Chapter 5

Cultural control of *Cosmopolites sordidus* in South Africa

Abstract

The banana weevil, *Cosmopolites sordidus*, is the most important insect pest of banana and plantain in the world. 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 and cortex, and the mean cross sectional damage percentage. 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 percentage cross sectional damage of the central cylinder, the damage parameter most closely related to yield, by 14.18%.

Keywords: Cultural control, soil cover, yield, damage, banana weevil

5.1 Introduction

The banana weevil, *Cosmopolites sordidus* (Germar), is a major insect pest of banana and plantain in the world (Waterhouse & Norris 1987; Gold *et al*. 1999). Eggs are usually laid at ground level (Franzmann 1972) in the crown of the rhizome and pseudostem base (Abera *et al*. 1999). The larvae are the damaging stage and tunnel into the rhizome and occasionally the pseudostem, interfering with root initiation (Treverrow *et al*. 1992), plant nutrition (Chavarria-Carvajal & Irizarry 1997) and water transport (Collins *et al*. 1991), resulting in plant stunting, delayed maturation (Gold *et al*. 1998), reduced fruit size and bunch weight, and even plant snapping or toppling (Batchelder 1954, Franzmann 1972, Koppenhöfer 1993; Rukazambuga 1996). Interior corm damage possibly affects nutrient transport and stem growth (Taylor 1991), while peripheral damage may adversely affect root development (Gold *et al*. 1994). Morphological and physiological symptoms of infested plants include reduced vigour, leaf chlorosis (Franzmann 1972), choking of the bunch in the pseudostem (Pinese & Elder 2004), decreased vigour of followers (Rukazambuga 1996) and a different proportion of water suckers (Gold *et al*. 1999). Adult weevils feed on plant tissues or crop debris but the resultant damage is considered negligible (Franzmann 1972; Treverrow *et al*. 1992). Infestation by banana root nematodes can show similar symptoms, including a reduction in vigour, leaf chlorosis, plant toppling and yield reduction (Bujulu *et al*. 1983, Smith 1995; Willers *et al*. 2001).

Cultural control is an important strategy for managing the banana weevil in subsistence and organic farming systems (Simmonds 1959). It is based on the manipulation of the weevil habitat to adversely affect the pest and promote the banana plant. Cultural control is applied at the crop establishment (preventative control) and crop management (curative control) stages. The former includes using uninfested plants as propagating material to prevent the spread of the weevil and reduce damage, as eggs and larvae can be disseminated in infested planting material. If suckers are used, rhizomes should be trimmed and pared (Franzmann 1972; Fogain *et al*. 2002). Hot water treatment of suckers is also recommended (Gettman *et al*. 1992), but can be problematic (Gold *et al*. 1998). In South Africa, commercial growers mainly use *in vitro* planting material (Robinson 1996). Tissue culture plants are free of banana weevils and nematodes (Robinson 1996), making them ideal to 'start clean, stay clean' (Peasley & Treverrow 1986). All banana plant material

should be removed from fields to be replanted and left fallow or used for annual crops for a minimum of 1 year (Seshu Reddy *et al*. 1993), but 18 months or 2 years are preferred (Treverrow *et al*. 1992). New plantings should preferably be made in virgin soil and/or removed from infested fields. Deep planting (45-60 cm) delays weevil infestation rates and lower weevil incidence (Seshu Reddy *et al*. 1993). *Tephrosia* spp. and neem (*Azadirachta indica* A. Juss.) have a repellent effect (Walangululu *et al*. 1993), while the latter also negatively affects the physiology of the weevil (Musabyimana *et al*. 2001), thereby helping to delay infestation rates of new plantings (Musabyimana 1999; Fogain *et al*. 2002). Intercropping with coffee has also been reported to reduce weevil numbers (Kehe 1988) and susceptible banana cultivars and residues can serve as trap crops in multi-cultivar stands (Masanza 2003).

