

Behaviour, biology and seasonal abundance of Apple Dimpling Bug on commercial cotton crops

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Introduction

The apple dimpling bug (ADB), *Campylomma liebknechti* (Girault) is a sucking insect indigenous to Australia. The insect has been recorded on cotton crops in all cotton growing areas in Australia, but its pest status is not fully understood (Bishop, 1980). Adams and Pyke (1982) and Chinajariyawong and Walter (1990) has reported cotton square loss associated with ADB infestations. ADB has also been observed feeding on the eggs of two-spotted mites in the cotton field (Wilson *et al.*, 1998). Khan and Mensah (1998) also reported that, provision of *Helicoverpa* eggs to ADB females increased their fecundity and nymphal development. Some cotton growers and consultants consider ADB as cotton pest and therefore control them with synthetic insecticides when numbers exceed current CottonLOGIC threshold. Others especially those practising IPM sees ADB as a beneficial insect. The pest and predator status of ADB, therefore, has brought mixed conceptions about the true status of this insect in the cotton production system. This mixed attitude towards ADB, shows that there is a substantial gap in our knowledge of the ecology, biology and pest status of this insect. We have undertaken detail studies of the basic biology, behaviour, dynamics and pest status of ADB so that the true status of the insect can be clarified and also made, where appropriately suggestions as to measures required to manage this insect in the cotton system. This paper, reports some aspects of the life cycle, sources of ADB to cotton fields, sampling, economic thresholds and seasonal phenology of ADB. In addition, we have investigated the predator status of ADB in relation to *Helicoverpa* spp. eggs on cotton crops.

Methods

Life cycle of *C. liebknechti*

The life cycle of ADB was studied in the laboratory maintained at a temperature of $25\pm 1^{\circ}\text{C}$. The insects were cultured on an artificial diet prepared from cotton leaves and *Helicoverpa* spp. eggs in a small petridish. Duration of development of the different stages of ADB were recorded. We also recorded female fecundity, pre-oviposition period and the longevity of male and female. In addition, we studied developmental period of ADB under 8 different temperature regimes viz, 15, 20, 25, 30, 32, 35, 38 and 42°C .

Pest status of ADB

Experiments were conducted both in the field and mesh house at ACRI to assess the damage caused by ADB adults and nymphs to seedling and squaring cotton. Laboratory and field observations indicated that both adults and nymphs cause similar types of damage to cotton plants. Therefore, separate experiments were conducted using newly emerged adults and late instar nymphs to differentiate between the damage caused by adults and nymphs.

Effect of ADB feeding on seedling cotton.

The experiment was conducted in a commercial cotton field at ACRI. Four densities of ADB adults viz; 4, 6, 10 and 15 pairs per plant were established on cotton seedlings using an organdie cage. An uninfested seedling cotton was set up and used as control. Both treated and control plants were replicated 3 times. The insects were allowed to feed for 5 days after which they were removed and the damage assessed using a damage score method developed by Khan and Mensah, 1999. The consequences of seedling damage by ADB on the growth of the plant was also studied by allowing the damaged plants to grow until maturity. When the treated and control plants commenced to square, the number of squares and bolls were recorded every week. The date of appearance of the first square, flower and boll maturity (60% boll open) were also assessed and recorded.

Damage to cotton squares

Five different densities of ADB were established using organdie bags on squaring cotton plants to assess the damage caused by ADB to squares. The experiment was conducted in a commercial cotton field at ACRI. Five treatments consisting of 2, 4, 6 and 10 pairs of ADB adults per plant and control (without insect) were established using organdie bags. Each treatment was replicated three times.

Prior to infestation the number of cotton squares on each treated plants was recorded. After infestation the insects were allowed to feed for 3 days and then removed. The infested plants were left for another 3 days inside the organdie bag for damage symptoms to be visible then the number of damaged squares were counted and recorded.

Predator status of ADB

Effect of ADB on *Helicoverpa* spp. eggs

Studies were conducted to determine whether ADB can prey on *Helicoverpa* spp. eggs and also whether the presence of *Helicoverpa* spp. eggs on cotton plants can influence the degree of damage ADB can cause to cotton plants. Four treatments were established on cotton plants using Perspex cage. The treatments were 4 ADB, 4 ADB + 20 Hel. Egg, 10 ADB and 10 ADB + 20 Hel. Egg. Each treatment was replicated 3 times. Fourth instar ADB nymphs were introduced on the cotton plants for 3 days to feed. The number of eggs consumed and the damage caused by ADB to cotton plants were recorded.

