WHAT ARE DAMSEL BUGS DOING IN COTTON? IMPROVING IPM STRATEGIES FOR COTTON

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Introduction

The important role that beneficial arthropods play in cotton farming systems is increasingly being recognised across the industry. Many growers and consultants are now growing unsprayed 'nursery' crops to generate beneficials on-farm, releasing mass-reared beneficials into crops to bolster their numbers, and using less disruptive insecticides to preserve them. In addition, some are regularly sampling beneficials to use estimates of their abundance and potential impact to make dynamic pest management decisions.

An insight into the day to day behaviour of these beneficial species would greatly benefit integrated pest management (IPM) strategies for cotton by increasing our understanding of these biological control agents and our ability to better manipulate them. For example, would maculate ladybird beetles be less prone to an insecticide applied before or after sunrise? Is there an overlapping within plant distribution of green mirid nymphs and lynx spiders? The aim of the present study was to use direct visual observational methods to investigate the behaviour of a common predatory species, the damsel bug (*Nabis kinbergii* Reuter, Hemiptera: Nabidae) in the cotton agro-ecosystem.

Materials and Methods

The behaviour of damsel bugs was observed on 11 days in commercial cotton fields at Byee (South Burnett, Queensland) during the 2000-01 and 2001-02 growing seasons. On these days between late December and mid February the cotton was at late squaring to early open boll growth stages. The main selection criteria for choosing observation fields were moderate damsel bug abundance (at least 3/m) and good crop conditions (dry, not badly lodged and not sprayed in the past 10 days). Damsel bug abundance was estimated on key observation dates using a beat sheet (4 to 5 one-metre samples per field).

Damsel bug behaviour was recorded on each date at various times of the day between first light and complete darkness. Although important, night observations were abandoned after experiencing major difficulties in finding and then tracking the bugs. We also have unpublished data that demonstrates comparable damsel bug behaviour between the night and day in a glasshouse study.

Damsel bugs of any life-stage were located by careful visual inspection of the cotton plants. Observations commenced on an individual target bug after allowing a 'settling' time of up to one minute to reduce any possible effects of disturbance. Observation starting time (24-hour time) was noted and observations were made at 30-second intervals for up to 10 or 15 minutes duration during the 2000-01 or 2001-02 growing seasons. Data were recorded under the following categories:

- Activity: stationary, preening, walking, flying, feeding on an extra-floral nectary (EFN), feeding on arthropod prey (prey species and life-stage noted), mating, calling (sexual communication by males) or ovipositing (laying eggs by females). The last three categories were later combined into one 'reproduction' category
- Strata location: in the upper-third, mid-third or lower-third of the plant
- Plant structure location: on a leaf or petiole, terminal or stem, or fruiting structure (square, flower or boll).

The life-stage of each bug was noted. Meteorological conditions were recorded once during the observation period for each bug (only during 2001-02). A hand-held device (Kestrel® 3000 Pocket Weather Meter, Nielsen-Kellerman Australia) placed in the plant inter-row provided temperature (°C), relative humidity (%) and wind speed (m/s) measurements. Visual observations provided wind direction (°) and cloud cover (%) measurements. The actual (cumulative) distance and effective (straight-line or linear) distance travelled by each bug was visually estimated to calculate within plant movement (only during 2001-02).

For data analysis the raw behavioural observation data for each bug was first converted to a percentage of time at each respective activity and location. The converted data was then pooled across the various times, life-stages, activities and locations to develop a profile for each aspect of damsel bug behaviour.

Results

The behaviour of 331 individual damsel bugs was observed during an estimated 73 hours, 53 minutes of continuous observation. An additional 60 hours, 48 minutes was spent searching for bugs to observe.

There appeared to be a strong bias towards observing the larger bug life-stages as over 90% belonged to 5th instar nymph or adult life-stages. This partly reflects the ease of finding them due to their size and the age structure of the population which was skewed towards these older life-stages (ie. 58% were 5th instar nymphs or adults) (Table 1).