High weevil densities and inadequate fallow periods in local commercial systems lead to re-infestation of clean fields from neighbouring plantations. The growing habits (Robinson 1996) and susceptibility of *in vitro* plants to *C. sordidus* may negate their advantage (Nuno & Ribeiro 2002). Deep planting is labour intensive and under these conditions some plant varieties (e.g. plantains) will produce a new rhizome above the previous one (Seshu Reddy *et al*. 1993). High rates of powdered neem are phytotoxic (Musabyimana *et al*. 2000) and it is not effective as a curative treatment (Fogain *et al*. 2002). Moreover, intercropping can reduce banana yield (Uronu 1992) and is troublesome due to the closing of the banana canopy (Seshu Reddy *et al*. 1993). Most of the mechanisms by which diversified systems can reduce herbivore attack, including higher efficacy of natural enemies, effects on immigration/emigration rates and modification of the micro-environment, are not relevant to the banana weevil (Gold *et al*. 1999).

Locally, cultural control is more applicable at the crop management stage. Covering the base of stools with soil mounds up to 30 cm high was associated with low weevil infestations in the Ivory Coast (Kehe 1988). The additional soil assists in delaying high mat formation and provides a firm anchorage for the plant (Seshu Reddy *et al*. 1999). Felling pseudostems at ground level (Simmonds 1959; Annecke & Moran 1982) and diligent crop hygiene, the destruction or removal of accumulating crop trash and fallen plants, are also recommended to minimise additional sheltering and breeding sites of *C. sordidus* (Peasley & Treverrow 1986, Collins *et al*. 1991, Treverrow *et al*. 1992; Fogain *et al*. 2002). Desiccation rate is

enhanced by cutting debris along the longitudinal axis (Treverrow *et al* 1992). The area around plants should be free of trash and remnants should be placed in the inter-row (Stanton 1994). The efficacy of cultural control is not well understood and has not been evaluated under local conditions. The aim of the study was to quantify the efficacy of covering the base of banana stools with soil, alternate felling heights and practicing crop hygiene on weevil control in South Africa. The cultural control treatments were compared to treatment of plants with the registered chemical, aldicarb.

5.2 Material and methods

5.2.1 Research site

The banana weevil cultural control trial was conducted on a commercial farm at the South Coast of KwaZulu-Natal, South Africa. Soil in the area is a Glenrosa form, with an orthic A and lithocutanic B zone. It is a sandy loam soil with 16% clay, 30% loam and 54% sand (Dochez 1998). The trial site was in Ramsgate (30º52'33''S; 30º19'28''E), 130 meters above sea level. The experiment was conducted from August 2003 to November 2005. The location was all in a summer rainfall area (750-1000 mm per year), and during the trial the ambient temperature ranged from 12 to 25 °C.

The Cavendish cultivar, Grand Nain (AAA group), was grown at the trial, planted in November 2000 at a density of 2222 plants.ha^{-1} (300 × 150 cm). High mat was evident in the plantation, with the collar (junction between pseudostem and rhizome) commonly more than 10 cm above ground level. The plantation was sprinkler irrigated with 2 cm water/week, a practise only suspended if rainfall exceeded that value in the particular week. The site was treated at planting with the oxime carbamate, aldicarb (Temik 15% GR), at the registered dosage of 2.025 g.a.i./mat, to provide nematode and weevil control (Nel *et al*. 2002; Anonymous 2005). Regular chemical weed control with glyphosate (Roundup), leaf removal, desuckering and propping of bunch bearing plants were practised. Pre-trial plant inspections revealed rhizome tunnel damage by *C. sordidus*.

5.2.2 Experimental design

Four treatments were compared: harvesting at ground level and longitudinal

dissection of all remnants, covering the mat with soil up to 30 cm from the collar and moving all debris to the inter-row, application of aldicarb at the registered dosage and the standard practise of harvesting at 150 cm with no debris management or covering of the mat (control). The layout of the trial followed a randomised block design with three replicates. Each plot consisted of 72 plants and was separated by a two-row barrier. To standardise for abiotic influences, replicates were orientated perpendicular to the sea/land breeze and moisture gradient in the field.

