plus 4 traitements aux insecticides chimiques recommandés ou non recommandés. Ceci signifie qu'ils vont traiter leur champ **une seule fois sur les quatre**. Mais, est-ce qu'un seul traitement serait efficace? A quelle période faudrait-il le faire ? **L'installation des pièges à pheromone est non rentable au paysan.**

- **Cas 4 : 8 pièges/ha**

Les seuils de rentabilité sont de 8 traitements aux extraits aqueux, 3 et 2 traitements respectivement aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 8 traitements pour que l'installation des pièges lui soit profitable. Ce seuil ne peut pas être atteint car les paysans font au plus 8 traitements aux extraits aqueux. Mais,. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 3 et 2 traitements respectivement pour que l'installation des pièges lui soit profitable. **En conclusion, l'installation des pièges à pheromone serait rentable au paysan s'il traite 2 fois avec des insecticides chimiques non recommandés.**

- **Cas 5 : 6 pièges/ha**

Les seuils de rentabilité sont de 6 traitements aux extraits aqueux, 2 traitements aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 6 traitements pour que l'installation des pièges lui soit profitable. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 2 traitements pour que l'installation des pièges lui soit profitable. Dans les deux situations, ces seuils peuvent être atteints car les paysans font au plus 8 traitements aux extraits aqueux et 4 traitements au insecticides recommandés ou non recommandés. Mais, est-que 2 traitements aux extraits aqueux (par rapport 8 traitements) seraient efficace ? **L'installation des pièges à pheromone serait rentable au paysan s'il fait :**

*** 2 traitements aux insecticides recommandés au lieu de 4 traitements**

*** 2 traitements aux insecticides non recommandés au lieu de 4 traitements**

- **Le prix du 'leure' est fixé à 300 FCFA**

- **Cas 1 : 15 pièges/ha**

Les seuils de rentabilité sont de 16 traitements aux extraits aqueux, 5 et 4 traitements respectivement aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 16 traitements pour que l'installation des pièges lui soit profitable. S'il utilise les insecticides recommandés ou non, il lui faudra réduire (respectivement) au moins de 5 et 4 traitements pour que l'installation des pièges lui soit profitable. Dans les deux situations, ces seuils sont impossibles à atteindre car les paysans font au plus 8 traitements aux extraits aqueux et 4 traitements au insecticides recommandés ou non recommandés. **L'installation des pièges à pheromone est non rentable au paysan**.

- **Cas 2 : 12 pièges/ha**

Les seuils de rentabilité sont de 12 traitements aux extraits aqueux, 4 traitements aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 11 traitements pour que l'installation des pièges lui soit profitable. Ce seuil est impossible à atteindre car les paysans font au plus 8 traitements aux extraits aqueux. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 4 traitements pour que l'installation des pièges lui soit profitable. Dans ce cas, ce seuil peut être atteint car les paysans font habituellement 4 traitements au insecticides recommandés ou non recommandés. Dans les deux situations, ces seuils sont impossibles à atteindre car les paysans font au plus 8 traitements aux extraits aqueux et 4 traitements au insecticides recommandés ou non recommandés. **L'installation des pièges à pheromone est non rentable au paysan**

- **Cas 3 : 10 pièges/ha**

Les seuils de rentabilité sont de 10 traitements aux extraits aqueux, 3 traitements aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 10 traitements pour que l'installation des pièges lui soit profitable. Ce seuil est impossible à atteindre car les paysans font au plus 8 traitements aux extraits aqueux. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 3 traitements pour que l'installation des pièges lui soit profitable. Ceci signifie qu'il va traiter son champ **une seule fois sur les quatre**. Mais, est-ce qu'un seul traitement serait efficace? A quelle période faudrait-il le faire ? **L'installation des pièges à pheromone est non rentable au paysan.**

- **Cas 4 : 8 pièges/ha**

Les seuils de rentabilité sont de 8 traitements aux extraits aqueux, 3 traitements aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 8 traitements pour que l'installation des pièges lui soit profitable. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 3 traitements pour que l'installation des pièges lui soit profitable. Dans les deux situations, ces seuils peuvent être atteints car les paysans font au plus 8 traitements aux extraits aqueux et 4 traitements au insecticides recommandés ou non recommandés. Mais, il ne serait pas efficace de faire un seul traitement aux insecticides chimiques recommandés ou non, ou bien de ne pas traiter du tout (extraits aqueux). **En conclusion, l'installation des pièges à pheromone serait rentable au paysan s'il traite 1 fois avec des insecticides chimiques recommandés ou non.**

- **Cas 5 : 6 pièges/ha**

Les seuils de rentabilité sont de 6 traitements aux extraits aqueux, 2 traitements aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 6 traitements pour que l'installation des pièges lui soit profitable. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 2 traitements pour que l'installation des pièges lui soit profitable. Dans les deux situations, ces seuils peuvent être atteints car les paysans font au plus 8 traitements aux extraits aqueux et 4 traitements au insecticides recommandés ou non recommandés. Mais, est-que 2 traitements aux extraits aqueux (par rapport 8 traitements) seraient efficace ? **L'installation des pièges à pheromone serait rentable au paysan s'il fait :**

*** 2 traitements aux insecticides recommandés ou non au lieu de 4 traitements**

*** 2 traitements aux extraits aqueux au lieu de 8 traitements?**

➢ **Le prix du 'leure' est fixé à 430 FCFA**

- **Cas 1 : 15 pièges/ha**

Les seuils de rentabilité sont de 18 traitements aux extraits aqueux, 5 traitements aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 18 traitements pour que l'installation des pièges lui soit profitable. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 5 traitements pour que l'installation des pièges lui soit profitable. Dans les deux situations, ces seuils sont impossibles à atteindre car les paysans font au plus 8 traitements aux extraits aqueux et 4 traitements au insecticides recommandés ou non recommandés. **L'installation des pièges à pheromone est non rentable au paysan.**

- **Cas 2 : 12 pièges/ha**

Les seuils de rentabilité sont de 15 traitements aux extraits aqueux, 4 traitements aux insecticides chimiques recommandés et non recommandés. C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 15 traitements pour que l'installation des pièges lui soit profitable.. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 4 traitements pour que l'installation des pièges lui soit profitable. Ces seuils peuvent pas être atteints car les paysans font habituellement 4 traitements au insecticides recommandés ou non recommandés et au plus 8 traitements aux extraits aqueux. **L'installation des pièges à pheromone est non rentable au paysan**.