Meteorological conditions

Meteorological conditions were quite mild and varied little over a day (Figures 1 and 2). Temperature ranged 25-33°C between 05:00-08:00 hours and 11:00-14:00 hours (Figure 1). Relative humidity ranged 50-68% between 05:00-08:00 hours and 11:00-14:00 hours (Figure 1). Wind was from the SE (mean ± SEM of 147° ± 8°) with speeds of 0.08-0.32 m/s between 05:00-

08:00 hours and 17:00-20:00 hours (Figure 2). Cloud cover varied little between 38-55% over the day (17:00-20:00 hours to 14:00-17:00 hours) (Figure 2).

Activity

The most common behavioural activities of damsel bugs were stationary (67%) and walking (26%). The other activities combined only constituted 7% of their time (Figures 3 and 4). This includes 2% of feeding on 10 prey items comprising mainly cotton jassids (n=4) and green vegetable bugs (n=2) (Table 2). There was no apparent variation over a day in any of the behavioural activities (Figure 3). Differences in activity between the various bug life-stages were evident; the younger nymphs (1st-3rd instar) were slightly less stationary (62%) than the other life-stages (68% stationary). Conversely the younger nymphs were relatively more active searchers than were the other life-stages (36% vs 25% walking respectively, Figure 4). Adults were rarely seen flying or engaged in reproductive activities.

There were minor differences in the actual and effective distances travelled by damsel bugs over a day; slightly longer distances (35.2 cm actual or 19.9 cm effective) were travelled during the late afternoon (14:00-17:00 hours) (Figure 5). Adults travelled longer distances than the nymphs by 6.1 cm (actual) to 6.9 cm (effective) (Figure 6). Given that bugs are active for 24-hours of the day (unpublished data) the overall distance travelled of 31.6 cm (actual) or 16.6 cm (effective) (Figures 9 and 10) in 13.4 minutes potentially equates to 34.0 m (actual) or 17.8 m (effective) per day.

Strata location

Damsel bugs were mainly encountered in the upper-third of the plant (62%) (Figures 7 and 8). There was minor variation over a day in strata location; the upper-third region was mostly favoured during the late afternoon times (14:00-17:00 hours) (Figure 7). Nevertheless there were major differences in the strata location of the various bug life-stages (Figure 8); 35% of younger nymphs, 54% of older nymphs and 68% of adults were found in the upper-third of the plant.

Plant structure location

Damsel bugs were most commonly found on leaves and petioles (60%) followed by squares and bolls (27%) (Figures 9 and 10). There was no clear variation in plant structure location over a day (Figure 9). Similarly there was no difference in plant structure location by the various bug life-stages (Figure 10).

Discussion

Based on the high frequency of observing damsel bugs being stationary they appear to use a sit-and-wait or ambush strategy to locate prey in cotton. This particular type of searching strategy allows the environment to 'move past' the waiting bug (Bell 1990) and would predispose them towards targeting relatively mobile prey types such as green mirids rather than more sedentary prey such as aphids. The prey feeding records from this study provide further justification for this view as the majority belonged to relatively mobile prey groups. This foraging strategy may help damsel bugs hide from their natural enemies and reduce contact with insecticide residues. This is particularly important where certain residues are more toxic when they are wet (recently applied) than once dried (eg. indoxacarb (Steward®), unpublished data).

The strong tendency of damsel bugs to inhabit upper regions of the plant would influence their prey selection. Prey that commonly inhabit terminal regions such as heliothis eggs and very small to small larvae would be key potential prey items. Detailed sampling in cotton by Dillon and Fitt (1996) and Abbott and Fitt (1998) demonstrated that over 80% of heliothis eggs and very small-small larvae reside in the terminal plant region (upper 20cm). However given that most bugs occupy leaves it would make heliothis eggs rather than larvae better potential targets of predation. The main reason is that about 50% of heliothis eggs versus 20% of very small to small heliothis larvae are found on cotton leaves. Conversely around 25% of eggs versus 60% of very small to small larvae are found in squares and other fruiting structures (Abbott and Fitt 1998). However larvae hatched from eggs often on leaves would be exposed to waiting damsel bugs as they move extensively about leaves before commonly reaching squares.

Knowledge that bugs commonly inhabit upper regions of the cotton plant has important implications for sampling programs, particularly for those based on suction sampling and visual observation techniques that bias collection from the upper part of the plant (M. Wade personal observation). This behaviour can be considered when evaluating potentially lowered side-effects on beneficials from selectively spraying different regions of the plant.