The cultural treatments were maintained monthly in summer and bi-monthly in winter (soil cover was maintained seasonally) and the chemical applied to the soil, as recommended by the manufacturers, in October/November and March. Yield, damage parameters and pseudostem girth of plants felled during a 3-month period (August to November) in 2003 to 2005 were measured, while adult densities were assessed over 4 weeks in October/November (from 2003 to 2005) and April (from 2004 to 2005). To consider the effect of nematode damage on research results, nematode samples were analysed in October/November 2003 to 2005. Root samples were collected from three randomly selected mother plants per plot, and sent to the ARC - Institute for Tropical and Subtropical Crops (Nelspruit, Mpumalanga), where 30 g of roots (randomly selected per plot) were examined for nematodes. The initial data were recorded before any of the treatments were applied.

Yield was determined at the pack-house by weighing of bananas (bunches excluding the peduncle). Weevil damage and girth sampling of plants were conducted within a week of harvest. The Coefficient of Infestation (CI) was determined by paring the corm and scoring the proportion of the rhizome circumference with weevil galleries (Vilardebó 1973). Intervals of 2.5% were included up to a level of 10% damage. Damage was also rated by the Percentage Coefficient of Infestation (PCI) (Mitchell 1978, 1980), which involved scoring the presence/absence of peripheral damage for ten sections, each covering 18° of the corm surface. The latter was determined at 5 cm (Gold *et al.* 1994) and between 5 and 20 cm from the collar. These two PCI values were summed to provide a total PCI value. A cross section of the corm was made at 10 cm from the collar and the percentage damage of the cortex (XO) and central cylinder (XI) scored at 10% intervals, using a transparent circular grid divided into 36° sections (modified from Gold *et al.* 1994; Kiggundu 2000). The two cross section values were averaged to provide the mean cross sectional damage

(X mean). The circumference of harvested plants was measured at 100 cm from the collar.

Three split-pseudostem traps, placed individually next to three plants in the middle of each plot, were used to sample adult densities. Trap material was randomly selected from plants harvested within 2 weeks before trap preparation at a plantation similar to but isolated (by a dirt road) from the specific trial sites. Only one trap was prepared from each plant and pseudostems with internal damage/necrosis/tunnels were discarded. Pseudostem traps were 30 cm in length (pseudostem section 30-60 cm above the collar), bisected longitudinally and each half placed (with the cut surface ventrally) directly next to the mat of the plant. The two halves were placed on opposite sides of the mat and regarded as one trap. The split pseudostems were covered with mulch to delay desiccation and decomposition. Traps were replaced once a week, when the samples per trap were counted and destroyed.

5.2.3 Statistical analysis

Analysis of covariance (ANCOVA) (Sokal and Rohlf 1997) was used to quantify yield and girth over time, among treatments and between the interactions of time and treatment. The nematode number of all the species were combined and entered as a covariate. Nematode densities over time and between treatments were ascertained by factorial ANOVA, while the pre-treatment densities were compared by one-way ANOVA (Sokal and Rohlf 1997). The seven parameters used for damage estimation were compared over time, between treatments and among the interactions of time and treatment using repeated measures ANOVA. One-way ANOVA (Sokal and Rohlf 1997) was used to ascertain pre-trial differences in adult densities. Differences of adult densities over time, between treatments and between the interactions of the independent variables were determined by factorial ANOVA (Sokal and Rohlf 1997). The Tukey HSD test (Sokal and Rohlf 1997) was used for all *post hoc* analysis. Unless stated otherwise, the data were not transformed and showed a normal distribution and homogeneity of variances in the linear scale. The STATISTICA Version 7 (Statsoft Inc. 2004) software program was used for analysis.