- **Cas 3 : 10 pièges/ha**

Les seuils de rentabilité sont de 12 traitements aux extraits aqueux, 4 et 3 traitements aux insecticides chimiques recommandés et non recommandés (respectivement). C'est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 12 traitements pour que l'installation des pièges lui soit profitable. Ce seuil est impossible à atteindre car les paysans font au plus 8 traitements aux extraits aqueux. S'il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 4 et 3 traitements respectivement pour que l'installation des pièges lui soit profitable. Dans cette situation, ce seuil peut être atteind car les paysans font au plus 4 traitements aux insecticides chimiques recommandés ou non recommandés. Ceci signifie qu'ils vont traiter leur champ **une seule fois sur les quatre**. Mais, est-ce qu’un seul traitement serait efficace? **L’installation des pièges à pheromone est non rentable au paysan.**

- **Cas 4 : 8 pièges/ha**

Les seuils de rentabilité sont de 10 traitements aux extraits aqueux, 3 traitements aux insecticides chimiques recommandés et non recommandés. C’est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 10 traitements pour que l’installation des pièges lui soit profitable. Ce seuil est impossible à atteindre car les paysans font au plus 8 traitements aux extraits aqueux. S’il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 3 traitements pour que l’installation des pièges lui soit profitable. Dans cette situation, ce seuil peut être atteind car les paysans font au plus 4 traitements aux insecticides chimiques recommandés ou non recommandés. Ceci signifie qu’ils vont traiter leur champ **une seule fois sur les quatre**. Mais, est-ce qu’un seul traitement serait efficace? **L’installation des pièges à pheromone est non rentable au paysan.**

- **Cas 5 : 6 pièges/ha**

Les seuils de rentabilité sont de 7 traitements aux extraits aqueux, 2 traitements aux insecticides chimiques recommandés et non recommandés. C’est-à-dire que, si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 7 traitements pour que l’installation des pièges lui soit profitable. S’il utilise les insecticides recommandés ou non, il lui faudra réduire au moins de 2 traitements pour que l’installation des pièges lui soit profitable. Dans les deux situations, ces seuils peuvent être atteints car les paysans font au plus 8 traitements aux extraits aqueux et 4 traitements au insecticides recommandés ou non recommandés. Mais, est-que 1 traitement aux extraits aqueux (par rapport 8 traitements) serait-il efficace ? **L’installation des pièges à pheromone serait rentable au paysan s’il fait :**

- **2 traitements aux insecticides recommandés on non au lieu de 4 traitements**

•

Dans cette deuxième partie également nous avons un peu détaillé les résultats du tableau 6 en considérant les unités de mesure. Dans le colline l'unité de mesure est la parcelle et dans le couffo, le kanti. Un hectare est égale à 5 parcelles ou 25 kant

Les résultats obtenus sont présentés dans le tableau 7.

**Cas 1 : 3pièges/parcelle**

On constate que les seuils de rentabilité au niveau des extraita aqueux comm aux insecticides coton et recommandés ne sont pas du tout atteints. Cela veut dire que si le paysan utilise les extraits aqueux, il lui faudra réduire au moins de 14 traitements pour les extraits aqueux et de 5 traitements pour les insecticides coton et recommandés. Dans ce cas les pièges ne sont pas rentables au paysan

**Cas2 : 2 pièges/parcelle**

Les seuils de rentabilité sont atteints au moins de 18 traitements pour les extraits aqueux, 4 traitements pour les insecticides coton et recommandés. Cela veut dire que le paysan

**Conclusion et recommandations**

L'activité de production niébé rentable au producteur avec l'utilisation de pièges. Les pièges à pheromone permettent au producteur de rationaliser les traitements phytosanitaires. En installant les pièges, les producteurs doivent pouvoir réduire jusqu'à un seuil minimum le nombre de traitements pour en tirer profit. La rentabilité des pièges à pheromone dépend du prix du 'leure', du nombre de pièges installés par unité de superficie, et du type de traitements phytosanitaires appliqués. En cas d'utilisation des extraits aqueux, l'installation des pièges ne présente pas un intérêt financier pour le paysan quel que soit le prix du 'leure' et le nombre de pièges par unité de superficie (selon nos hypothèses). En ce qui concerne l'usage des insecticides recommandés et non recommandés, l'installation des pièges est rentable au paysan à condition de réduire le nombre de traitements jusqu'à un seuil minimum acceptable sans affecter le rendement du paysan. Pour quelqu'un qui utilise les insecticides chimiques et qui veut installer des pièges, il lui faut traiter au plus 2 fois son champ et placer au maximum 8 pièges/ ha. Plus le nombre de pièges par unité de superficie baisse, plus l'intérêt financier (avantage tangible) lié à la technique des pièges est élevé, de même que pour le prix du leure.

Pour faciliter l'adoption des pièges à pheromone, il faudra :

- tenir du prix du leure (200, 250, 300, 430 FCFA/ unité)
- sensibiliser les paysans sur le rôle des pièges et leur interet pour les paysans
- Monter des essais pour voir les normes recommandables en ce qui concerne le nombre de pièges par unité de superficie en tenant compte de l'efficacité biologique et de l'efficience (minimiser le coût d'installation des pièges). Ceci permettra de préconiser des techniques simples pour une installation optimale des pièges.(15, 12, 10, 8 ou 6/ ha)
- Associer les groupements villageois dans vulgarisation ou diffusion de la technique des pièges à pheromone.
- Encourager l'adoption collective de la technique en vue réduire ou minimiser le coût d'installation par personne,

## ANNEXE

***Tableau 1:*** **Temps d'installation de piege**

| Rebriques | Temps (h-j) |
|---|---|
| Eau | 1.1 |
| Piquet | 1.17 |
| Savon | 1.08 |
| fil de fer | 1.06 |
| bidon | 1.76 |
| TOTAL (h) | 6.17 |
| TOTAL (h-j) | 1.028 |