The distinct differences between strata location and activity of the bug life-stages may reflect subtle differences in their resource requirements and searching strategy. Older nymph and adult life-stages may be better suited to feeding on more robust (eg. green vegetable bugs) and mobile (eg. jassids) prey species and life-stages that appear to commonly frequent these upper plant locations (M. Wade, personal observation). Conversely the younger nymphs may be better adjusted to finding relatively more sedentary prey types (eg. silvanid beetles) in middle to lower plant regions (M. Wade, personal observation).

Although nymphs walked more than adults this activity did not seem to translate into them travelling longer distances. It appears they are constrained by their smaller body size and inability to fly. Increased frequency of walking by the younger nymphs may increase their relative exposure to insecticide residues and other natural enemies.

Damsel bug behaviour varied little over a day. As a result this species would be equally susceptible to insecticides applied at different times of the day. The likely effect of variation in meteorological conditions over a day would be to restrict bug foraging behaviour to more suitable times (Bell 1990). However as meteorological conditions in this study differed little over a day they had only slight influences on bug behaviour. Wade *et al.* (2001) found that more varied meteorological conditions over a day in cotton appeared to have minor effects on predatory bug behaviour; they attributed small changes in predatory bug abundance to this. However meteorological conditions immediately adjacent to the plant (ie. boundary layer) where the bugs occur may be more ideal and thus have less impact than those measured in the inter-row.

Variation in prey abundance over a day would be expected to change bug behaviour. This is supported by Wade *et al.* (2001) who found considerable deviation in abundance of selected potential arthropod prey groups. Perhaps the ability of damsel bugs to utilise a wide range of prey types at varying densities helps them overcome the variation in this resource.

Although damsel bugs seldom feed on prey (2%) their daily per capita predation rates may still be 'adequate' to suppress pest populations, particularly when the size of the predator and prey populations are considered. Edgar (1970) incorporated behavioural data similar to this study into an equation to estimate predation rates. Applied to this study this equation considers that 2% of time spent prey feeding is equivalent to 28.8 minutes per day. This assumes all times of the day are available for feeding (unpublished data and partly this study). Thus total potential feeding time divided by an average feeding duration of 10-45 minutes per prey (M. Wade, personal observation) produces an estimated daily predation rate of 0.64-2.88 prey items per predator. This figure is partially supported by unpublished data where daily per capita predation rates by damsel bugs of around 0.5 were derived in glasshouse large cage studies.

Further studies on damsel bug behaviour should focus on their response at other times of the year and determine the cues used by them to identify resources in the environment at various spatial scales with a view to better manipulate their behaviour and abundance. Similar studies on other key beneficial and pest species are also warranted.

Conclusions

Behavioural studies of damsel bugs on cotton at Byee revealed that:

- ✓ Behaviour of the various bug life-stages may differ considerably (especially for strata location)
- ✓ There is generally little variation in their behaviour over a day
- ✓ They most often occupy leaves (60% of the time) in the upper-third of the plant (62%)
- ✓ They use a sit-and-wait foraging strategy (67% stationary)
- ✓ Nevertheless they move an estimated 34m per day
- ✓ This information can be used to improve IPM strategies for cotton.

Acknowledgments

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Table 1. Details of damsel bugs observed and their abundance.

Measure	1st instar nymphs	2nd instar nymphs	3rd instar nymphs	4th instar nymphs	5th instar nymphs	Adult males	Adult females	Total
Proportion (%) of bugs observed [actual no.]	1.5 [n=5]	1.2 [n=4]	2.1 [n=7]	4.8 [n=16]	29.3 [n=97]	36.9 [n=122]	24.2 [n=80]	100.0 [n=331]
Mean relative abundance per metre (%) [actual no.]	6.6 [0.30]	17.3 [0.77]	9.1 [0.41]	9.1 [0.41]	24.4 [1.09]	16.8 [0.75]	16.8 [0.75]	100.0 [4.48]

Table 2. Prey feeding records for damsel bugs.