5.3 Results

5.3.1 Yield, girth and nematodes

No differences were found in yield ($F_{3, 7} = 0.14$, $P = 0.934$) or plant girth ($F_{3, 7} = 0.65$, $P = 0.607$) between plots before the onset of the trial (spring 2003). The initial nematode densities between plots were also similar ($F_{3, 8} = 0.07$, $P = 0.973$). While the average bunch weight increased from 2004 (29.67 ± 0.510 (SE) kg per bunch) to 2005 (32.12 ± 0.815 (SE) kg per bunch), no significant difference in yield was found ($F_{1, 15} = 4.40$, $P = 0.053$). The bunch yield for the different treatments (range: 30.60 to 31.08 kg per bunch) was similar ($F_{3, 15} = 0.01$, $P = 0.998$) and no interaction between the independent variables was found ($F_{3, 15} = 0.29$, $P = 0.835$). Plant girth showed no significant effect of time (2004: 67.179 ± 0.7512 (SE) cm, 2005: 67.828 ± 0.8445 (SE) cm) ($F_{1, 15} = 0.06$, $P = 0.809$), treatment (range: 66.612 cm to 68.694 cm) ($F_{3, 15} = 1.61$, $P = 0.229$), or interaction between time and treatment ($F_{3, 15} = 0.57$, $P = 0.642$).

The density of the nematode-complex was similar in October/November of 2004 and 2005 ($F_{1, 16} = 0.46$, $P = 0.507$). The average number of nematodes per 30 g roots ranged from 700.00 to 1316.67 for the aldicarb and low harvest-and-remnant destruction treatments, respectively. No significant difference was, however, found between the treatments ($F_{3, 16} = 2.24$, $P = 0.123$), or the interaction between time and treatment ($F_{3, 16} = 0.15$, $P = 0.926$). The annual samples (2003 to 2005) mainly comprised of spiral nematodes (*Helicotylenchus* spp.), while relatively low numbers of root knot (*Meloidogyne* spp.) and lesion nematodes (*Pratylenchus* spp.) were present. No burrowing nematodes (*Radopholus similis* (Cobb)) were found during the study.

5.3.2 Damage parameters

The pre-trial plant damage estimations of the PCI (0-5 cm), PCI (5-20 cm), Total PCI, CI, XO, XI and X mean were similar between plots ($F_{3, 8} = 0.09$, $P = 0.963$; $F_{3, 8} = 0.18$, $P = 0.907$; $F_{3, 8} = 0.07$, $P = 0.974$; $F_{3, 8} = 0.11$, $P = 0.951$; $F_{3, 8} = 0.13$, $P = 0.942$; $F_{3, 8} = 0.39$, $P = 0.766$ and $F_{3, 8} = 0.13$, $P = 0.938$, respectively). No temporal effect was found for any of the dependent variables between 2004 and 2005 ($0.002 < F_{1, 16} < 1.66$, $0.216 < P < 0.962$). A significant treatment effect was only found for CI ($F_{3, 16} = 4.17$, $P = 0.023$). Post ANOVA analysis showed that the soil cover and movement of debris-treatment significantly reduced the damage parameter compared to the control (Fig. 5.1). The former treatment also showed the lowest values for the three PCI

damage parameters (Fig. 5.1). Relative to control plants, covering of the plant bases with soil and movement of debris to the inter-row caused the greatest reduction in the percentage damage to the cortex and X mean, while aldicarb application showed the greatest reduction in the XI (Fig. 5.2).

5.3.3 Adult densities

The pre-trial adult densities were not different between plots ($F_{3, 8}$ = 1.92, P = 0.206). Subsequent collections showed a significant difference in the number of adults collected ($F_{3, 32}$ = 6.96, P = 0.001). There were no significant treatment effects or an interaction between time and treatment ($F_{3, 32}$ = 0.79, P = 0.506; $F_{9, 32}$ = 1.52, P = 0.184, respectively). The Tukey *post hoc* test showed that the mean number of adults collected in April 2005 (11.48 ± 1.014 (SE)), was significantly less than the numbers in October/November 2005 (19.08 ± 1.801 (SE)), April 2004 (19.14 ± 1.581 (SE)) and October/November 2004 (19.17 ± 1.551 (SE)), which were all statistically similar. Covering the plant bases with soil and movement of debris to the inter-row caused a slight reduction in the adult density (Fig. 5.3).

