WORLD COTTON RESEARCH CONFERENCE-3

COTTON PRODUCTION FOR THE NEW MILLENNIUM

WORLD COTTON RESEARCH CONFERENCE - 3 -

9 - 13 MARCH 2003 • CAPE TOWN, RSA

Chief editor

A Swanepoel

Scientific editors

Dr Samuel Alabi	Nigeria	Breeding
Dr Sarel Broodryk	South Africa	Entomology
Dr Roy Cantrell	USA	Breeding
Dr Greg Constable	Australia	Breeding
Dr John Gorham	UK	Physiology/Biochemistry
Dr Kater Hake	USA	Biotechnology
Dr Rory Hillocks	UK	Plant pathology
Dr Lawrance Hunter	South Africa	Fiber quality
Dr Geoff McIntyre	Australia	Irrigation/Water stress
Dr Jodi McLean	Australia	Agronomy
Dr Mustafa	Sudan	Breeding
Dr Bruce Pyke	USA	Extension
Dr Derek Russell	UK	Entomology
Dr Shuki Saranga	Israel	Agronomy
Ms Jeannie Van Biljon	South Africa	Nematology

Managing editor

A Swanepoel

Cape Town, South Africa, 9-13 March 2003

Cataloging in Publication Entry

World Cotton Research Conference (3rd: 2003: Cape Town, South Africa)

Proceedings of the World Cotton Research Conference-3:
Cotton production for the new millennium: Submitted papers. Cape Town, South Africa, 9-13 March, 2003.
Chief editor: A. Swanepoel

1. Cotton – Research – Conference
I. Swanepoel, A. (Annette)

Printed in Pretoria, South Africa, May 2004.

Publisher: Agricultural Research Council - Institute for Industrial Crops
Layout and design: D.Comm
Print: D.Comm

In preparing the proceedings of the World Cotton Research Conference-3, the editors have made a good faith effort to avoid any errors, omissions or other editing mistakes in the process of converting presentations and papers into these proceedings. However, the editors cannot ensure against all such errors.

ORGANISING COMMITTEE

International organizing committee

Dr Terry P Townsend (Chairman)	Executive Director of the International Cotton Advisory Committee
Dr Jean-Philippe Deguine	Deputy Director, CIRAD-CA, France
Peter Griffee	Plant Production and Protection Division, FAO, Italy
Dr Francisco Davila-Ricciardi	President, CONALGODON, Columbia
Dr Andrew Jordan	Technical Director, National Cotton Council of America, USA
Dr Joe CB Kablssa	General Manager, Tanzanian Cotton Lint and Seed Board, Tanzania
Dr Abdusattor Abdukarimov	Director General, Institute of Genetics & Plant Exp. Biology, Uzbekistan
Mr Ralph Schulze (Chairman WCRC-1)	Executive Director, Cotton Research & Development Corporation, Australia
Dr Kiratso Kosmldou-Dlmltropoulou (Chairman WCRC-2)	Director, Hellenic Cotton Board, Greece
Dr Deon Joubert (Chairman WCRC-3)	Director, ARC Institute for Industrial Crops, South Africa

National organizing committee

Chairman	Dr Deon Joubert, Director ARC Institute for Industrial Crops
Secretary	Ms Jeannie van Biljon, Snr Researcher, ARC Institute for Industrial Crops
Members	Mr Hennie Bruwer, CEO Cotton SA Mr Hein Schroder, Quality Control Cotton SA Mr Chris Nolte, Clark Cotton

SPONSORS

ABSA
Agricultural Research Council
CIRAD-CA
Clark Cotton
Cotton SA
CTA
D&PL International
Danida
deNim
FAO
Frame Textiles
GTZ
ICAC
Monsanto
Rockefeller Foundation
SA Cotton Trust
SACTMA
SBH Cotton Mills

Scientific Committee

Prof Lawrence Hunter	Divisional Fellow and Leader: Scientific and Technical Excellence, Division of Manufacturing and Materials Technology of the CSIR and Professor Extraordinary and Head of the post-graduate Department of Textile Science , University of Port Elizabeth
Prof Sakkie Pretorius	Professor and chairperson – Department of Plant Sciences, University of the Free State
Ms Annette Swanepoel	Senior researcher – ARC-Institute for Industrial Crops
Dr Martie Botha	Senior researcher – ARC-Institute for Industrial Crops
Dr Frans Weitz	Plant systematist – Department of Biodiversity and Conservation Biology, University of Western Cape
Dr Deon Joubert	Director – ARC-Institute for Industrial Crops
Dr Chris Steenkamp	Consultant
Dr Sarel Broodryk	IPM Advisor
Prof Maryke Labuschagne	Professor, Department of Plant Sciences, University of the Free State
Dr Graham Thompson	Assistant Director, ARC-Vegetable and Ornamental Plants Institute
Mr Jean-Luc Hofs	Researcher – Department of Plant Production and Soil Science, University of Pretoria
Prof Charles Reinhardt	Professor and Head of the Department – Plant Production and Soil Science, University of Pretoria

Activity spectrum of spinosad and indoxacarb: Rationale for an innovative pyrethroid resistance management strategy in West Africa

O.G. Ochou[1] and T. Martin[1,2]
[1]Centre National de Recherche Agronomique (CNRA), Bouaké COTE D'IVOIRE
[2]Centre de Coopération International en Recherche Agronomique (CIRAD), Montpellier FRANCE
Correspondence author ochougo@africaonline.co.ci