Number of feeding records	Prey species	Prey life stage
1	Cotton jassid	Nymph
3	Cotton jassid	Adult
2	Green vegetable bug	Nymph
1	Flower beetle	Larva
1	Silvanid beetle	Adult
1	Midge	Adult
1	Crab spider	Juvenile
10	All	-

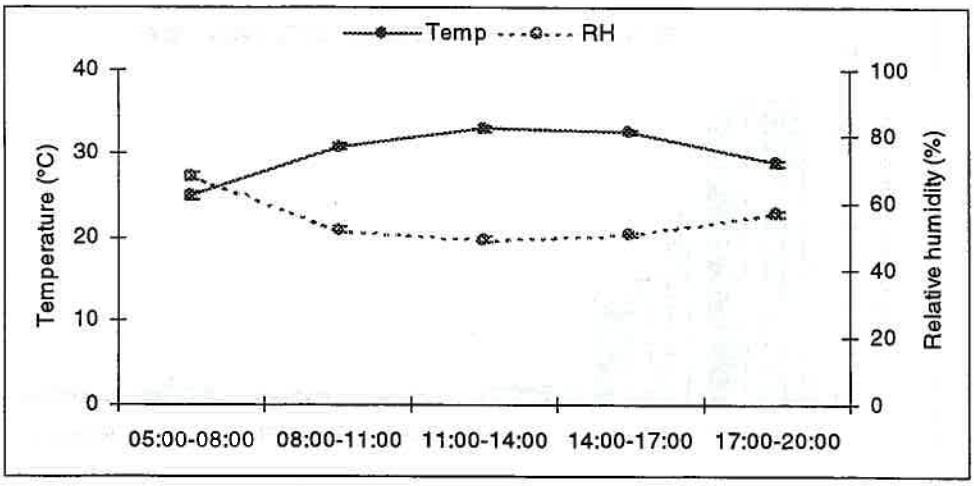

Figure 1. Variation over a day in mean ± SEM temperature (°C) and relative humidity (%).

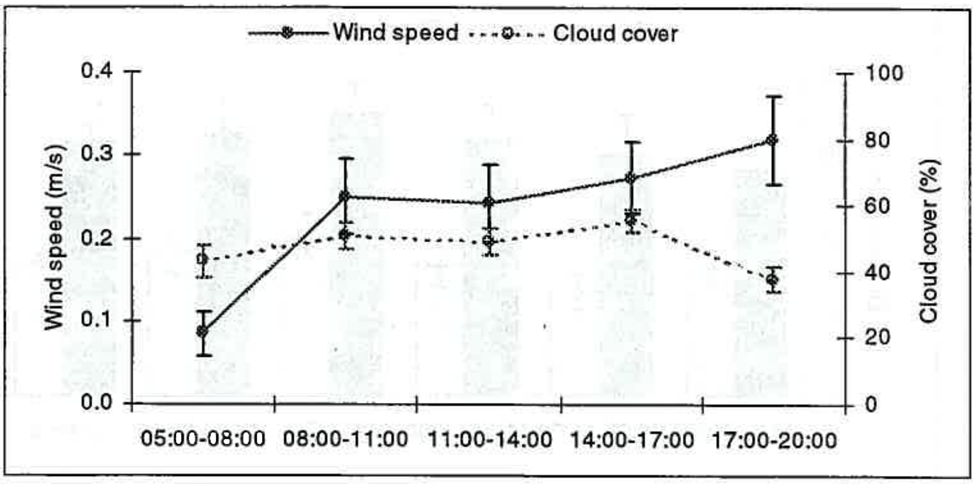

Figure 2. Variation over a day in mean ± SEM wind speed (m/s) and cloud cover (%).

