Integrated pest management of the banana weevil, *Cosmopolites sordidus* (Germar), in South Africa

by

Johan de Graaf

Submitted in partial fulfilment of the requirements for the degree Philosophiae Doctor (Entomology), in the Faculty of Natural & Agricultural Science

University of Pretoria
Pretoria

May 2006

CONTENTS

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Johan de Graaf

Supervisors: Dr. Prem Govender, Dr. Altus Viljoen and Dr. At S. Schoeman

Department of Zoology and Entomology

Thesis submitted for the degree of Philosophiae Doctor (Entomology)

SUMMARY

The banana weevil, *Cosmopolites sordidus*, is an economical pest of *Musa*, distributed to most areas where the crop is grown. The beetle larvae produce feeding tunnels in the pseudostem and rhizome, reducing bunch weight and causing toppling or snapping of plants. In developing an integrated pest management system for South Africa, specific aims of the study were to quantify the genetic diversity of the species around the world, investigate the population dynamics of the insect, determine the potential of semiochemical mass trapping, elucidate the efficacy of cultural and chemical control methods and establish economic thresholds for the banana weevil on Cavendish bananas in South Africa.

Pest status of the insect is variable around the world, and may be influenced by genetically distinct populations of the weevil. Six populations from four countries were sampled: Australia, Costa Rica, South Africa (South Coast, North Coast and Tzaneen) and Uganda. DNA was isolated from 12 individuals per population and subjected to amplified fragment length polymorphism (AFLP) analysis. The AFLP analysis involved DNA restriction with *Eco*RI and *Pst*I enzymes, ligation of adapters, and a pre-selective and five selective PCR amplifications. Empirical analysis of the AFLP fingerprints showed that, within populations, genetic diversity varied from 16-53%, with the South Coast and Tzaneen/Australian populations the least and most variable, respectively. The coefficient of gene differentiation showed that the Tzaneen population were the most differentiated from the South Coast population, while the South and North Coast populations were the most similar. All the populations showed statistically distinct marker frequencies, except for the Costa Rican and South and North Coast populations, which were similar. Based on the simple mismatch coefficient, a neighbour-joining tree showed the Australian, Ugandan and South

African coastal populations produced monophyletic groups, while the South African Tzaneen population were removed from the other populations and presented an ancestral state.

The population dynamics of the insect was investigated over two seasons and at three locations in the South Coast of KwaZulu-Natal. Adult activity was monitored with semiochemical (Cosmolure®) baited pitfall traps. Traps were moved monthly to a random independent location, or left *in situ* for the duration of the experiment. The ontogeny was determined by dissecting felled plants and toppled plants (up to 2-week-old fresh residues), and harvested plants visually classified as an early and a late rotting stage (decayed residues). Replicated, randomised block designs were used in the experiments. The adult beetles were sexed and the percentage females with eggs and the number of eggs per female were recorded. Larval head capsule widths were measured with an electronic caliper. Ambient temperature and precipitation (rainfall + irrigation) were measured on site. Weevils were active throughout the year and mainly collected in stationary traps, with a collection peak in May and high numbers in early spring and late autumn/early winter. The activity was usually a negative and a positive function of ambient temperature and corrected rainfall, respectively. Eggs per female and percentage females with eggs were reduced during winter and a positive function of ambient temperature. The beetles sampled from plant material represented an equal sex ratio, while the pheromone traps collected a female biased sex ratio during spring and autumn/early winter. The beetle had overlapping generations with a peak of adults and larvae in autumn and late summer, respectively. Adults were mainly associated with decayed residues while larvae were mostly found in freshly toppled plants. Adults were the main over-wintering stage. The earliest larval instars were usually sampled during autumn. The data suggested that the beetle is multivoltine in the study areas and provided valuable information for the optimal management of the insect pest.