ABSTRACT

To face pyrethroid resistance in the cotton bollworm Helicoverpa armigera *(Hübner), endosulfan (700 g/ha) has been used in a resistance management strategy for four years in Côte d'Ivoire, West Africa. Lately the recommendation is being questioned with regard to its acute mammalian toxicity and environmental issues. Earlier works revealed that insecticides such as spinosad (48 g/ha) and indoxacarb (25 g/ha) proved as effective as endosulfan in controlling* H. armigera. *In contrast to endosulfan, the activity spectrum of these non-pyrethroids insecticides appears to be restricted to a few bollworm and leaf-feeding pests. The present study pointed out the strength and weakness of these new insecticides with respect to major insect pests and beneficial species. On the basis of their activity spectrum and in the light of cotton crop and main pest phenology, new IRM was designed. Indoxacarb is more appropriate in the fruiting stage (101-115 DAE (Days After Emergence)) as it appeared very effective against the cotton stainer* Dysdercus voëlkeri *(Schmidt) while showing lower performance against* Earias *spp. and the mite* Polyphagotarsonemus latus *(Bank). In contrast, spinosad is preferred at the vegetative stage (45-66 DAE) as it proved safer to coccinellids, more effective against* Earias *spp., while its lower effectiveness against* D. voëlkeri *suggests avoiding its positioning at the later stages of cotton growth. Various benefits related to these new insecticides strongly advise their use as alternatives to pyrethroids. However, to be more attractive, their activity needs to be reinforced by other insecticides in such a way as to control the whole arthropod pest complex.*

Introduction

The development of resistance in H. armigera

Pyrethroids are known to be very effective in controlling *Helicoverpa armigera* (Hübner) and most cotton bollworm pests and pyrethroids have been widely used for more than twenty years in Côte d'Ivoire. Recently, laboratory data obtained on *H. armigera* strains from 1996 to1998 pointed out significant increases in the LD_{50} for both deltamethrin (Figure 1) and cypermethrin (Vassal *et al*., 1997; Vaissayre *et al*., 1998; Martin *et al*., 2000). Field data recorded for eight consecutive years (Figure 2) revealed that the pest infestation profiles changed greatly from 1991 to 1998 (Ochou *et al*., 1998). Moreover, cases of ineffectiveness of the pest control program against *H. armigera* have been reported during exceptional pest outbreaks in Côte d'Ivoire. With this in mind, the routine calendar-based program, applying six fortnightly sprays of pyrethroid-organophosphate insecticide mixtures over the whole cotton season, has been questioned. The pyrethroid resistance problem in *H. armigera* was confirmed by Ochou and Martin (2000). Similar cases of resistance were reported in *H. armigera* in most West African countries (Benin, Burkina Faso, Guinea, Mali, Senegal, Togo) (Unpublished data from the West African pyrethroid resistance network with the authors).

Development of the IRM strategy against H. armigera

To face pyrethroid resistance in the cotton bollworm, *H. armigera*, an Insect Resistance Management (IRM) program, inspired from the "Australian" strategy (Sawicki and Denholm, 1987; Forrester *et al*., 1993), was designed in Côte d'Ivoire. In practice, the strategy has led to the determination of a pyrethroid-free season nationwide by using non-pyrethroid insecticides (endosulfan 700-750 g/ha and profenofos 750 g/ha) in a "window" program in order to lessen pyrethroid selection pressure. The pyrethroid-free season is established according to cotton growing zones (commencing August 10 and August 20 respectively for the northern and southern regions). The main impact which seems to have come out from the nationwide adoption of the pyrethroid resistance management program by cotton farmers is the large decrease in the field populations of the *H. armigera* since 1998 (Figure 2) (Ochou and Martin, 2002).

Endosulfan has been widely used in the current pyrethroid resistance management program over the last four years in Côte d'Ivoire, and so far, no resistance to endosulfan has been detected (Martin *et al*., 2002). However, its recommendation is being questioned now with regard to its mammalian toxicity, environmental issues and farmer safety. To tackle this problem, investigations are being undertaken to tailor a relatively low dose of endosulfan (525 g/ha) to the actual field infestation of *H. armigera* (Ochou and Martin, 2000) and to assess micro-encapsulated formulations of endosulfan, assumed safer than the EC formulations to operators and possibly beneficial insects. At the same time, investigations have been made on newer insecticides such as spinosad and indoxacarb as potential alternatives to endosulfan. Spinosad is a naturally produced derivative of the actinomycete *Saccaropolyspora spinosa*. Its mode of action is described as an activation of the nicotine acetylcholine receptor, but at a different site from nicotine or imidacloprid; it is active by contact and ingestion, causing paralysis (BCPC Pesticide Manual, 12th edition, v2). Indoxacarb is an oxadiazine product whose active component blocks sodium channels in nerve cells; it is active by contact and ingestion, and affected insects cease feeding, with poor co-ordination, paralysis and ulti-

mately death (Pesticide Manual, 12th edition, v2). Due to their novel mode of action, both insecticides appear ideal for resistance management programs. However, to be rationally used, there is a need to understand the activity spectrum of these new insecticides compared with that of endosulfan for controlling *H. armigera* (Ochou and Martin, 2002).

The present study assesses the activity spectrum of spinosad and indoxacarb with regard to beneficials and major components of the cotton pest complex in Côte d'Ivoire. The need to reinforce their activity by other insecticides is also assessed. On the basis of the strength and weakness of these new insecticides and with respect to cotton crop phenology and seasonal occurrence of main pests, appropriate recommendations are made to justify their integration into the pyrethroid resistance management programs.