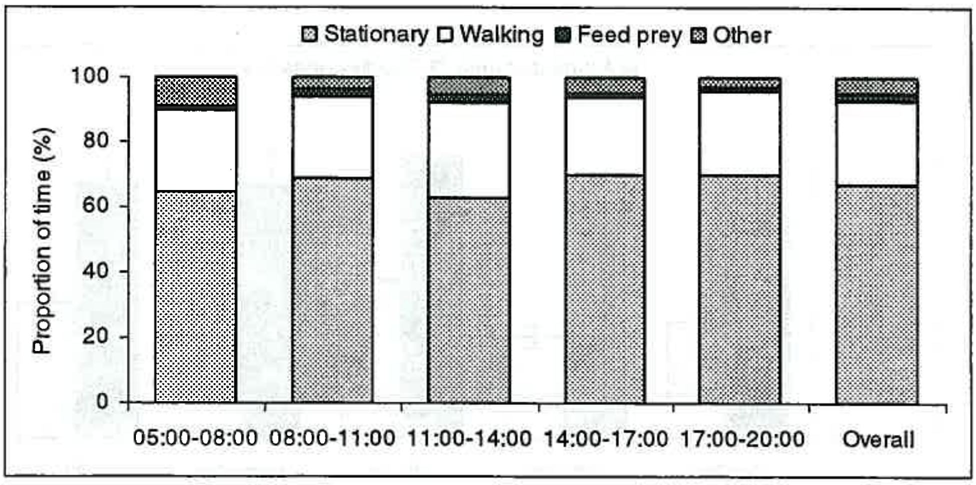

Figure 3. Variation over a day in the mean percentage of time damsel bugs were observed doing various activities.

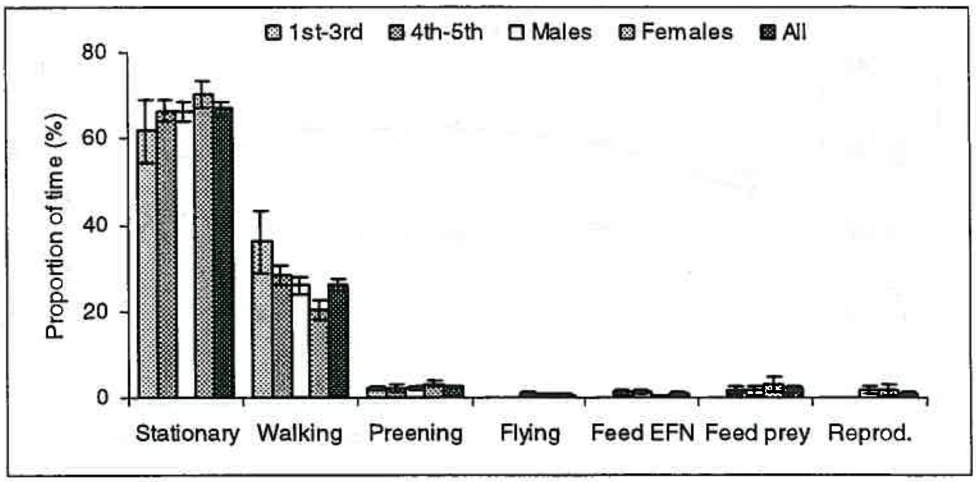

Figure 4. Mean ± SEM percentage of time damsel bugs were observed doing various activities.

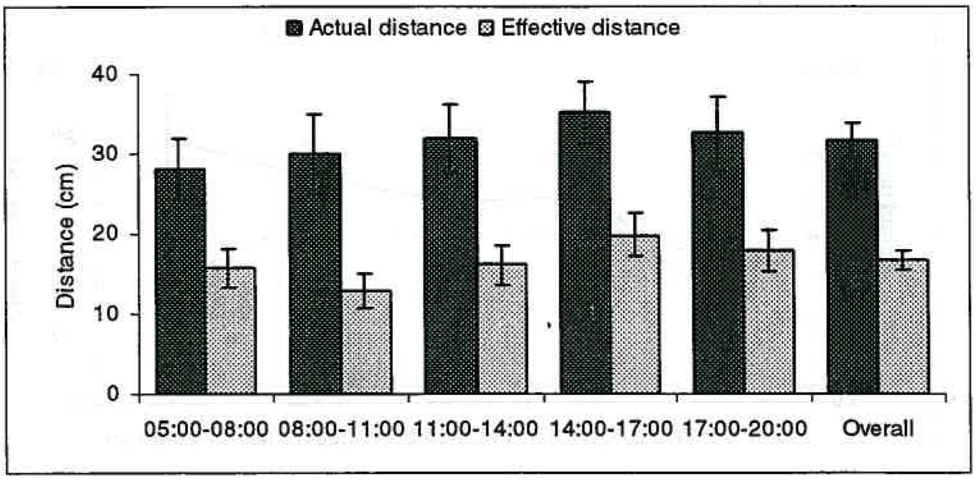

Figure 5. Variation over a day in mean ± SEM actual (cumulative) and effective (linear) distances travelled by damsel bugs.