***Tableau 2*: Cout d'installation d'un piege (Cout d'achat + frais de transport + MOD) (/ha)**

| Cas 1. coût unitaire de piége fixé à 200 fcfa | | | | | |
|---|---|---|---|---|---|
| | Quantite | PU (sans transport) | Monts (sans transport) | PU (avec transport) | Monts (avec transport) |
| bidon | 1 | 540 | 540 | 550 | 550 |
| leure | 3 | 200 | 600 | 210 | 630 |
| Savon | 1 | 135 | 135 | 145 | 145 |
| fil de fer | 1 | 205 | 205 | 215 | 215 |
| Main d'oeuvre (H-J) | 1 | 500 | 500 | 500 | 500 |
| TOTAL | | | 1980 | | 2040 |

| Cas 2. coût unitaire de piége fixé à 250 fcfa | | | | | |
|---|---|---|---|---|---|
| | Quantite | PU (sans transport) | Monts (sans transport) | PU (avec transport) | Monts (avec transport) |
| bidon | 1 | 540 | 540 | 550 | 550 |
| leure | 3 | 250 | 750 | 260 | 780 |
| Savon | 1 | 135 | 135 | 145 | 145 |
| fil de fer | 1 | 205 | 205 | 215 | 215 |
| Main d'oeuvre (H-J) | 1 | 500 | 500 | 500 | 500 |
| TOTAL | | | 2130 | | 2190 |

| Cas 3. coût unitaire de piége fixé à 300 fcfa | | | | | |
|---|---|---|---|---|---|
| | Quantité | PU (sans transport) | Monts (sans transport) | PU (avec transport) | Monts (avec transport) |
| bidon | 1 | 540 | 540 | 550 | 550 |
| leure | 3 | 300 | 900 | 310 | 930 |
| Savon | 1 | 135 | 135 | 145 | 145 |
| fil de fer | 1 | 205 | 205 | 215 | 215 |
| Main d’œuvre (H-J) | 1 | 500 | 500 | 500 | 500 |
| TOTAL | | | 2280 | | 2340 |

| Cas 4. coût unitaire de piége fixé à 430 FCFA | | | | | |
|---|---|---|---|---|---|
| | Quantité | PU (sans transport) | Monts (sans transport) | PU (avec transport) | Monts (avec transport) |
| bidon | 1 | 540 | 540 | 550 | 550 |
| leure | 3 | 430 | 1290 | 440 | 1320 |
| Savon | 1 | 135 | 135 | 145 | 145 |
| fil de fer | 1 | 205 | 205 | 215 | 215 |
| Main d'œuvre (H-J) | 1 | 500 | 500 | 500 | 500 |
| TOTAL | | | 2670 | | 2730 |

***Tableau 3:*** **Cout d'un traitement a l'insecticide chimique (ha)**

| Rebriques | insecticide non recommande (Dursban) | | | insecticide recommande(Orthene) | | |
|---|---|---|---|---|---|---|
| | Quantite | PU | Montants | Quantite | PU | Montants |
| insecticide (ha) | 1.5 | 4750 | 7125 | 1.5 | 4250 | 6375 |
| cout de location d'appareil ULV | 1 | 800 | 800 | 1 | 800 | 800 |
| MOD (pulverisation) | 2.3 | 500 | 1150 | 2.3 | 500 | 1150 |
| TOTAL : | | | **9075** | | | **8325** |

***Tableau 4:*** **Cout d'un traitement a l'extrait aqueux de neem ou papayer**

| Rebriques | Quantite | PU | Montants |
|---|---|---|---|
| cout de location d'appareil ULV | 1 | 800 | 800 |
| MOD (Preparation de l'extrait) | 2.29 | 500 | 1145 |
| MOD (Pulverisation) | 2.24 | 500 | 1120 |
| Total | | | **2265** |

**Tableau 5 : Bugdet partiel de l'installation de piege a pheromone (fcfa/ha)**

| Cas 1. coût unitaire de piége fixé à 200 fcfa | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Systemes | **Rendements** | **P.U. (Niebe)** | **Revenu brut** | **semence** | **engrais** | **Insecticide (traitement)** | **Installation piege** | **cout totaux** | **profit net** | **Ratio B/C (financier)** |
| VL + Sans insect. + Sans Trt + avec piège | 530 | 175 | 92750 | 5000 | 0 | 0 | 30600 | 35600 | 57150 | 2.605337079 |
| VL + Insect. RN + 4Trt + avec piege | 500 | 175 | 87500 | 5000 | 0 | 33300 | 30600 | 68900 | 18600 | 1.269956459 |
| VA + insect. RN + 6Trt + avec piege | 1040 | 175 | 182000 | 5000 | 0 | 49950 | 30600 | 85550 | 96450 | 2.127410871 |
| VA + insect. RN(orthene+neem) + 6Trt + avec piege | 1540 | 175 | 269500 | 5000 | 0 | 49950 | 30600 | 85550 | 183950 | 3.150204559 |
| VA + insect R. (orthene) + 6Trt + sans piege | 1190 | 175 | 208250 | 5000 | 0 | 49950 | 0 | 54950 | 153300 | 3.789808917 |
| VL + extrait Neem/Papayer + 6Trt + sans piege | 475 | 175 | 83125 | 5000 | 0 | 13590 | 0 | 18590 | 64535 | 4.471490048 |
| VL + insect. RN(orthene+neem) + 6Trt + sans piege | 716 | 175 | 125300 | 5000 | 0 | 49950 | 0 | 54950 | 70350 | 2.280254777 |
| VA + extrait Neem/Papayer + 6Trt + sans piege | 1250 | 175 | 218750 | 5000 | 0 | 13590 | 0 | 18590 | 200160 | 11.76707907 |

