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

1 July 1999 – 31 March 2003

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30 September 2003

This publication is an output from a research project funded by the United Kingdom Department for International Development for the benefit of developing countries. The views expressed are not necessarily those of DFID. (R7441, Crop Protection Programme)
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OUTPUTS

Output 1: Pheromone traps for *M. vitrata* fully optimised
  • Trap and lure optimisation experiments in Benin
    - Trap optimisation experiments
    - Lure optimisation experiments
  • Pheromone blend experiment in Nigeria
  • Identification of potential supplier or manufacturer of pheromone lures
    - Supply of ready-made lures
    - Supply of pheromone components and local production of lures
    - Investigation of registration issues

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
    - Monitoring study in Ghana in 2001
    - Monitoring study in Nigeria in 2001
    - PRONAF farmer field school activities in 2001
  • Regional monitoring of *M. vitrata* with pheromone and light traps
    - Trapping in Benin
    - Trapping in Nigeria/Niger

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 trap use
    - November 2000 survey
    - January – February 2002 survey
  • Traps used to test action thresholds in trials of novel IPM approaches
    - First on-station trial
    - Second on-station trial
    - On-farm trial
  • Economic analysis of benefits of pheromone technology
Output 4: Project findings demonstrated and disseminated

- Joint PRONAF/Bean-Cowpea CRSP/NRI workshop
- Other conference presentations
- Publications
- Training
- Testing of pheromone lures by non-project partners

CONTRIBUTION OF OUTPUTS

Output 1: Pheromone traps for *M. vitrata* fully optimised
Output 2: Trap-catch data interpreted in relation to pest biology and distribution
Output 3: Traps for *M. vitrata* used in development of IPM strategies for control of cowpea pests
Output 4: Project findings demonstrated and disseminated

Further Work and Uptake of Outputs

ACKNOWLEDGEMENTS

REFERENCES CITED

ANNEXES – SEE SEPARATE VOLUME

ANNEX 2 – Downham et al. (2002), paper to World Cowpea Research Conference III, 2000
ANNEX 3 – Downham et al. (2003), J. Chem. Ecol. 24, 989-1011
ANNEX 5 – Downham et al. (in press), paper accepted for publication by Ent. Expl et Appl.
ANNEX 6 – Adati et al. (in press), paper to 15th Conference of the African Association of Insect Scientists, 2003
ANNEX 7 – Adetonah et al. (unpub. report)
ANNEX 8 – Hammond et al. (2002), selected presentations to the joint PRONAF/Bean-Cowpea CRSP/Project workshop, 2002 (CD-R)
ANNEX 9 – Downham et al. (2002), poster to International Society of Chemical Ecology, 19th Annual Meeting, 2002

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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 pour 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 (Afua *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*...
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 type⁵ (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.

⁵ 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.