Semiochemical adult trapping methods were compared in field trials using a randomised block design. Pseudostem traps, pitfall traps containing a pheromone (either Cosmolure® (Pheromone A) or Cosmolure+® (Pheromone B)), and unbaited pitfall traps (control), were compared over 5 weeks during all seasons along the Southeast coast of South Africa. Pseudostem traps treated with an insecticide, and rhizome traps were included as additional treatments in autumn. In summer two treatments were also added: individual suspension of both pheromones above a pitfall

trap either in combination with or without a pseudostem trap. The adult beetles were sexed, and the number of internal eggs noted. Pheromone A proved to be the most effective of the different traps. Grouping of the pheromones resulted in a synergistic response, while combining the pseudostem did not enhance trap efficacy. The different plant material traps and the control were usually equally effective in catching weevils. Plant material traps caught greater numbers of fecund females, but pheromone traps captured a higher proportion of females. Treatment effects were much less pronounced in summer, and compared to a pseudostem trap, pitfall traps were the most efficacious during spring. Compared to conventional pseudostem trapping, Pheromone A pitfall traps should be optimally applied during spring in South Africa.

Cultural control methods were investigated over 2 years at an ongoing trial in the Southern KwaZulu Natal, South Africa. Harvesting at ground level and dissection of remnants, and covering of the mat with soil and moving debris to the inter-row, were compared to a positive control that involved treatment of plants with a registered pesticide, and a negative control that involved harvesting at approximately 150 cm with no soil or sanitation amendments. Yield, weevil damage and pseudostem girth of plants were measured from August to November annually, while adult beetle densities were assessed over 4 weeks in October/November and April. Nematode samples were analysed in October/November every year. Damage parameters included the Coefficient of Infestation, the Percentage Coefficient of Infestation (PCI) at two intervals, the summed PCI value, the percentage cross sectional damage of the central cylinder (XI) and cortex, and the mean cross sectional damage percentage (X mean). A replicated block design was used in the experiment. The parameters were similar before the onset of the trial. Fruit yield and plant girth, corrected by nematode densities, were not significantly different in any treatment, nor were the nematodes controlled. Soil cover and recession of remnants was the only effective treatment, significantly reducing the Coefficient of Infestation, but not the adult density or any other damage parameter. The former showed promise as a cultural control method because it only needs to be applied seasonally and reduced the XI, the damage parameter most closely related to yield, by 14.18%.

The weevil is difficult to control, and chemical control arguably provides the best opportunity to manage the pest. The efficacy of injecting bifenthrin, chlorpyrifos, fipronil, imidacloprid, oxamyl and water (control) into residual banana plants was

determined. The chemicals were administered every even numbered month over 2 years at two locations in Southern KwaZulu-Natal, South Africa. Yield, weevil damage and pseudostem girth of plants felled from August to October were measured, while adult beetle densities were assessed over 4 weeks in October and April. Nematode samples were analysed in October every year. Damage parameters included were similar to that of the cultural control trial. Replicated block designs were used in the experiments. The parameters were similar before the onset of the trial. Fruit yield and plant girth, corrected by nematode densities, were not significantly increased after chemical applications, nor were the nematodes controlled. Fipronil and imidacloprid were highly effective against *C. sordidus*, minimising damage to the periphery, cortex and central cylinder of the rhizome and significantly reduced adult density. Fipronil caused a 95% and imidacloprid a 100% reduction in the XI. Injection of fipronil and imidacloprid provides an optimal chemical strategy in an integrated pest management programme for the banana weevil.

Economic thresholds of the insect were investigated on bananas at four locations in the South Coast of KwaZulu-Natal. Yield (bunch weights) and larval damage to felled plants were measured from August to October in 2003, while adult densities were assessed over 4 weeks in October 2003. Nematode samples were collected and analysed in October 2003. Damage parameters included were similar to that of the cultural control trial. Replicated block designs were used in the experiments. The economic-injury level (EIL) for chemical and cultural control was calculated. Nematode densities did not influence the yield of plants. The XI was the best predictor of yield, but under certain conditions X mean was the most important. Chemical control showed the lowest EIL, with more than 1 and 7% damage to the central cylinder when applying fipronil and imidacloprid, respectively. The EIL for cultural control was more than 11% damage to the central cylinder. A recommendation algorithm, considering all the findings of the individual studies, is provided for IPM of the banana weevil in the South Africa. The potential use of microbial and invertebrate (especially parasitoids) biological control and semiochemical mass trapping of the weevil requires further research. Long-term research should focus on host resistance, and weevil damage to the central cylinder can serve as indicator of susceptibility of Cavendish bananas.