**Tableau 5 : Bugdet partiel de l'installation de piege a pheromone (fcfa/ha)**

| ***Cas 2. coût unitaire de piége fixé à 250 fcfa*** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ***Systemes*** | **Rendements** | **P.U. (Niebe)** | **Revenu brut** | **semence** | **engrais** | **Insecticide (traitement)** | **Installation piege** | **cout totaux** | **profit net** | **Ratio B/C (financier)** |
| VL + Sans insect. + Sans Trt + avec piège | 530 | 175 | 92750 | 5000 | 0 | 0 | 32850 | 37850 | 54900 | 2.450462351 |
| VL + Insect. RN + 4Trt + avec piege | 500 | 175 | 87500 | 5000 | 0 | 33300 | 32850 | 71150 | 16350 | 1.229796205 |
| VA + insect. RN + 6Trt + avec piege | 1040 | 175 | 182000 | 5000 | 0 | 49950 | 32850 | 87800 | 94200 | 2.072892938 |
| VA + insect. RN(orthene+neem) + 6Trt + avec piege | 1540 | 175 | 269500 | 5000 | 0 | 49950 | 32850 | 87800 | 181700 | 3.069476082 |
| VA + insect R. (orthene) + 6Trt + sans piege | 1190 | 175 | 208250 | 5000 | 0 | 49950 | 0 | 54950 | 153300 | 3.789808917 |
| VL + extrait Neem/Papayer + 6Trt + sans piege | 475 | 175 | 83125 | 5000 | 0 | 13590 | 0 | 18590 | 64535 | 4.471490048 |
| VL + insect. RN(orthene+neem) + 6Trt + sans piege | 716 | 175 | 125300 | 5000 | 0 | 49950 | 0 | 54950 | 70350 | 2.280254777 |
| VA + extrait Neem/Papayer + 6Trt + sans piege | 1250 | 175 | 218750 | 5000 | 0 | 13590 | 0 | 18590 | 200160 | 11.76707907 |

**Tableau 5 : Bugdet partiel de l'installation de piege a pheromone (fcfa/ha)**

| Cas 3. coût unitaire de piége fixé à 300 fcfa | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Systemes** | **Rendements** | **P.U. (Niebe)** | **Revenu brut** | **semence** | **engrais** | **Insecticide (traitement)** | **Installation piege** | **cout totaux** | **profit net** | **Ratio B/C (financier)** |
| VL + Sans insect. + Sans Trt + avec piège | 530 | 175 | 92750 | 5000 | 0 | 0 | 35100 | 40100 | 52650 | 2.312967581 |
| VL + Insect. RN + 4Trt + avec piege | 500 | 175 | 87500 | 5000 | 0 | 33300 | 35100 | 73400 | 14100 | 1.192098093 |
| VA + insect. RN + 6Trt + avec piege | 1040 | 175 | 182000 | 5000 | 0 | 49950 | 35100 | 90050 | 91950 | 2.021099389 |
| VA + insect. RN(orthene+neem) + 6Trt + avec piege | 1540 | 175 | 269500 | 5000 | 0 | 49950 | 35100 | 90050 | 179450 | 2.992781788 |
| VA + insect R. (orthene) + 6Trt + sans piege | 1190 | 175 | 208250 | 5000 | 0 | 49950 | 0 | 54950 | 153300 | 3.789808917 |
| VL + extrait Neem/Papayer + 6Trt + sans piege | 475 | 175 | 83125 | 5000 | 0 | 13590 | 0 | 18590 | 64535 | 4.471490048 |
| VL + insect. RN(orthene+neem) + 6Trt + sans piege | 716 | 175 | 125300 | 5000 | 0 | 49950 | 0 | 54950 | 70350 | 2.280254777 |
| VA + extrait Neem/Papayer + 6Trt + sans piege | 1250 | 175 | 218750 | 5000 | 0 | 13590 | 0 | 18590 | 200160 | 11.76707907 |

**Tableau 5 : Bugdet partiel de l'installation de piege a pheromone (fcfa/ha)**

| Cas 4. coût unitaire de piége fixé à 430 fcfa | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Systemes* | **Rendements** | **P.U. (Niebe)** | **Revenu brut** | **semence** | **engrais** | **Insecticide (traite-ment)** | **Installation piege** | **cout totaux** | **profit net** | **Ratio B/C (financier)** |
| VL + Sans insect. + Sans Trt + avec piège | 530 | 175 | 92750 | 5000 | 0 | 0 | 40950 | 45950 | 46800 | 2.018498368 |
| VL + Insect. RN + 4Trt + avec piege | 500 | 175 | 87500 | 5000 | 0 | 33300 | 40950 | 79250 | 8250 | 1.104100946 |
| VA + insect. RN + 6Trt + avec piege | 1040 | 175 | 182000 | 5000 | 0 | 49950 | 40950 | 95900 | 86100 | 1.897810219 |
| VA + insect. RN(orthene+neem) + 6Trt + avec piege | 1540 | 175 | 269500 | 5000 | 0 | 49950 | 40950 | 95900 | 173600 | 2.810218978 |
| VA + insect R. (orthene) + 6Trt + sans piege | 1190 | 175 | 208250 | 5000 | 0 | 49950 | 0 | 54950 | 153300 | 3.789808917 |
| VL + extrait Neem/Papayer + 6Trt + sans piege | 475 | 175 | 83125 | 5000 | 0 | 13590 | 0 | 18590 | 64535 | 4.471490048 |
| VL + insect. RN(orthene+neem) + 6Trt + sans piege | 716 | 175 | 125300 | 5000 | 0 | 49950 | 0 | 54950 | 70350 | 2.280254777 |
| VA + extrait Neem/Papayer + 6Trt + sans piege | 1250 | 175 | 218750 | 5000 | 0 | 13590 | 0 | 18590 | 200160 | 11.76707907 |

Tableau 6A : Comparaison entre coûts d'installation de pièges et coûts lies à la réduction du nombre de traitements (FCFA/ha) : prix d'achat unitaire d'un piège 200 FCFA

| CAS 1 : installation de 15 pièges/ha | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Types de traitements** | **Coût d'installation de pièges /ha** | **Coûts du Nombre de traitements réduits** | | | | ***Gains ou pertes tangibles/ traitements réduits*** | | | | | **Avantages non tangibles** |
| | | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | Conclusions | |
| Extrait aqueux | 30600 | 2265 | 4530 | 6795 | 9060 | -28335 | -26070 | -23805 | -21540 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 30600 | 8325 | 16650 | 24975 | 33300 | -22275 | -13950 | -5625 | 2700 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 30600 | 9075 | 18150 | 27225 | 36300 | -21525 | -12450 | -3375 | 5700 | rentable | protection de l'environnement, de la santé individuelle et publique |
| **CAS 2 : installation de 12 pièges/ha** | | | | | | | | | | | |
| **Types de traitements** | **Coût d'installation de pièges /paysan** | **Coûts du Nombre de traitements réduits** | | | | **Gains ou pertes tangibles/traitements réduits** | | | | | **Avantages non tangibles** |
| | | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | Conclusions | |
| Extrait aqueux | 24480 | 2265 | 4530 | 6795 | 9060 | -22215 | -19950 | -17685 | -15420 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 24480 | 8325 | 16650 | 24975 | 33300 | -16155 | -7830 | 495 | 8820 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 24480 | 9075 | 18150 | 27225 | 36300 | -15405 | -6330 | 2745 | 11820 | rentable | protection de l'environnement, de la santé individuelle et publique |