Experimental procedure

The study was carried out for three consecutive years (1999-2001) at the cotton research station of CNRA based at Bouaké and at the experimental station of LCCI at Nambingué, both in Côte d'Ivoire. Initially, the biological activity of the two specific insecticides (spinosad 48 g/ha (Laser 480 SC, Dow AgroSciences) and indoxacarb 25 g/ha (Avaunt 150 SC, Du Pont) was assessed in reference with endosulfan 750 g/ha (Phaser 375 EC, Aventis), and deltamethrin 12 g/ha (Decis 12 EC, Aventis) through a complete block design with six replicates. Individual plots were of 10 rows x 15 m. Further field trials were undertaken in a similar design with the two insecticides in association with other insecticides. Tested mixtures included spinosad 48g/ha + profenofos 300g/ha; spinosad 48g/ha + acetamiprid 10g/ha; indoxacarb 25g/ha + profenofos 300g/ha; indoxacarb 25g/ha + acetamiprid 10g/ha and cypermethrin 36g/ha + profenofos 300g/ha.

Insecticides sprays were performed with an adapted horizontal boom knapsack sprayer discharging 60 l/ha of product-water mixture. Plots were treated every 14 days from 45th to 115th DAE (day after emergence of cotton). Fields were scouted directly on plants once a week from 30th to 122nd DAE and every two weeks on green bolls from 70th to 112th DAE for endocarpic bollworms. Target pests and beneficial organisms were recorded as follows: a) mite *Polyphagotarsonemus latus* infested plants in 3 rows x 15m; b) aphid *Aphis gossypii* infested plants in 3 rows x 15 m; c) jassid *Jacobiella fascialis* infested plants per 30 plants; d) individual sucking pests (*Dysdercus voëlkeri, Bemisia tabaci*), leafworms (*Spodoptera littoralis, Anomis flava, Syllepte derogata*) and exocarpic bollworms (*H. armigera, Earias* spp., *Diparopsis watersi*) per 30 plants; e) endocarpic bollworms (*Cryptophlebia leucotreta, Pectinophora gossypiella*) per 100 green bolls; and f)- individual beneficial arthropods (ladybirds, spiders, etc.) per 30 plants. Three year average data for all bollworms and one-two year average data for sucking pests, leaf pests and beneficials were compiled.

Results

Effectiveness of spinosad and indoxacarb against cotton bollworms

Data presented in Figures 3a to 3d show comparative effectiveness of the pyrethroid deltamethrin and the non-pyrethroid insecticides, indoxacarb, spinosad and endosulfan on cotton exocarpic bollworm species (*H. armigera, Earias* spp., *D. watersi*) and endocarpic bollworm species (*C. leucotreta and P. gossypiella*).

Spinosad activity on the exocarpic bollworm species (*H. armigera, Earias* spp. and *D. watersi*) was equivalent to that of endosulfan. Overall activity of spinosad against the exocarpic bollworm species was higher than that of deltamethrin.

Indoxacarb activity was equivalent to that of deltamethrin for *H. armigera* (4.9 versus 5.1 larvae per 30 plants), but less effective against *Earias* spp. In contrast, the activity of both insecticides (spinosad and indoxacarb) on endocarpic species remained low in relation to that of deltamethrin (6.4 and 7.1 versus 3.2 endocarpic larvae per 100 bolls, for spinosad, indoxacarb and deltamethrin respectively).

Effectiveness of spinosad and indoxacarb against sucking pests

Data presented in Figures 4a-d reveal comparative activity of the pyrethroid deltamethrin and the non-pyrethroid insecticides on cotton sucking pests *J. fascialis*, *A. gossypii*, *D. voëlkeri* and the mite *P. latus*. The effect of spinosad was at least equivalent to deltamethrin on the jassid *J. fascialis* (1.2 versus 1 jassid attacked plants per 30 plants) and on the mite *P. latus* (4 mite infested plants per 3 rows). In contrast, spinosad appeared less effective than endosulfan against the aphid *A. gossypii* (57 versus 37 aphid infested plants per 3 rows x 15m) and the cotton stainer *D. voëlkeri* (169 versus 141 *Dysdercus* per 30 plants). In contrast to spinosad, the effect of indoxacarb was equivalent to that of deltamethrin on *D. voëlkeri* (110 versus 102 *Dysdercus* per 30 plants) and on the aphid *A. gossypii* (43 versus49 aphid infested plants per 3 rows x 15 m) while showing less effectiveness compared to endosulfan against the mite *P. latus* (12 versus 2mite infested plants per 3 rows x 15m).

Effectiveness of spinosad and indoxacarb against cotton leafworms

Data presented in Figures 5a and 5b show comparative effects of the pyrethroid deltamethrin and the non pyrethroid insecticides on cotton leafworm *S.*

littoralis and *A. flava*. Spinosad and indoxacarb proved very effective against the leafworm *S. littoralis* (0.7 and 0.8 versus 1.5 larvae per 30 plants, respectively for indoxacarb, spinosad and deltamethrin). Their activity of on *A. flava* remained roughly equivalent to deltamethrin and endosulfan (1.2 and 2.2 versus 1.8 larvae per 30 plants, for spinosad, indoxacarb and endosulfan respectively).

Activity of spinosad and indoxacarb on beneficials

Figures 6a and 6b show data on the comparative activity of the pyrethroid deltamethrin and the non-pyrethroid insecticides on beneficial predators. Spinosad (and indoxacarb to a lesser extent) proved safer on ladybirds (*Coccinella* spp.) as compared to endosulfan (10.7 and 5.8 coccinellids per 30 plants respectively for spinosad and indoxacarb versus for endosulfan). The effect of both insecticides on the spiders was equivalent to that of endosulfan and deltamethrin (6.5 versus 6.6 spiders per 30 plants).