5.4 Discussion

Neither the cultural control methods investigated in this study, nor the chemical registered for control of the banana weevil in South Africa, caused a significant increase in plant yield or plant girth after 2 years. The cultural treatments and chemical application did not significantly reduce adult beetle densities or any of the damage parameters either, except when the mat was covered with soil and remnants were moved to the inter-row, which resulted in lower damage to the periphery of plants. It was interesting that neither the weevil density, nor root infestation by nematodes, was reduced by aldicarb, a chemical known for its effect on these banana pests (Jones & Dieckmann 1982; De Jager *et al*. 1991). The beneficial mechanism of a soil cover may be related to weevil oviposition and/or an increase in plant vigour. Covering the mat with soil may provide additional support to plants, especially when high mat is present. In Uganda, plants harvested low and covered with soil had lower oviposition (400%) compared to uncovered plants during the wet season, although the dry season showed a 73% higher oviposition rate between the treatments (Masanza 2003). The application of cultural methods is usually problematic due to labour costs

(Dochez 1998). Soil cover of plant bases only needs to be applied seasonally, because plant roots grow into and attach the additional soil to the rhizome. In the short term, covering stools with soil are recommended in South Africa. The trial will be continued to determine the long-term effects of the cultural control treatments.

Movement of remnants of banana pseudostems and leaves to the inter-row is expected to reduce moisture and adult activity near the mat of plants. Recession of the mulch to more than 100 cm from the pseudostem compared to mulching to the base of the pseudostem over a 3-year period in Uganda, however, did not significantly reduce weevil density or damage to the plant (McIntyre *et al*. 2003). In Australia, dissection of pseudostems and raking mulch into the mid-row three to four times per year also did not result in a reduction of weevil adults or damage over 3 years (Smith 1995). The most effective component of the combined soil cover and residue recession treatment, therefore, appears to be the former, assuming there were no interaction effects between the treatments.

The rationale for low harvesting of plants is to accelerate desiccation of residues, a condition unfavourable for weevil development. However, Daniells and O'farrell (1987) found that harvesting at a 200 cm versus 10 cm height increased bunch mass on the follower by 12% and decreased time to the next harvest by 5%. Some nutrients may be lost to a plant from using harvested pseudostems for mulch as opposed to senesced pseudostems that may 'feed' followers through direct nutrient translocation (Wortman *et al*. 1994). In this study, we have hoped that a significant reduction in weevil damage could have compensated for the yield loss that one would have expected. The damage, however, remained relatively constant under low harvest conditions, suggesting that the effect of felling height on yield may vary between cropping systems, or that more than two seasons are required before the effect is evident. The efficacy of banana crop sanitation is questionable because residual corms, that are the most important source of pest populations, are not amendable to the practise of crop hygiene (Nanne & Klink 1975; Treverrow & Maddox 1993). Removal of the rhizome is labour intensive and will weaken followers by reducing the support of the mat. Residues can serve as traps and in some varieties it is more attractive to egg-laying females than standing plants (Waterhouse & Norris 1987, Gold *et al*. 1999; Masanza 2003). Poor sanitation can, however, increase weevil damage and the beetle population (Masanza 2003, Masanza *et al*. 2005b). Double the number of weevils complete development in toppled compared to standing plants,

because of greater ovipositional accessibility to softer corm material and an increased oviposition area (Treverrow *et al*. 1992). The developmental rate may also be positively related to residue age (Masanza 2003), although fresh residues are usually more attractive (Masanza *et al*. 2005a). In the current study, more than 2 years of assessment could, therefore, have been required before the beneficial effects of sanitation became evident, as was found in Uganda (Masanza 2003; Masanza *et al*. 2005b).