| CAS 3 : installation de 10 pièges/ha | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Types de traitements** | **Coût d'installation de pièges par paysan** | **Coûts du Nombre de traitements réduits** | | | | Gains tangibles | | | | | **Avantages non tangibles** |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Conclusions | |
| Extrait aqueux | 20400 | 2265 | 4530 | 6795 | 9060 | -18135 | -15870 | -13605 | -11340 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 20400 | 8325 | 16650 | 24975 | 33300 | -12075 | -3750 | 4575 | 12900 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 20400 | 9075 | 18150 | 27225 | 36300 | -11325 | -2250 | 6825 | 15900 | rentable | protection de l'environnement, de la santé individuelle et publique |

| CAS 4 : installation de 8 pièges/ha | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Types de traitements** | **Coût d'installation de pièges supporte par paysan** | **Coûts du Nombre de traitements réduits** | | | | **Gains ou perte tangibles** | | | | | **Avantages non tangibles** |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Conclusions | |
| Extrait aqueux | 16320 | 2265 | 4530 | 6795 | 9060 | -14055 | -11790 | -9525 | -7260 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 16320 | 8325 | 16650 | 24975 | 33300 | -7995 | 330 | 8655 | 16980 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 16320 | 9075 | 18150 | 27225 | 36300 | -7245 | 1830 | 10905 | 19980 | rentable | protection de l'environnement, de la santé individuelle et publique |

| CAS 5 : installation de 6 pièges/ha | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Types de traitements** | **Coût d'installation de pièges /paysan** | **Coûts du Nombre de traitements réduits** | | | | ***Gains tangibles*** | | | | | ***Avantages non tangibles*** |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Conclusions | |
| Extrait aqueux | 12240 | 2265 | 4530 | 6795 | 9060 | -9975 | -7710 | -5445 | -3180 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 12240 | 8325 | 16650 | 24975 | 33300 | -3915 | 4410 | 12735 | 21060 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 12240 | 9075 | 18150 | 27225 | 36300 | -3165 | 5910 | 14985 | 24060 | rentable | protection de l'environnement, de la santé individuelle et publique |

Tableau 6B : Comparaison entre coûts d'installation de pièges et coûts lies à la réduction du nombre de traitements (FCFA/ha) : prix d'achat unitaire du 'leure' 250 FCFA

| **CAS 1 : installation de 15 pièges/ha)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Types de traitements** | **Coût d'installation de pièges /ha** | **Coûts du Nombre de traitements réduits** | | | | ***Gains ou pertes tangibles/ traitements réduits*** | | | | | **Avantages non tangibles** |
| | | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | Conclusions | |
| Extrait aqueux | 32850 | 2265 | 4530 | 6795 | 9060 | -30585 | -28320 | -26055 | -23790 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 32850 | 8325 | 16650 | 24975 | 33300 | -24525 | -16200 | -7875 | 450 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 32850 | 9075 | 18150 | 27225 | 36300 | -23775 | -14700 | -5625 | 3450 | rentable | protection de l'environnement, de la santé individuelle et publique |
| **CAS 2 : installation de 12 pièges/ha)** | | | | | | | | | | | |
| **Types de traitements** | **Coût d'installation de pièges /paysan** | **Coûts du Nombre de traitements réduits** | | | | **Gains ou pertes tangibles/traitements réduits** | | | | | **Avantages non tangibles** |
| | | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | Conclusions | |
| Extrait aqueux | 26280 | 2265 | 4530 | 6795 | 9060 | -24015 | -21750 | -19485 | -17220 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 26280 | 8325 | 16650 | 24975 | 33300 | -17955 | -9630 | -1305 | 7020 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 26280 | 9075 | 18150 | 27225 | 36300 | -17205 | -8130 | 945 | 10020 | rentable | protection de l'environnement, de la santé individuelle et publique |

| CAS 3 : installation de 10 pièges/ha) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Types de traitements** | **Coût d'installation de pièges par paysan** | **Coûts du Nombre de traitements réduits** | | | | Gains tangibles | | | | | **Avantages non tangibles** |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Conclusions | |
| Extrait aqueux | 21900 | 2265 | 4530 | 6795 | 9060 | -19635 | -17370 | -15105 | -12840 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 21900 | 8325 | 16650 | 24975 | 33300 | -13575 | -5250 | 3075 | 11400 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 21900 | 9075 | 18150 | 27225 | 36300 | -12825 | -3750 | 5325 | 14400 | rentable | protection de l'environnement, de la santé individuelle et publique |
| **CAS 4 : installation de 8 pièges/ha** | | | | | | | | | | | |
| **Types de traitements** | **Coût d'installation de pièges supporte par paysan** | **Coûts du Nombre de traitements réduits** | | | | **Gains ou perte tangibles** | | | | | **Avantages non tangibles** |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Conclusions | |
| Extrait aqueux | 17520 | 2265 | 4530 | 6795 | 9060 | -15255 | -12990 | -10725 | -8460 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 17520 | 8325 | 16650 | 24975 | 33300 | -9195 | -870 | 7455 | 15780 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 17520 | 9075 | 18150 | 27225 | 36300 | -8445 | 630 | 9705 | 18780 | rentable | protection de l'environnement, de la santé individuelle et publique |
| **CAS 5 : installation de 6 pièges/ha** | | | | | | | | | | | |
| **Types de traitements** | **Coût d'installation de pièges /paysan** | **Coûts du Nombre de traitements réduits** | | | | ***Gains tangibles*** | | | | | ***Avantages non tangibles*** |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Conclusions | |
| Extrait aqueux | 13140 | 2265 | 4530 | 6795 | 9060 | -10875 | -8610 | -6345 | -4080 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 13140 | 8325 | 16650 | 24975 | 33300 | -4815 | 3510 | 11835 | 20160 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 13140 | 9075 | 18150 | 27225 | 36300 | -4065 | 5010 | 14085 | 23160 | rentable | protection de l'environnement, de la santé individuelle et publique |