Effectiveness of spinosad and indoxacarb in mixtures with other insecticides

Data presented in Figures 7a to 7d showed comparative activity of profenofos and acetamiprid based mixtures with spinosad and indoxacarb, and pyrethroid based mixtures on cotton bollworms and some sucking pests. The profenofos-based mixtures with spinosad or indoxacarb provided an activity level at least equivalent to the cypermethrin-profenofos mixture against *H. armigera* (0.3 and 1 versus 1.1 larva per 30 plants, respectively for indoxacarb-profenofos, spinosad-profenofos and cypermethrin-profenofos). The same tendency was observed against the mite *P. latus* (0.1 and 2.5 versus 2.9 mite infested plants per three rows).

The acetamiprid-based association with spinosad was at least equivalent to the cypermethrin-acetamiprid association against *D. voëlkeri* (74.2 per 90.7 *Dysdercus* per 30 plants). This association was more effective against *D. voëlkeri* than the indoxacarb-acetamiprid association (109.3 *Dysdercus* per 30 plants). Concerning the endocarpic bollworm species (*C. leucotreta* and *P. gossypiella*) the spinosad-acetamiprid association showed an activity level equivalent to the cypermethrin-acetamiprid (4 versus 2 larvae per 100 bolls) while the activity remained very low for the indoxacarb-acetamiprid association (9.5 larvae per 100 bolls).

Discussion

The present study points out the strength and weakness of spinosad and indoxacarb with respect to major insect pests and beneficial species. The activity of spinosad and indoxacarb varied significantly according to insect pest species or beneficial species.

Spinosad activity spectrum comprised exocarpic bollworm species (*H. armigera*, *Earias* spp., *D. watersi*) and the cotton leafworms *S. littoralis* and *A. flava*. It appeared to have a certain activity against the endocarpic bollworm species (*C. leucotreta* and *P. gossypiella*), the jassid *J. fascialis* and the mite *P. latus*. This activity on sucking pests such as the jassid *J. fascialis* and the mite *P. latus* need to be confirmed in more field trials, for the pesticide manual (Pesticide manual) states that spinosad is non-toxic to sucking pests. Indeed, spinosad appeared very limited against the aphid *A. gossypii* and the cotton stainer *D. voëlkeri*. With regard to beneficials, spinosad proved safer to *Coccinella* spp. and spiders.

In contrast to the spinosad, indoxacarb activity spectrum was restricted to certain bollworm species (*H. armigera*, *D. watersi*) and the cotton leafworm *S. littoralis*. In addition, it appeared to have some effectiveness against the jassid *J. fascialis*, the aphid *A. gossypii* and the cotton stainer *D. voëlkeri*. Indoxacarb appeared inactive against *Earias* spp., the mite *P. latus* and the endocarpic bollworm species (*C. leucotreta* and *P. gossypiella*).

On the basis of their activity spectrum and in the light of cotton crop phenology and seasonal occurrence of main pests, differential pyrethroid resistant management plans were designed (Figures 8a and 8b) utilizing spinosad and indoxacarb either at the vegetative or fruiting stages of cotton. Due to its high effectiveness on exocarpic bollworm species mainly *H. armigera* and *Earias* spp., and its relative safety to major beneficials such as ladybird *Coccinella* spp., spinosad could be preferentially used at the vegetative stage (45-66 DAE). The relatively broad activity spectrum of spinosad makes it ideal for use at the vegetative stage of cotton, appearing as a true alternative to endosulfan. Its positioning at a late stage of cotton development could also be more suitable provided it is used in association with other insecticides such as acetamiprid, effective against *D. voëlkeri* and *A. gossypii*.

Due to its activity spectrum, which is relatively restricted in relation to spinosad, indoxacarb appears more appropriate to the cotton fruiting stage (101-115 DAE), as it proved effective against the cotton stainer *D. voëlkeri* while showing lower performance against *Earias* spp. and the mite *P. latus*. Association of indoxacarb with other insecticides such as profenofos could enhance its activity at least against the mite *P. latus*. The use of indoxacarb is not advisable during the period that coincides with maximum flowering as it had a limited effect on endocarpic bollworm species (*C. leucotreta* and *P. gossypiella*) which occur in largest numbers at this stage; it is therefore necessary to maintain a pyrethroid-based mixture at this stage in order to control endocarpic bollworm species.

Various benefits related to these new insecticides strongly advise their use as alternatives to pyrethroids.

However, to be more attractive, their activity needs to be reinforced by other insecticides in such a way to control the whole arthropod pest complex. Conjoint laboratory activities are being achieved to help set more reliable strategies and improve the whole pest management strategy. Bioassays performed with several classes of insecticides, especially non pyrethroid insecticides such as DDT, endosulfan, profenofos, indoxacarb and spinosad did not show any cross-resistance with pyrethroids in *H. armigera* (Martin, unpublished data), which is important given that pyrethroid resistance in *H. armigera* from West Africa is due to greater degradation of pyrethroids involving oxidases from the P450 family (Martin *et al*., 2002).

Conclusion

The earlier use of endosulfan and profenofos as pyrethroid alternatives in *H. armigera* resistance management in Côte d'Ivoire has helped reduce substantially field infestations of *H. armigera* for the last four years. No resistance was still detected to endosulfan or profenofos in field populations indicating the current success of these pyrethroid alternatives. However, endosulfan and profenofos resistance has been shown in *H. armigera* from Pakistan (Ahmad *et al*., 1995) and Australia (Forrester *et al*., 1993; Gunning *et al*., 1993) indicating the risk of selecting resistant larvae in Côte d'Ivoire if those insecticides are to be used for a number of years without alternatives. For pyrethroid resistance management to be sustainable, there is a clear need to adopt alternative insecticides such as spinosad and indoxacarb in a rational non-pyrethroid insecticide rotation plan. Spinosad and indoxacarb could be used in appropriate resistance management programs either alone or reinforced in mixtures by other insecticides or in mosaics with endosulfan and profenofos in such a way to avoid the selection of resistance problems.