LIST OF TABLES

LIST OF FIGURES

Figure 3.2b. The mean monthly number (+SE) and head capsule width (mm) (±SE) (secondary y-axis) of larval *Cosmopolites sordidus* in decayed (D, black bars) and fresh (F, white bars) banana residues at Munster (KZN, South Africa) from May 2003 to April 2004. The shaded area represents the mean monthly densities. The black dots indicate the mean larval head capsule width in the decayed residues, while the white filled dots present the head capsule width in the fresh residues.

Figure 3.3. The mean weekly activity (+SE) of adult *Cosmopolites sordidus* measured by semiochemical (Cosmolure®) baited pitfall traps in stationary positions (triangles with solid lines) and independent monthly positions (squares with dotted lines) at Ramsgate (KZN, South Africa) from May 2003 to April 2005, represented as annual figures. Significance of the mean monthly activity (shaded area) are indicated on the x-axis's, where letters in common indicate no significant difference (*P*>0.05).

Figure 3.4a. The mean monthly number (+SE) and percentage (±SE) (secondary y-axis) of adult *Cosmopolites sordidus* in decayed (D, black bars) and fresh (F, white bars) banana residues at Ramsgate (KZN, South Africa) from May 2003 to April 2005, represented as annual figures. The shaded area represents the mean monthly densities. The black dots indicate the percentage of adults in decayed residues, while the white filled dots present the adult percentage in the fresh residues.

Figure 3.4b. The mean monthly number (+SE) and head capsule width (mm) (±SE) (secondary y-axis) of larval *Cosmopolites sordidus* in decayed (D, black bars) and fresh (F, white bars) banana residues at Ramsgate (KZN, South Africa) from May 2003 to April 2005, represented as annual figures. Significance of the mean monthly densities (shaded area) is indicated on the x-axis, where letters in common indicate no significant difference (*P*>0.05). The black dots indicate the mean larval head capsule width in the decayed residues, while the white filled dots present the head capsule width in the fresh residues.

Figure 3.5. The mean weekly activity (+SE) of adult *Cosmopolites sordidus* measured by semiochemical (Cosmolure®) baited pitfall traps in stationary positions (triangles with solid lines) and independent monthly positions (squares with dotted

lines) at Leisure Bay (KZN, South Africa) from June 2004 to May 2005. Significance of the mean monthly activity (shaded area) is indicated on the x-axis, where letters in common indicate no significant difference (*P*>0.05).

Figure 3.6a. The mean monthly number (+SE) and percentage (±SE) (secondary y-axis) of adult *Cosmopolites sordidus* in decayed (D, black bars) and fresh (F, white bars) banana residues at Leisure Bay (KZN, South Africa) from June 2004 to May 2005. Significance of the mean monthly densities (shaded area) is indicated on the x-axis, where letters in common indicate no significant difference (*P*>0.05). The black dots indicate the percentage of adults in decayed residues, while the white filled dots present the adult percentage in the fresh residues.

Figure 3.6b. The mean monthly number (+SE) and head capsule width (mm) (±SE) (secondary y-axis) of larval *Cosmopolites sordidus* in decayed (D, black bars) and fresh (F, white bars) banana residues at Leisure Bay (KZN, South Africa) from June 2004 to May 2005. Significance of the mean monthly densities (shaded area) is indicated on the x-axis, where letters in common indicate no significant difference (*P*>0.05). The black dots indicate the mean larval head capsule width in the decayed residues, while the white filled dots present the head capsule width in the fresh residues.

Figure 4.1. The mean (+ standard error) number of *Cosmopolites sordidus* attracted per week to different traps during August 2002 (winter). Means with letters in common indicate no significant difference (*P* > 0.05).