Tableau 6C : Comparaison entre coûts d'installation de pièges et coûts lies à la réduction du nombre de traitements (FCFA/ha) : prix d'achat unitaire d'un piège 300 FCFA

| **CAS 1 : installation de 15 pièges/ha)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Types de traitements** | **Coût d'installation de pièges /ha** | **Coûts du Nombre de traitements réduits** | | | | ***Gains ou pertes tangibles/ traitements réduits*** | | | | | **Avantages non tangibles** |
| | | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | Conclusions | |
| Extrait aqueux | 35100 | 2265 | 4530 | 6795 | 9060 | -32835 | -30570 | -28305 | -26040 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 35100 | 8325 | 16650 | 24975 | 33300 | -26775 | -18450 | -10125 | -1800 | non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 35100 | 9075 | 18150 | 27225 | 36300 | -26025 | -16950 | -7875 | 1200 | rentable | protection de l'environnement, de la santé individuelle et publique |

| **CAS 2 : installation de 12 pièges/ha)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Types de traitements** | **Coût d'installation de pièges /paysan** | **Coûts du Nombre de traitements réduits** | | | | **Gains ou pertes tangibles/traitements réduits** | | | | | **Avantages non tangibles** |
| | | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | Conclusions | |
| Extrait aqueux | 28080 | 2265 | 4530 | 6795 | 9060 | -25815 | -23550 | -21285 | -19020 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 28080 | 8325 | 16650 | 24975 | 33300 | -19755 | -11430 | -3105 | 5220 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 28080 | 9075 | 18150 | 27225 | 36300 | -19005 | -9930 | -855 | 8220 | rentable | protection de l'environnement, de la santé individuelle et publique |

| CAS 3 : installation de 10 pièges/ha) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Types de traitements | Coût d'installation de pièges par paysan | Coûts du Nombre de traitements réduits | | | | Gains tangibles | | | | | Avantages non tangibles |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Conclusions | |
| Extrait aqueux | 23400 | 2265 | 4530 | 6795 | 9060 | -21135 | -18870 | -16605 | -14340 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 23400 | 8325 | 16650 | 24975 | 33300 | -15075 | -6750 | 1575 | 9900 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 23400 | 9075 | 18150 | 27225 | 36300 | -14325 | -5250 | 3825 | 12900 | rentable | protection de l'environnement, de la santé individuelle et publique |

| CAS 4 : installation de 8 pièges/ha) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Types de traitements | Coût d'installation de pièges supporte par paysan | Coûts du Nombre de traitements réduits | | | | Gains ou perte tangibles | | | | | Avantages non tangbles |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Conclusions | |
| Extrait aqueux | 18720 | 2265 | 4530 | 6795 | 9060 | -16455 | -14190 | -11925 | -9660 | Non rentable | protection de l'environnement, de la sante individuelle et publique |
| insecticide recommande | 18720 | 8325 | 16650 | 24975 | 33300 | -10395 | -2070 | 6255 | 14580 | rentable | protection de l'environnement, de la sante individuelle et publique |
| insecticide non recommande | 18720 | 9075 | 18150 | 27225 | 36300 | -9645 | -570 | 8505 | 17580 | rentable | protection de l'environnement, de la sante individuelle et publique |

| CAS 5 : installation de 6 pièges/ha | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Types de traitements | Coût d'installation de pièges /paysan | Coûts du Nombre de traitements réduits | | | | *Gains tangibles* | | | | | *Avantages non tangbles* |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Conclusions | |
| Extrait aqueux | 14040 | 2265 | 4530 | 6795 | 9060 | -11775 | -9510 | -7245 | -4980 | Non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 14040 | 8325 | 16650 | 24975 | 33300 | -5715 | 2610 | 10935 | 19260 | rentable | protection de l'environnement, de la sante individuelle et publique |
| insecticide non recommande | 14040 | 9075 | 18150 | 27225 | 36300 | -4965 | 4110 | 13185 | 22260 | rentable | protection de l'environnement, de la sante individuelle et publique |

Tableau 6D : Comparaison entre coûts d'installation de pièges et coûts lies à la réduction du nombre de traitements (FCFA/ha) : prix d’achat unitaire d’un piège 430 FCFA

| **CAS 1 : installation de 15 pièges/ha)** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Types de traitements** | **Coût d'installation de pièges /ha** | **Coûts du Nombre de traitements réduits** | | | | ***Gains ou pertes tangibles/ traitements réduits*** | | | | | **Avantages non tangibles** |
| | | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | Conclusions | |
| Extrait aqueux | 40950 | 2265 | 4530 | 6795 | 9060 | -38685 | -36420 | -34155 | -31890 | non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 40950 | 8325 | 16650 | 24975 | 33300 | -32625 | -24300 | -15975 | -7650 | non rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 40950 | 9075 | 18150 | 27225 | 36300 | -31875 | -22800 | -13725 | -4650 | non rentable | protection de l'environnement, de la santé individuelle et publique |
| **CAS 2 : installation de 12 pièges/ha)** | | | | | | | | | | | |
| **Types de traitements** | **Coût d'installation de pièges /paysan** | **Coûts du Nombre de traitements réduits** | | | | **Gains ou pertes tangibles/traitements réduits** | | | | | **Avantages non tangibles** |
| | | **1** | **2** | **3** | **4** | **1** | **2** | **3** | **4** | Conclusions | |
| Extrait aqueux | 32760 | 2265 | 4530 | 6795 | 9060 | -30495 | -28230 | -25965 | -23700 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 32760 | 8325 | 16650 | 24975 | 33300 | -24435 | -16110 | -7785 | 540 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 32760 | 9075 | 18150 | 27225 | 36300 | -23685 | -14610 | -5535 | 3540 | rentable | protection de l'environnement, de la santé individuelle et publique |