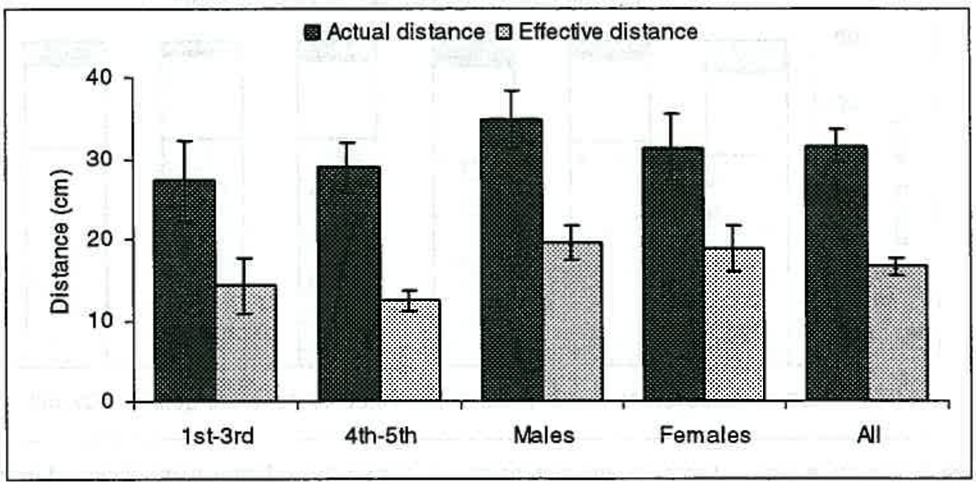

Figure 6. Mean ± SEM actual (cumulative) and effective (linear) distances travelled by damsel bugs.

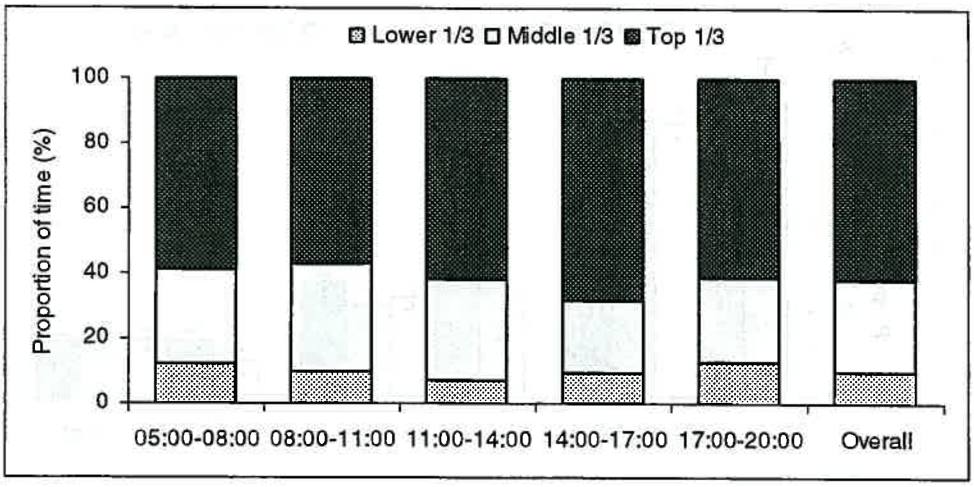

Figure 7. Variation over a day in the mean percentage of time damsel bugs were observed at various plant strata locations.