Figure 4.2a. The mean (+ standard error) total, female, male and percent of females of *Cosmopolites sordidus* individuals attracted per week to different traps during October/November 2003 (spring). Percentage means are indicated by black dots and refer to the secondary y-axis. For each dependent variable, means with letters in common indicate no significant difference (*P* > 0.05).

Figure 4.2b. The mean (+ standard error) number of eggs per female and percent of females containing eggs of *Cosmopolites sordidus* individuals attracted per week to different traps during October/November 2003 (spring). Percentage means are indicated by black dots and refer to the secondary y-axis. For each dependent variable, means with letters in common indicate no significant difference ($P > 0.05$).

Figure 4.3a. The mean (+ standard error) total, female, male and percent of females of *Cosmopolites sordidus* attracted per week to different traps during February/March 2004 (summer). Percentage means are indicated by black dots and refer to the secondary y-axis. For each dependent variable, means with letters in common indicate no significant difference ($P > 0.05$). Ph, Pheromone; PS, Pseudostem.

Figure 4.3b. The mean (+ standard error) number of eggs per female and percent of females containing eggs of *Cosmopolites sordidus* attracted per week to different traps during February/March 2004 (summer). Percentage means are indicated by black dots and refer to the secondary y-axis. For each dependent variable, means with letters in common indicate no significant difference ($P > 0.05$). Ph, Pheromone; PS, Pseudostem.

Figure 4.4a. The mean (+ standard error) total, female, male and percent of females of *Cosmopolites sordidus* attracted per week to different traps during April 2003 (autumn). Percentage means are indicated by black dots and refer to the secondary y-axis. For each dependent variable, means with letters in common indicate no significant difference ($P > 0.05$). Ph, Pheromone; PS, Pseudostem.

Figure 4.4b. The mean (+ standard error) number of eggs per female and percent of females containing eggs of *Cosmopolites sordidus* attracted per week to different traps during April 2003 (autumn). Percentage means are indicated by black dots and refer to the secondary y-axis. For each dependent variable, means with letters in common indicate no significant difference ($P > 0.05$). Ph, Pheromone; PS, Pseudostem.

Figure 4.5a. The mean (+ standard error) total fraction, female fraction, male fraction and percent of females of *Cosmopolites sordidus* attracted per week to all seasonally corresponding traps during spring (October/November 2003), summer (February/March 2004) and autumn (April 2003). Fractions represent indices of increase relative to pseudostem traps. Percentage means are indicated by black dots and refer to the secondary y-axis. For each dependent variable, means with letters in

significantly different (*P*>0.05). Chem = Aldicarb, Harv = Low harvesting and destroying remnants, Cover = Soil cover and movement of debris to the inter-row.

Figure 6.1. The mean values of the Percentage Coefficient of Infestation (PCI) and Coefficient of Infestation (secondary axis) damage parameters of untreated (control) plants and plants treated bimonthly with four chemicals at Munster (KZN, South Africa) from October 2003 to August 2005. For each dependent variable, means with letters in common are not significantly different (*P*>0.05) and upper case letters refer to the secondary axis. 20 = PCI from > 5 to 20 cm from the collar, To = Summed total PCI, Bifen = Bifenthrin, Chlor = Chlorpyrifos, Fip = Fipronil and Oxa = Oxamyl.

Figure 6.2. The mean adult banana weevil density values of untreated (control) plots and plots treated bimonthly with four chemicals at Munster (KZN, South Africa) from October 2003 to August 2005. For each dependent variable, means with letters in common are not significantly different (*P*>0.05). Bifen = Bifenthrin, Chlor = Chlorpyrifos, Fip = Fipronil and Oxa = Oxamyl.