| CAS 3 : installation de 10 pièges/ha) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Types de traitements | Coût d'installation de pièges par paysan | Coûts du Nombre de traitements réduits | | | | Gains tangibles | | | | | Avantages non tangibles |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Conclusions | |
| Extrait aqueux | 27300 | 2265 | 4530 | 6795 | 9060 | -25035 | -22770 | -20505 | -18240 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 27300 | 8325 | 16650 | 24975 | 33300 | -18975 | -10650 | -2325 | 6000 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide non recommande | 27300 | 9075 | 18150 | 27225 | 36300 | -18225 | -9150 | -75 | 9000 | rentable | protection de l'environnement, de la santé individuelle et publique |
| **CAS 4 : installation de 8 pièges/ha)** | | | | | | | | | | | |
| Types de traitements | Coût d'installation de pièges supporte par paysan | Coûts du Nombre de traitements réduits | | | | Gains ou perte tangibles | | | | | Avantages non tangbles |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Conclusions | |
| Extrait aqueux | 21840 | 2265 | 4530 | 6795 | 9060 | -19575 | -17310 | -15045 | -12780 | rentable | protection de l'environnement, de la sante individuelle et publique |
| insecticide recommande | 21840 | 8325 | 16650 | 24975 | 33300 | -13515 | -5190 | 3135 | 11460 | rentable | protection de l'environnement, de la sante individuelle et publique |
| insecticide non recommande | 21840 | 9075 | 18150 | 27225 | 36300 | -12765 | -3690 | 5385 | 14460 | rentable | protection de l'environnement, de la sante individuelle et publique |
| **CAS 5 : installation de 6 pièges/ha** | | | | | | | | | | | |
| Types de traitements | Coût d'installation de pièges /paysan | Coûts du Nombre de traitements réduits | | | | Gains tangibles | | | | | *Avantages non tangbles* |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Conclusions | |
| Extrait aqueux | 16380 | 2265 | 4530 | 6795 | 9060 | -14115 | -11850 | -9585 | -7320 | rentable | protection de l'environnement, de la santé individuelle et publique |
| insecticide recommande | 16380 | 8325 | 16650 | 24975 | 33300 | -8055 | 270 | 8595 | 16920 | rentable | protection de l'environnement, de la sante individuelle et publique |
| insecticide non recommande | 16380 | 9075 | 18150 | 27225 | 36300 | -7305 | 1770 | 10845 | 19920 | rentable | protection de l'environnement, de la sante individuelle et publique |

Tableau 7 : Comparaison entre coûts d'installation de piège et  coûts lies a la réduction du nombre de traitements (FCFA/ha)

| EXEMPLE DE PARCELLE A SAVE, Collines (1 ha= 5 parcelles) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Coûts du Nombre de traitements réduits** | | | | | | | | **Gains ou pertes tangibles/ traitements réduits** | | | | | | | |
| **Cas 1: 3pieges/parcelle soit 15 pieges/ha** | **cout d'installa tion** | **1** | **2** | **3** | **4** | **5** | **6** | **18** | **19** | **1** | **2** | **3** | **4** | **5** | **6** | **18** | **19** |
| **extrait aqueux** | 8190 | 453 | 906 | 1359 | 1812 | 2265 | 2718 | 8154 | 8607 | -7737 | -7284 | -6831 | -6378 | -5925 | -5472 | -36 | 417 |
| **Insect.Rec** | 8190 | 1665 | 3330 | 4995 | 6660 | 8325 | 9990 | 29970 | 31635 | -6525 | -4860 | -3195 | -1530 | 135 | 1800 | 21780 | 23445 |
| **Insect.non Recom** | 8190 | 1815 | 3630 | 5445 | 7260 | 9075 | 10890 | 32670 | 34485 | -6375 | -4560 | -2745 | -930 | 885 | 2700 | 24480 | 26295 |
| | | | | | | | | | | | | | | | | | |
| **Cas 2: 2piege/parcelle soit 10pieges/ha** | | **1** | **2** | **3** | **4** | **5** | **6** | **18** | **19** | **1** | **2** | **3** | **4** | **5** | **6** | **18** | **19** |
| **extrait aqueux** | 5460 | 453 | 906 | 1359 | 1812 | 2265 | 2718 | 8154 | 8607 | -5007 | -4554 | -4101 | -3648 | -3195 | -2742 | 2694 | 3147 |
| **Insect.Rec** | 5460 | 1665 | 3330 | 4995 | 6660 | 8325 | 9990 | 29970 | 31635 | -3795 | -2130 | -465 | 1200 | 2865 | 4530 | 24510 | 26175 |
| **Insect.non Recom** | 5460 | 1815 | 3630 | 5445 | 7260 | 9075 | 10890 | 32670 | 34485 | -3645 | -1830 | -15 | 1800 | 3615 | 5430 | 27210 | 29025 |
| | | | | | | | | | | | | | | | | | |
| **Cas 3: 1piege/parcelle soit 5pieges/ha** | | | | | | | | | | | | | | | | | |
| **extrait aqueux** | 2730 | 453 | 906 | 1359 | 1812 | 2265 | 2718 | 8154 | 8607 | -2277 | -1824 | -1371 | -918 | -465 | -12 | 5424 | 5877 |
| **Insect.Rec** | 2730 | 1665 | 3330 | 4995 | 6660 | 8325 | 9990 | 29970 | 31635 | -1065 | 600 | 2265 | 3930 | 5595 | 7260 | 27240 | 28905 |
| **Insect.non Recom** | 2730 | 1815 | 3630 | 5445 | 7260 | 9075 | 10890 | 32670 | 34485 | -915 | 900 | 2715 | 4530 | 6345 | 8160 | 29940 | 31755 |
| | | | | | | | | | | | | | | | | | |
| **EXEMPLE DE KANTI A KLOUEKANME A SAVE, Collines (1 ha= 25 kanti, 1parcelle = 5 kanti)** | | | | | | | | | | | | | | | | | |
| Cas 1: 1pieges/ 1kanti soit 25pieges/ha | **cout d'installa tion** | **1** | **2** | **3** | **4** | **5** | **6** | **18** | **19** | **1** | **2** | **3** | **4** | **5** | **6** | **18** | **19** |
| **extrait aqueux** | 1638 | 90.6 | 181.2 | 271.8 | 362.4 | 453 | 543.6 | 1630.8 | 1721.4 | -1547.4 | -1456.8 | -1366.2 | -1275.6 | -1185 | -1094.4 | -7.2 | 83.4 |
| **Insect.Rec** | 1638 | 333 | 666 | 999 | 1332 | 1665 | 1998 | 5994 | 6327 | -1305 | -972 | -639 | -306 | 27 | 360 | 4356 | 4689 |
| **Insect.non Recom** | 1638 | 363 | 726 | 1089 | 1452 | 1815 | 2178 | 6534 | 6897 | -1275 | -912 | -549 | -186 | 177 | 540 | 4896 | 5259 |
| | | | | | | | | | | | | | | | | | |
| **Cas 2: 1pieges/ 2kanti soit 12 pieges/ha** | **cout d'installa tion** | **1** | **2** | **3** | **4** | **5** | **6** | **18** | **19** | **1** | **2** | **3** | **4** | **5** | **6** | **18** | **19** |
| **extrait aqueux** | 3276 | 181.2 | 362.4 | 543.6 | 724.8 | 906 | 1087.2 | 3261.6 | 3442.8 | -3094.8 | -2913.6 | -2732.4 | -2551.2 | -2370 | -2188.8 | -14.4 | 166.8 |
| **Insect.Rec** | 3276 | 666 | 1332 | 1998 | 2664 | 3330 | 3996 | 11988 | 12654 | -2610 | -1944 | -1278 | -612 | 54 | 720 | 8712 | 9378 |
| **Insect.non Recom** | 3276 | 726 | 1452 | 2178 | 2904 | 3630 | 4356 | 13068 | 13794 | -2550 | -1824 | -1098 | -372 | 354 | 1080 | 9792 | 10518 |