Threshold trials

Previous experiments using ADB and green mirids showed that ADB's damage to cotton plants did not translate to yield loss. Therefore a different approach was taken to determine the economic threshold for ADB on cotton. Since ADB and green mirid (GM) do similar types of damage (Khan and Mensah 1998) and the economic threshold for green mirid is one per metre (see IPM Guidelines for Cotton 1999), instead of directly calculating ADB threshold from damage density relationships we rather calculated the equivalent numbers of ADB that can cause the same degree of damage as one green mirid and used this as an economic threshold for ADB. The equivalent numbers were calculated from regression models for seedling and squaring cotton plants.

Five different densities (0, 2, 4, 6 and 10) of ADB and of green mirids were established per plant on squaring cotton plants. In another study four different densities (0, 2, 4 and 6) of ADB and of GM were established per plant on seedling cotton. The insects were allowed to feed for 3 days. Damage was assessed using damage score method.

Determination of the most efficient sampling method for ADB.

The estimation of insect population is usually the base of any ecological or pest management study. To estimate an insect population it is important to sample the habitat where the particular insect occur. There is no universal sampling method and the appropriate method for a particular insect should be determined based on the distribution and life cycle of the insect. In this study, four different sampling methods viz, D-vac, sweepnetting, visual counting and shaking were tested to determine the most efficient method to estimate the abundance of ADB on cotton crops. All four sampling methods tested are currently being used by growers and consultants in their day-to-day scouting of cotton plants. The study was conducted in both conventional and transgenic cotton crops at Yarral near Narrabri. Sampling was undertaken during the seedling, squaring and flowering stages of the cotton crops. In addition, visual sampling on different times of the day was also undertaken to determine the best times of the day to sample for ADB.

Seasonal phenology of ADB on cotton and other host plants

The study was undertaken in commercial cotton crops at (1) the Australian Cotton Research Institute (ACRI) in Narrabri; (2) Yarral farm near Narrabri and (3) Norwood farm near Moree. At ACRI and Norwood sampling was done for 1997-98, 1998-99 and 1999-00 seasons and at Yarral for 1997-98 and 1998-99 seasons. At each site, ADB was sampled from both transgenic (Ingard®) and normal cotton crops. A 20m row cotton crops were sampled once every week using a portable suction machine (D-vac). Sample commenced when the cotton crops were in the seedling (2-4 true leaf) stage. Insect samples were processed in the laboratory and counted under a dissecting microscope.

Alternative and overwintering host plants which serves as sources of ADB to cotton crops were also sampled at Norwood and ACRI.

Results and Discussion

Life cycle of *C. liebknechti*

ADBs' lay their egg singly into the plant tissue leaving only the egg cap exposed for respiration purposes. Eggs are kidney-shaped and when newly laid are transparent white colour. With age, the eggs turn pale yellow with two red spots on top. The two red spots indicate the compound eyes of the developing nymphs. Eggs take 7 days to hatch. After hatching, ADB passes through 5 nymphal stages to become adult. From 1st instar to adult, ADB males and females take 11.2 and 10.8 days respectively. The number of days each nymphal stage (1st to 5th) take are 2.6 ± 0.16 , 2.1 ± 0.18 , 1.6 ± 0.12 , 2.2 ± 0.15 and 2.7 ± 0.18 days for males and 2.6 ± 0.17 , 2.0 ± 0.17 , 1.7 ± 0.17 , 1.8 ± 0.13 , and 2.7 ± 0.17 days for females. The first instar nymphs are initially pale white in colour and as they mature, they gradually become pale to bright yellow. The wing pads develop at the third instar stage. There are two distinguishing characters found on ADB. The first is a dark spicules on the legs, which is visible in the 5th instar prior to moulting to adult. The second is a dark brownish ring at the far end of second antennal segment which is visible in the adult stage. ADB female lay 41.3 ± 4.33 eggs in her life time. ADB takes about 18.1 days from egg to adult at an average temperature $25 \pm 1^\circ\text{C}$. The females live longer than males, 15.4 and 11.4 days respectively.