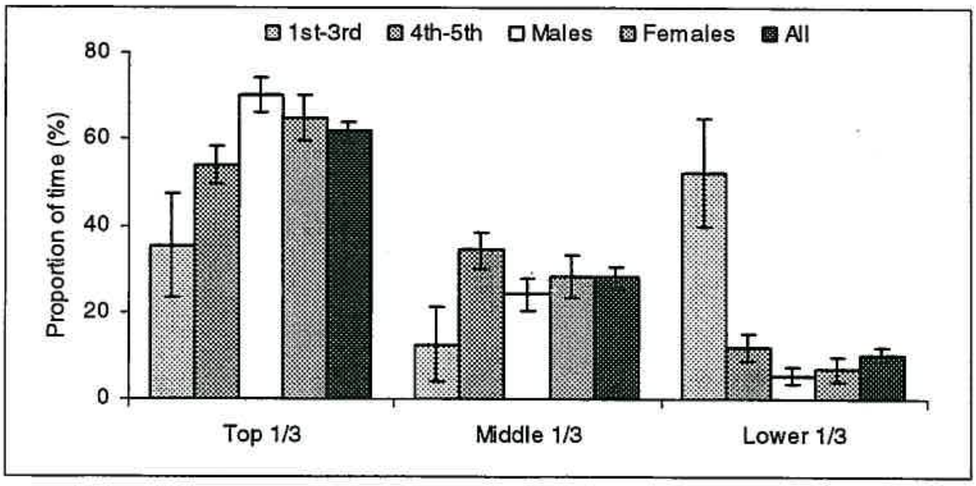

Figure 8. Mean ± SEM percentage of time damsel bugs were observed at various plant strata locations.

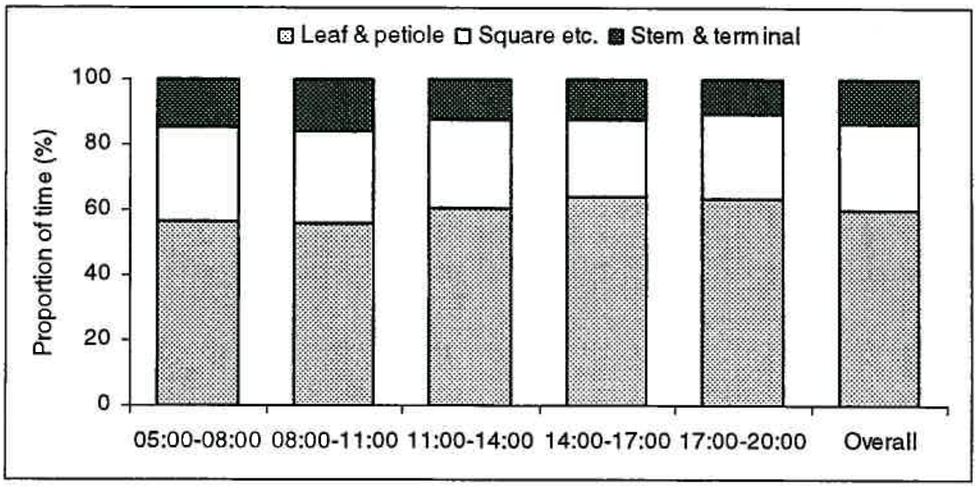

Figure 9. Variation over a day in the mean percentage of time damsel bugs were observed on various plant structures.

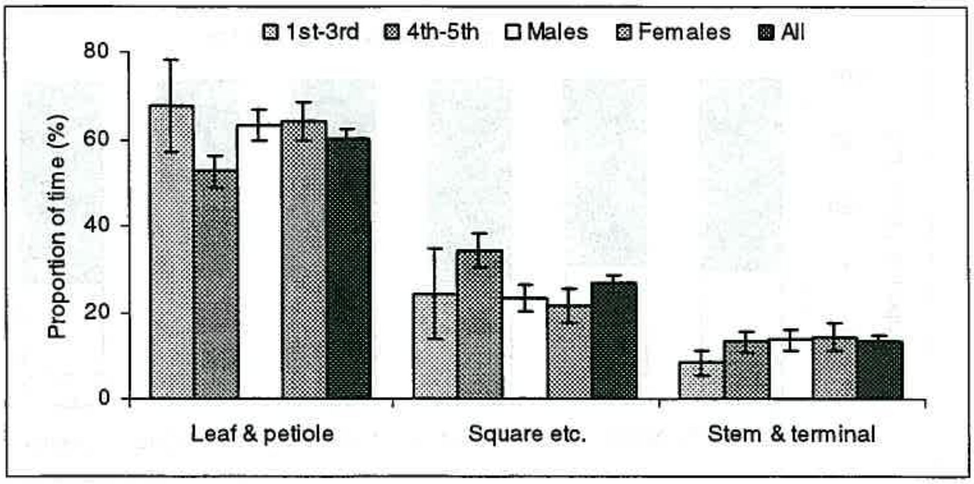

Figure 10. Mean ± SEM percentage of time damsel bugs were observed on various plant structures.