Plants were propped during the trial and plant loss, which can contribute more to yield loss than reduction in bunch weight (Rukazambuga 1996), was not considered. The damage parameter of Cavendish bananas that is most closely related to effective bunch weight (fruit weight) is the percentage damage to the central cylinder (Chapter 7). Under certain conditions, however, the mean percentage damage to the cortex and central cylinder of the corm is also important (Chapter 7). Soil cover and recession of remnants reduced the respective parameters by 14.18% and 31.52%, respectively.

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Figure legends

Figure 5.1. 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 with aldicarb, and the two cultural control treatments, from October/November 2003 to October/November 2005 at Ramsgate (KZN, South Africa). 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, Chem = Aldicarb, Harv = Low harvesting and destroying remnants, Cover = Soil cover and movement of debris to the inter-row.

Figure 5.2. The mean values of the cross sectional damage parameters of untreated (control) plants and plants treated with aldicarb, and the two cultural control treatments, from October/November 2003 to October/November 2005 at Ramsgate (KZN, South Africa). 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, Chem = Aldicarb, Harv = Low harvesting and destroying remnants, Cover = Soil cover and movement of debris to the inter-row.

Figure 5.3. The mean adult density values of untreated (control) plots and plots treated with aldicarb, and the two cultural control treatments, from October/November 2003 to October/November 2005 at Ramsgate (KZN, South Africa). For each dependent variable, means with letters in common are not 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 5.1

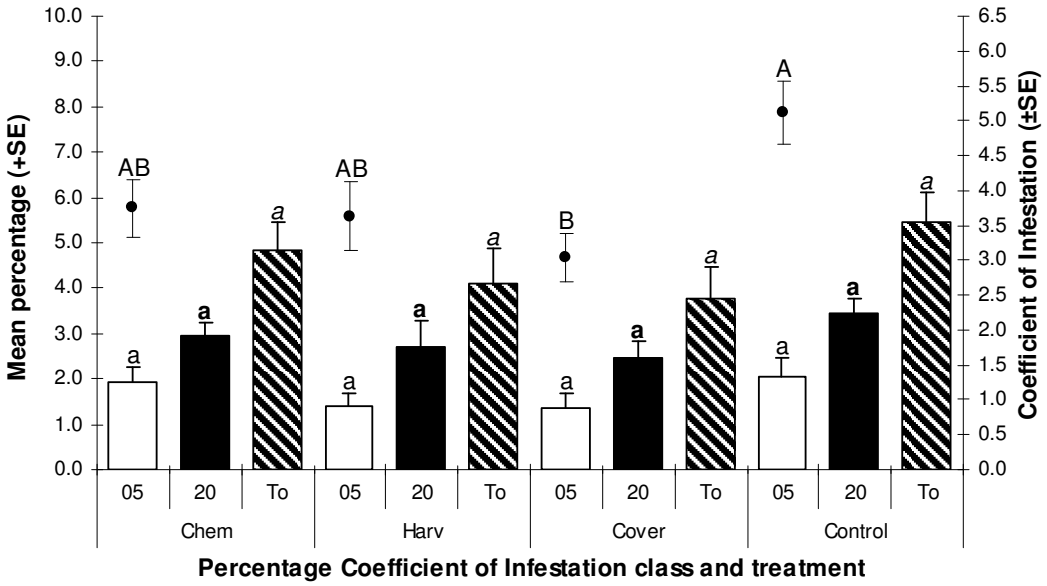

Mean percentage (+SE)
Coefficient of Infestation (±SE)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
AB
AB
B
A
a
a
a
a
a
a
a
a
a
a
a
a
05
20
To
05
20
To
05
20
To
05
20
To
Chem
Harv
Cover
Control
Percentage Coefficient of Infestation class and treatment