Nymphal development of ADB is temperature dependent. The optimum temperatures for ADB development is $30-32^\circ\text{C}$. The development slow down at above or below optimum temperatures and at 15°C ADB fail to complete development. ADB cannot survive at or above 40°C .

Effect of ADB damage to seedling cotton seedling

ADBs prefer to feed on growing parts of seedling cotton particularly terminals, tips of folded and unfolded leaves and branch primordia. Their feeding cause the feeding sites to burn and blacken. An abrasive brown spots also occur at the feeding site on the plant. Damage-density experiments showed that the damage caused by ADB to cotton plants (damage percentage) increased with insect numbers (Figure 1). Cotton plants infested with 10 - 15 ADB per plant suffered significantly more damage than the plants infested with 0 - 6 ADB per plant (Figure 1).

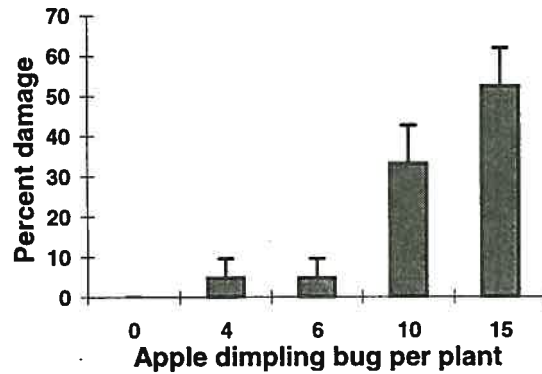


Figure 1. Damage caused by apple dimpling bug on seedling cotton in field

When cotton plants are severely damaged at two leaf stage, the plant growth rate is reduced. However, due to the cotton plant's compensatory ability (Sadras and Wilson 1998) the plant can compensate for the damage. Compensation may result in the delay of boll maturity. Table 1 gives the consequences of ADB damage to cotton plants at two leaf stage.

The results of the study showed that ADB infested plants had fewer squares than the uninfested plants. For plants infested with 15 ADB per plant, the number of squares per plant was 50 per cent less than the uninfested plants during early squaring period. Despite the difference in the no. of squares per plant, no significant difference was detected in the number of bolls per plant between treated and control plants. However, the plants infested with 15 ADB per plant suffered 5, 7 and 5 days delay at first square, flower and boll compared to control plants.

ADB/ replic ation	Square no. at early squaring stage \pm se	Square no. at max. squaring stage \pm se	Boll no. at maturity \pm se	Delay in first squaring (days) \pm se	Delay in flowering (days) \pm se	Delay in boll maturity (days) \pm se
0	10.3 \pm 0.88	38.3 \pm 2.03	18.0 \pm 2.00	0.0 \pm 0.00	0.0 \pm 0.00	0.0 \pm 0.00
4	7.7 \pm 0.67	33.3 \pm 4.91	16.3 \pm 2.19	0.3 \pm 0.33	0.7 \pm 0.33	0.3 \pm 0.33
6	6.0 \pm 0.58	32.7 \pm 4.06	15.3 \pm 3.53	1.7 \pm 0.88	1.3 \pm 0.88	0.7 \pm 0.67
10	6.3 \pm 0.88	32.3 \pm 4.48	15.0 \pm 1.53	2.3 \pm 1.45	3.3 \pm 1.20	2.0 \pm 1.15
15	5.0 \pm 0.58	25.3 \pm 1.76	16.0 \pm 2.65	5.3 \pm 0.88	7.0 \pm 1.53	4.7 \pm 1.20

Table 1. Consequences of ADB feeding on cotton plants at two leaf stage in field

Damage to squares

The effect of ADB feeding damage to squares of cotton plants are given in Figure 2. ADB preferred to feed on very small squares. The symptoms of ADB damage to squares is necrosis in the internal organs, particularly anthers. The insect can also cause the pinhead squares to shed. Small or medium sized squares are usually not shed by ADB feeding. The shedding of pin head squares will depend in part on the number of ADB feeding on the square and the point of feeding. The study showed that higher numbers of ADB resulted in higher shedding of pinhead squares (Figure 2). The result also showed that 10 ADB per plant shed significantly more pinhead squares than 0-4 ADB per plant.