Acknowledgements

The authors acknowledge the research and development staff of cotton companies of Côte d'Ivoire (CIDT, IC, LCCI) and M.M. Konan, K. Jérôme, Kouadio René and Kouadio Gérard of the cotton entomology technical research team of CNRA for their assistance in collecting field data. Thanks are due to chemical companies Dow AgroScience, Du Pont de Nemours, Aventis CropScience and Syngenta for insecticide samples provided.

References

- Ahmad, M., Arif, M.I. and Ahmad, Z. (1995). Monitoring insecticide resistance of *Helicoverpa armigera* (Lepidoptera Noctuidae) in Pakistan. *Journal of Economic Entomology*, **88**: 771-776.
- Forrester, N.W., Cahill, M., Bird, L.J. and Layland, J.K. (1993). Management of pyrethroid and endosulfan resistance in *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Australia. In Bull. Entomol. Res. Supplement Series N°1. International Institute of Entomology pp. 1-132.
- Gunning, R.V. and Easton, C.S. (1993). Resistance to organophosphate insecticides in *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in Australia. *General Applied Entomology*, **25**: 27-34.
- Martin, T., Ochou, G.O., Hala, N.F., Vassal, J.M. and Vaissayre, M. (2000). Pyrethroid resistance in the cotton bollworm, *Helicoverpa armigera* (Hübner), in West Africa. *Pest Management Science*, **56**: 549-554.
- Martin, T., Chandre, F., Ochou, O.G., Vaissayre, M. and Fournier, D. (2002). Pyrethroid resistance mechanisms in the cotton bollworm *Helicoverpa armigera* (Lepidoptera: Noctuidae) from West Africa. *Pesticide Biochemical Physiology*, **74**: 17-26.
- Martin, T., Ochou, O.G., Vaissayre, M. and Fournier, D. (2002). Positive and Negative Cross-resistance to Pyrethroids in *Helicoverpa armigera* from West Africa. *Resistant Pest Management Newsletter*, **12**: 1.
- Ochou, O.G., Martin, T. and Hala, N.F (1998). Cotton insect pest problems and management strategies in Côte d'Ivoire, W. Africa. Proceedings of the world Cotton Research Conference-2. Athens, Greece, September 6-12, pp 833-837.
- Ochou, O.G. and Martin, T. (2000). Prévention et gestion de la résistance de *Helicoverpa armigera* (Hübner) aux pyréthrinoïdes en Côte d'Ivoire. 2ème Rapport d'exécution technique du projet régional PR-PRAO. 93 p.
- Ochou, G.O. and Martin, T. (2002). Pyrethroid Resistance in *Helicoverpa armigera* (Hübner): Recent Developments and Prospects for its Management in Côte d'Ivoire, West Africa. *Resistant Pest Management Newsletter*, **12**: 1.
- Sawiki, R.M. and Denholm, I. (1987). Management of resistance to pesticides in cotton pests. *Tropical Pest Management*, **33:** 262-272.
- Vaissayre, M., Vassal, J. M. and Martin, T. (1998). Pyrethroid resistance in the bollworm *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in West Africa. Proceedings of the World Cotton Research Conference-2. Athens, Greece, September 6-12, pp. 701-705
- Vassal, J.M., Vaissayre, M. and Martin, T. (1997). Decrease in the susceptibility of *Helicoverpa armigera* (Hübner) (Lepidoptera : Noctuidae) to pyrethroid insecticides in Côte d'Ivoire. *Resistant Pest Management*, **9**:, 14-15.

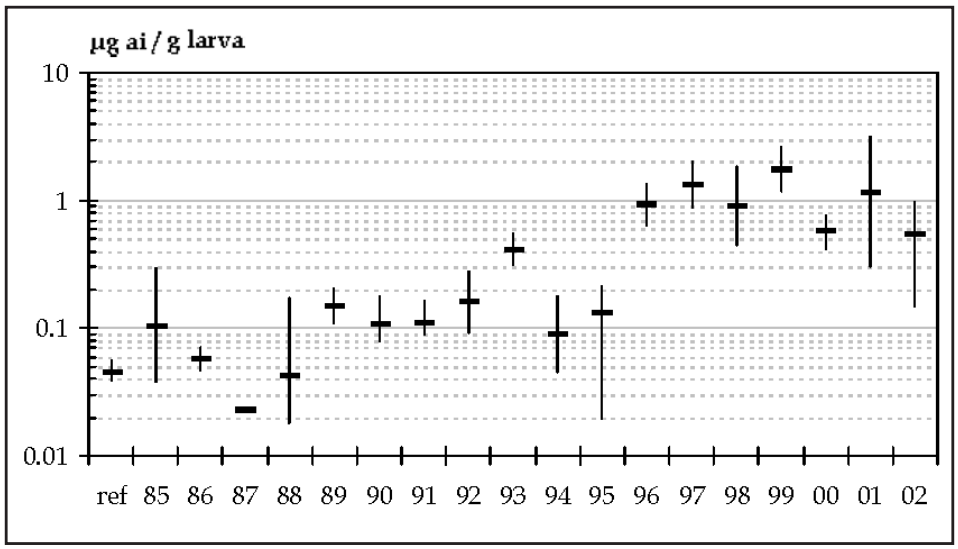


Figure 1. *LD_{50} survey of deltamethrin from 1985 to 1998 with topical application tests on* Helicoverpa armigera *Bouaké strain.*