| Cas 3: 1pieges/ 3kanti soit 8 pieges/ha | cout d'installation | 1 | 2 | 3 | 4 | 5 | 6 | 18 | 19 | 1 | 2 | 3 | 4 | 5 | 6 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| extrait aqueux | 4914 | 271.8 | 543.6 | 815.4 | 1087.2 | 1359 | 1630.8 | 4892.4 | 5164.2 | -4642.2 | -4370.4 | -4098.6 | -3826.8 | -3555 | -3283.2 | -21.6 | 250.2 |
| Insect.Rec | 4914 | 999 | 1998 | 2997 | 3996 | 4995 | 5994 | 17982 | 18981 | -3915 | -2916 | -1917 | -918 | 81 | 1080 | 13068 | 14067 |
| Insect.non Recom | 4914 | 1089 | 2178 | 3267 | 4356 | 5445 | 6534 | 19602 | 20691 | -3825 | -2736 | -1647 | -558 | 531 | 1620 | 14688 | 15777 |
| | | | | | | | | | | | | | | | | | |
| Cas 4: 1piege/5kanti soit 5pieges/ha | cout d'installation | 1 | 2 | 3 | 4 | 5 | 6 | 18 | 19 | 1 | 2 | 3 | 4 | 5 | 6 | 18 | 19 |
| extrait aqueux | 2730 | 453 | 906 | 1359 | 1812 | 2265 | 2718 | 8154 | 8607 | -2277 | -1824 | -1371 | -918 | -465 | -12 | 5424 | 5877 |
| Insect.Rec | 2730 | 1665 | 3330 | 4995 | 6660 | 8325 | 9990 | 29970 | 31635 | -1065 | 600 | 2265 | 3930 | 5595 | 7260 | 27240 | 28905 |
| Insect.non Recom | 2730 | 1815 | 3630 | 5445 | 7260 | 9075 | 10890 | 32670 | 34485 | -915 | 900 | 2715 | 4530 | 6345 | 8160 | 29940 | 31755 |
| | | | | | | | | | | | | | | | | | |
| Cas 5: 2piege/5kantis soit 10pieges/ha | cout d'installation | 1 | 2 | 3 | 4 | 5 | 6 | 18 | 19 | 1 | 2 | 3 | 4 | 5 | 6 | 18 | 19 |
| extrait aqueux | 5460 | 453 | 906 | 1359 | 1812 | 2265 | 2718 | 8154 | 8607 | -5007 | -4554 | -4101 | -3648 | -3195 | -2742 | 2694 | 3147 |
| Insect.Rec | 5460 | 1665 | 3330 | 4995 | 6660 | 8325 | 9990 | 29970 | 31635 | -3795 | -2130 | -465 | 1200 | 2865 | 4530 | 24510 | 26175 |
| Insect.non Recom | 5460 | 1815 | 3630 | 5445 | 7260 | 9075 | 10890 | 32670 | 34485 | -3645 | -1830 | -15 | 1800 | 3615 | 5430 | 27210 | 29025 |
| | | | | | | | | | | | | | | | | | |
| Cas 6: 3pieges/5kanti soit 15 pieges/ha | cout d'installation | 1 | 2 | 3 | 4 | 5 | 6 | 18 | 19 | 1 | 2 | 3 | 4 | 5 | 6 | 18 | 19 |
| extrait aqueux | 8190 | 453 | 906 | 1359 | 1812 | 2265 | 2718 | 8154 | 8607 | -7737 | -7284 | -6831 | -6378 | -5925 | -5472 | -36 | 417 |
| Insect.Rec | 8190 | 1665 | 3330 | 4995 | 6660 | 8325 | 9990 | 29970 | 31635 | -6525 | -4860 | -3195 | -1530 | 135 | 1800 | 21780 | 23445 |
| Insect.non Recom | 8190 | 1815 | 3630 | 5445 | 7260 | 9075 | 10890 | 32670 | 34485 | -6375 | -4560 | -2745 | -930 | 885 | 2700 | 24480 | 26295 |

## **ANNEX 8 – Publication 17**

Hammond, W.N.O., Adéoti, R. and Gbaguidi, B. (Eds.). Selected presentations to the joint PRONAF/Bean-Cowpea CRSP/Project workshop held 8-11 April 2002, IITA, Cotonou, Republic of Benin. (*CD compilation*). See attached CD-R.

## ANNEX 9 – Publication 21

Mark Downham, David Hall, Alan Cork, Dudley Farman, Manuele Tamò, Didier Dahounto, Benjamin Datinon, Sounkoura Adetonah & David Chamberlain. Developing an attractive pheromone blend for the Legume Podborer, *Maruca vitrata* (F.) (Lepidoptera: Pyralidae). Poster presented at: International Society of Chemical Ecology, 19th Annual Meeting, University of Hamburg, Germany. 3-7 August 2002. (p.139 of programme). *(See http://www.chemecol.org/meetings/hamburg_02.htm).*