Figure 6.3. The mean values of the Percentage Coefficient of Infestation (PCI) and Coefficient of Infestation (secondary axis) damage parameters of untreated (control) plants and plants treated bimonthly with five chemicals at Ramsgate (KZN, South Africa) from October 2003 to August 2005. For each dependent variable, means with letters in common are not significantly different (*P*>0.05) and upper case letters refer to the secondary axis. 05 = PCI from 0 to 5 cm from the collar, 20 = PCI from > 5 to 20 cm from the collar, To = Summed total PCI, Bifen = Bifenthrin, Chlor = Chlorpyrifos, Fip = Fipronil, Imi = Imidacloprid and Oxa = Oxamyl.

Figure 6.4. The mean values of the cross sectional damage parameters of untreated (control) plants and plants treated bimonthly with five chemicals at Ramsgate (KZN, South Africa) from October 2003 to August 2005. For each dependent variable, means with letters in common are not significantly different (*P*>0.05). XO = Cross section damage percentage of the cortex, XI = Cross section damage percentage of the central cylinder, X mean = Average cross sectional damage of the corm, Bifen = Bifenthrin, Chlor = Chlorpyrifos, Fip = Fipronil, Imi = Imidacloprid and Oxa = Oxamyl.

AIMS

The aims of the study were to:

1. Evaluate and review literature of *Musa* and *Cosmopolites sordidus* from a South African perspective.
2. Investigate the molecular phylogeny of *C. sordidus* from South Africa, Australia, Uganda and Costa Rica, using the amplified fragment length polymorphism technique.
3. Determine the population dynamics of *C. sordidus* under field conditions in South Africa.
4. Ascertain the relative efficacy of pheromone compared to conventional traps for *C. sordidus* during different seasons in South Africa.
5. Investigate the field efficacy of cultural control methods compared to registered chemicals in providing a curative control for *C. sordidus* in South Africa.
6. Quantify the field efficacy of chemical plant injections in providing a curative control for *C. sordidus* in South Africa.
7. Formulate an integrated pest management programme for *C. sordidus* in South Africa.

HYPOTHESIS

Null ($\mathbf{H_0}$) and alternative ($\mathbf{H_A}$) hypothesis included the following:

1. $\mathbf{H_0}$: There is no genetical disparity between *C. sordidus* from South Africa (Lowveld, North-east and Southeast Coast), Australia, Uganda and Costa Rica.

   $\mathbf{H_A}$: There is a genetical disparity between *C. sordidus* from South Africa (Lowveld, North-east and Southeast Coast), Australia, Uganda and Costa Rica.
2. $\mathbf{H_0}$: There is no significant difference in the density of *C. sordidus* larvae or adults in the field throughout the year.

   $\mathbf{H_A}$: There is a significant difference in the density of *C. sordidus* larvae or adults in the field throughout the year.
3. $\mathbf{H_0}$: No significant relationship exists between *C. sordidus* incidence (in plants and traps) and temperature and/or rainfall.

H_A: A significant relationship exists between *C. sordidus* incidence (in plants and traps) and temperature and/or rainfall.

4. **H_0**: There is no difference between pheromone and split-pseudostem-trap efficacy relative to season, adult, female and male catches, sex ratios, proportion of females with eggs and/or fecundity.

   H_A: There is a difference between pheromone and split-pseudostem-trap efficacy relative to season, adult, female and male catches, sex ratios, proportion of females with eggs and/or fecundity.

5. **H_0**: Cultural control over two years has no significant influence on adult densities, different plant damage assessments, plant girth and/or bunch weight.

   H_A: Cultural control over two years has a significant influence on adult densities, different plant damage assessments, plant girth and/or bunch weight.

6. **H_0**: Chemical injection of plants every second month over two years has no significant influence on adult densities, different plant damage assessments, plant girth and/or bunch weight.

   H_A: Chemical injection of plants every second month over two years has a significant influence on adult densities, different plant damage assessments, plant girth and/or bunch weight.

STATISTICAL ANALYSIS

The statistical analysis of all the data were conducted on the software program STATISTICA Version: 7 (Statsoft Inc. 2004). All data conformed to the assumptions of the specific statistic analysis applied (Sokal & Rohlf 1997). Where applicable, the specifics of the analysis are elaborated. Significance level was set at the biological standard 5% level.