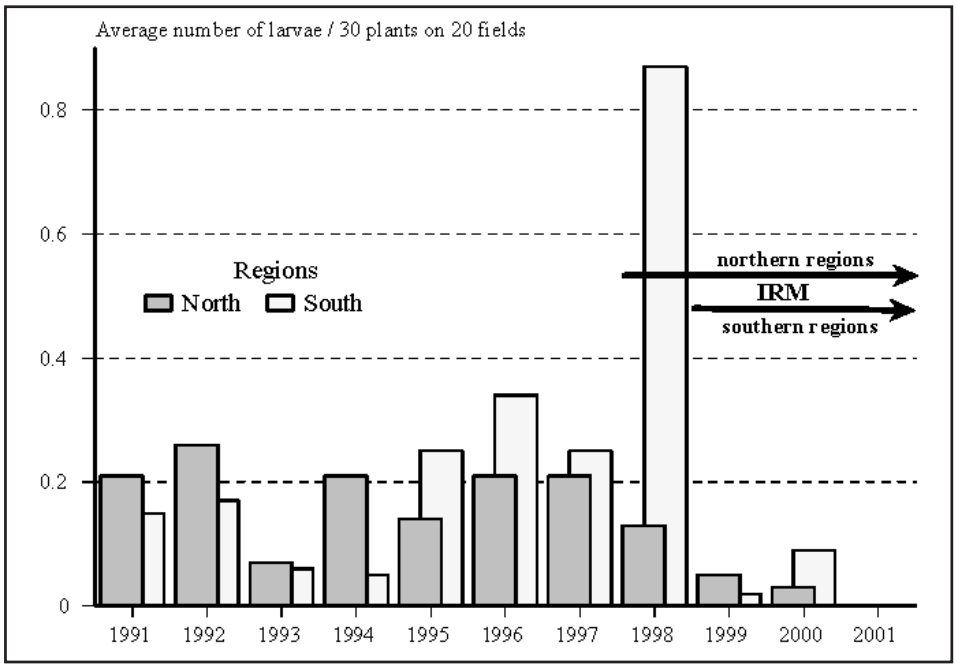
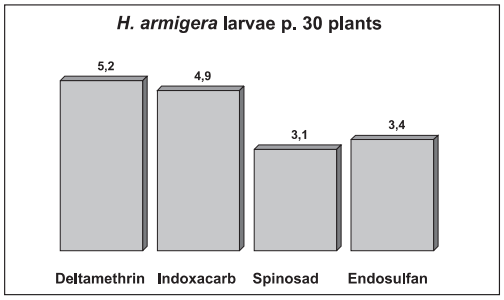
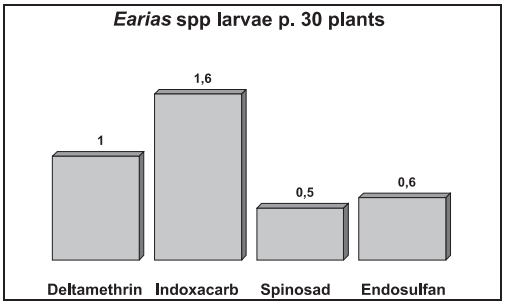


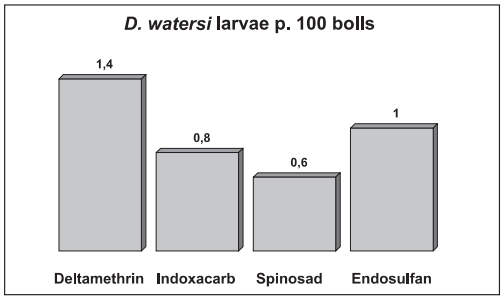
Figure 2. *Annual variations in average field infestation levels of* H. armigera *in cotton areas of Côte d'Ivoire before and after IRM.*



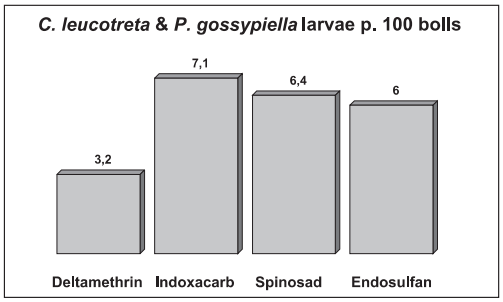
a Compared activity of insecticides on *Helicoverpa armigera*



b. Compared activity of insecticides on *Earias* spp.

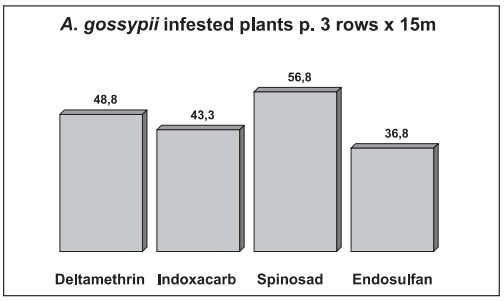


c. Compared activity of insecticides on *Diparopsis watersi.*

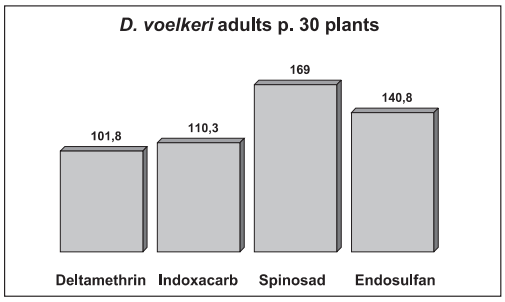


d. Compared activity of insecticides on endocarpic bollworms.