Figure 5.2

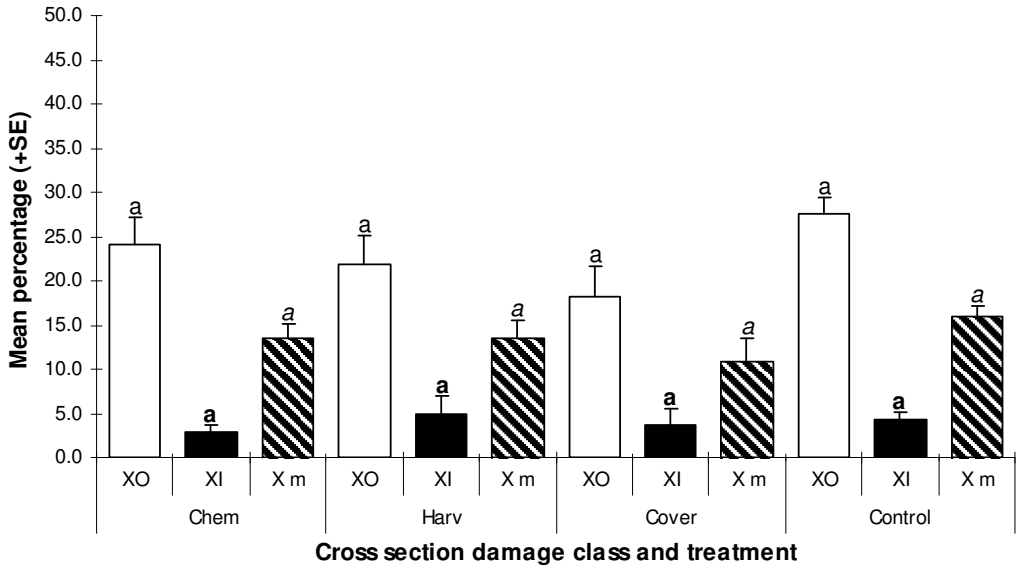
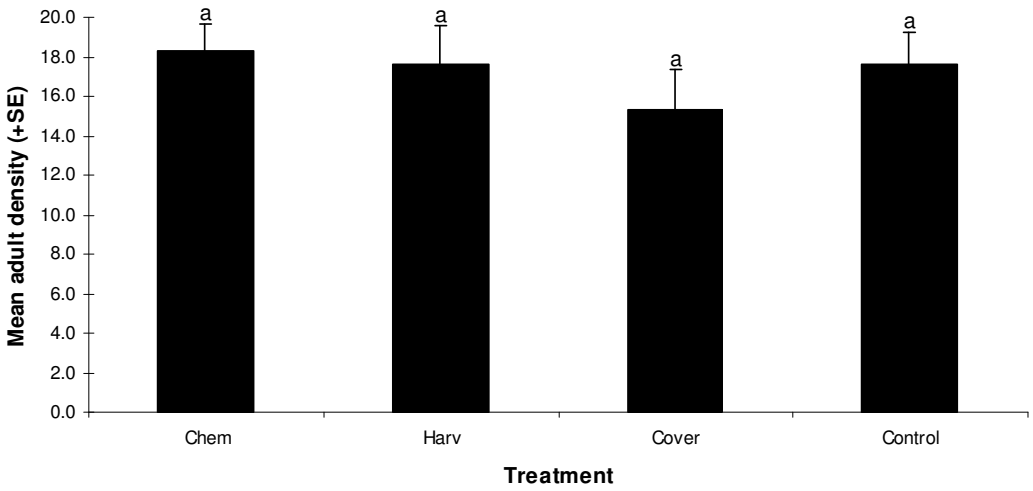

50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Mean percentage (+SE)
a
XO
XI
X m
Chem
Harv
Cover
Control
Cross section damage class and treatment

Fig. 5.3


20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Mean adult density (+SE)
a
a
a
a
Chem
Harv
Cover
Control
Treatment