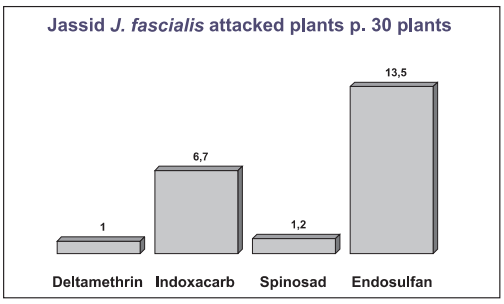
Figure 3.
Compared effectiveness of spinosad and indoxacarb against cotton bollworms in Côte d'Ivoire.



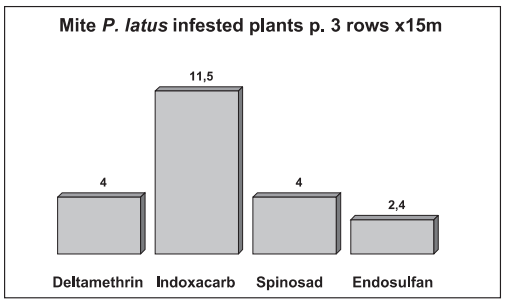
a. Compared activity of insecticides on *Aphis gossypii*



b. Compared activity of insecticides on *Dysdercus voelkeri*

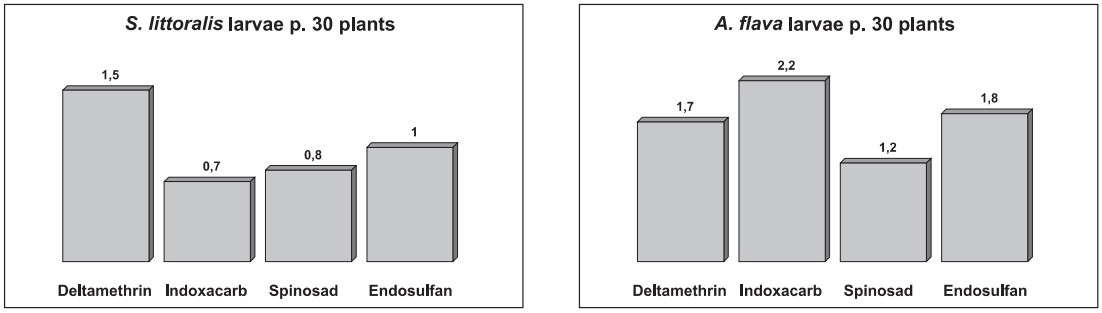


c. Compared activity of insecticides on *Jacobiella fascialis*



d. Compared activity of insecticides on *Polyphagotarsonemus latus*

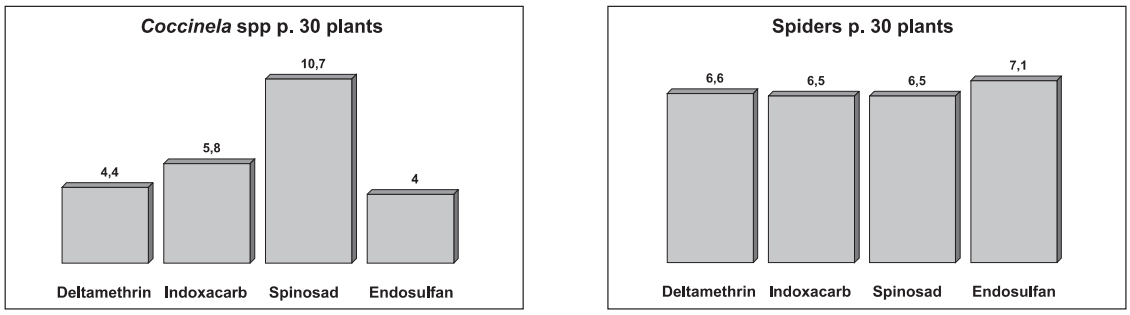
Figure 4.
Compared effectiveness of spinosad and indoxacarb against cotton sucking pests in Côte d'Ivoire.



a. Compared activity of insecticides on *Spodoptera littoralis*

b. Compared activity of insecticides on *Anomis flava*

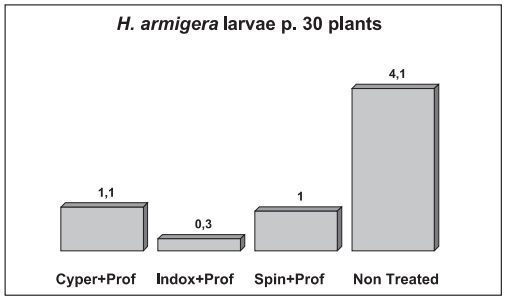
Figure 5.
Compared effectiveness of spinosad and indoxacarb against cotton leafworm pests in Côte d'Ivoire.



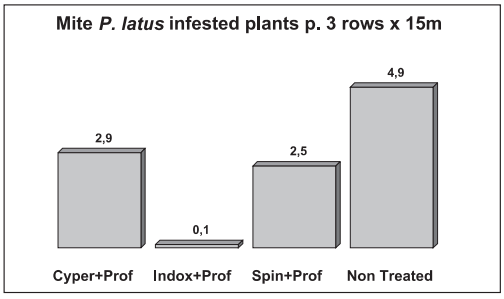
a. Compared activity of insecticides on *Coccinella* spp.

b. Compared activity of insecticides on spiders

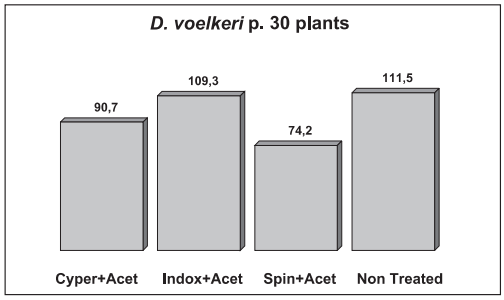
Figure 6.
Compared activity of spinosad and indoxacarb on beneficials in Côte d'Ivoire.



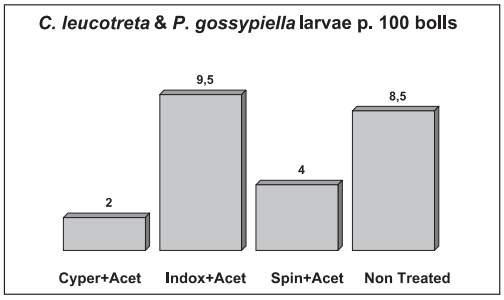
a. Compared activity of profenofos based mixtures with spinosad and indoxacarb on *Helicoverpa armigera*



b. Compared activity of profenofos based mixtures with spinosad and indoxacarb *on Polyphagotarsonemus latus*



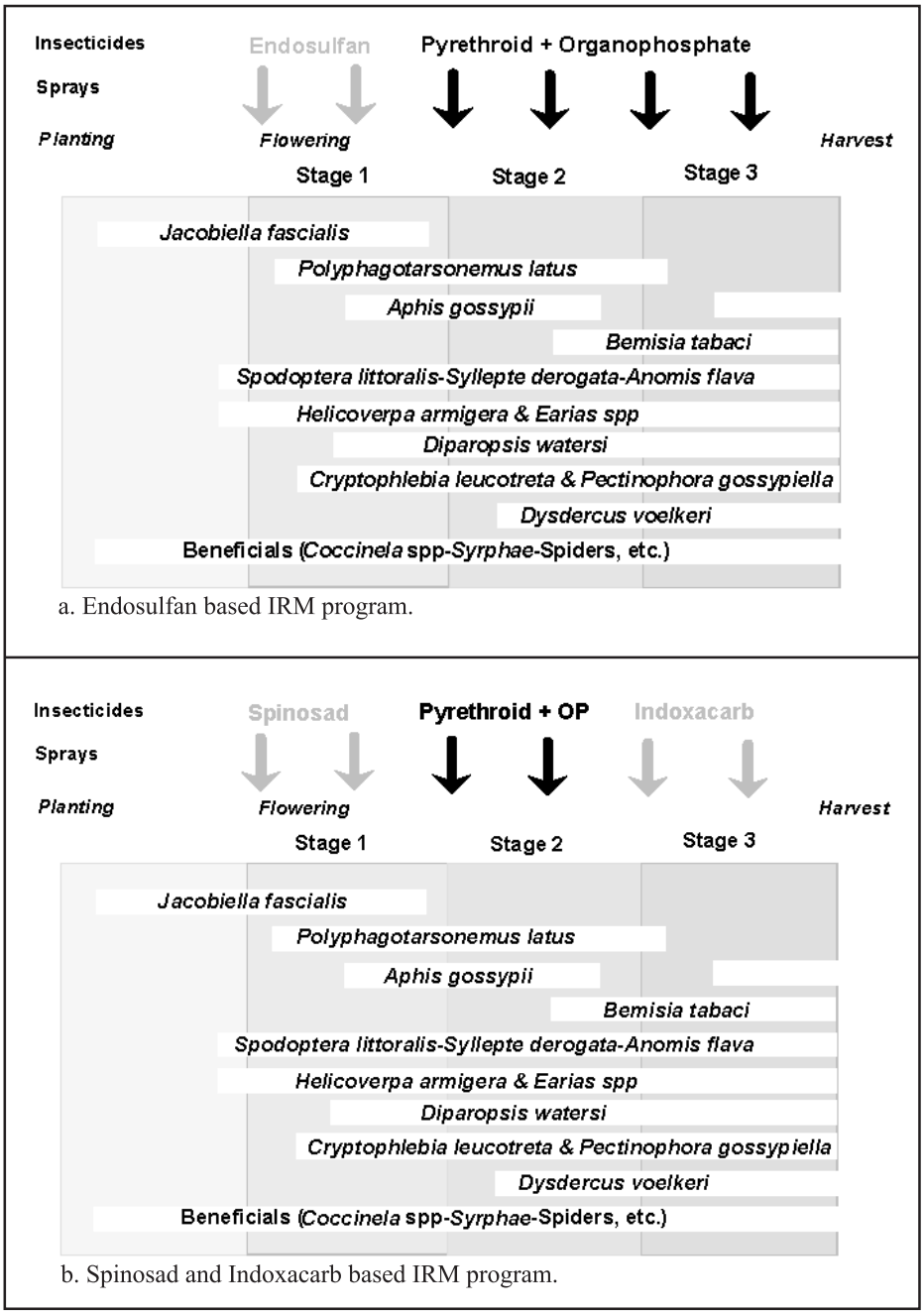
7c. Compared activity of acetamiprid based mixtures with spinosad and indoxacarb on endocarpic bollworms



7d. Compared activity of acetamiprid based mixtures with spinosad and indoxacarb on *Dysdercus voelkeri*

Figure 7.
Compared activity of profenofos or acetamiprid based mixtures with spinosad and indoxacarb on cotton pests in Côte d'Ivoire.

Figure 8. *Current and innovative pyrethroid management programs.*



a. Endosulfan based IRM program.

b. Spinosad and Indoxacarb based IRM program.