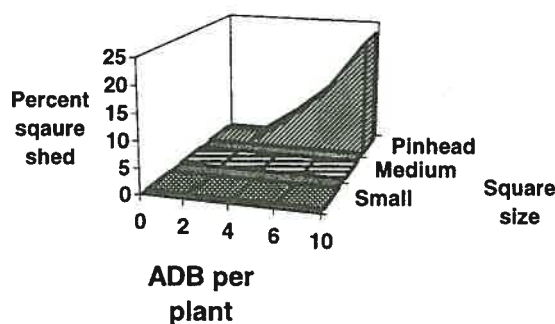


Figure 2. Effect of ADB feeding on cotton squares in the field.

Influence of *Helicoverpa* spp. eggs on ADB damage to cotton plants

The presence of *Helicoverpa* spp. eggs on cotton plants reduced ADB feeding damage at higher ADB densities (Figure 3). Field observation showed no relationship between numbers of *Helicoverpa* spp. egg and ADB numbers on cotton plants indicating that ADB does not infest cotton plants because of *Helicoverpa* spp. eggs. Cotton may serve as a food reservoir for ADB.

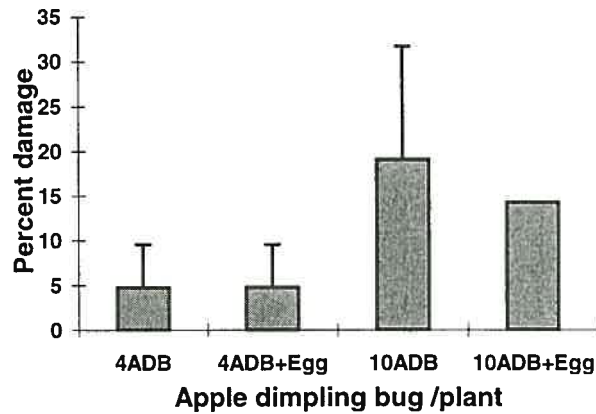


Figure 3. Provision of *Helicoverpa* spp. eggs on cotton plants and damage caused by ADB to plants in the mesh house.

Economic threshold of ADB for seedling stage

The relationship between ADB and GM densities, and damage caused by cotton plants are shown in Figure 4. The regression models show that when seedling cotton was infested with either 1 ADB or 1 GM the cotton plant suffered 2.63 and 19.78 percent damage respectively. From this relationship we calculated the equivalent number of ADB which can cause the same amount of damage as 1 GM. Our calculation showed 11.3 ADB can cause the same damage as 1 GM to seedling cotton. Therefore the economic threshold for ADB on seedling cotton is 11.3.

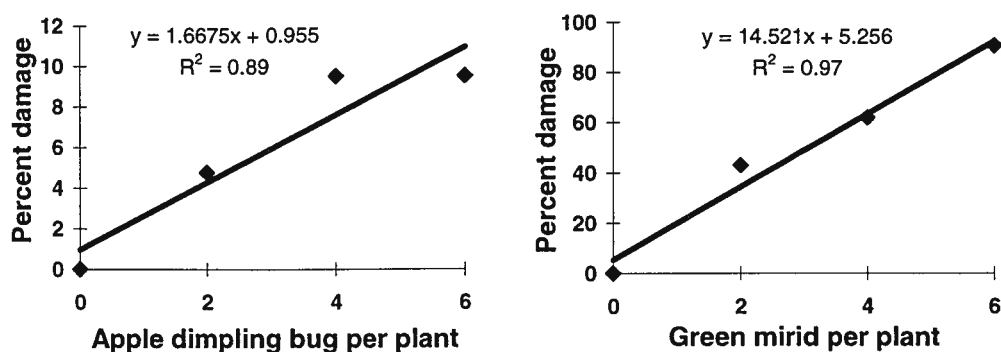


Figure 4. Density-damage relationship of ADB and GM on seedling cotton

Economic threshold of ADB for squaring cotton

The damage-density relationship of ADB and GM for squaring plants were found to be $Y = 0.4701X + 1.7477$ and $Y = 1.9431X + 4.4643$ respectively (Figure 5). Based on these equations, 9.8 ADB can shed the same amount of squares as 1 GM. Therefore if 1 GM is the economic threshold in cotton then the economic threshold for ADB is 9.8.

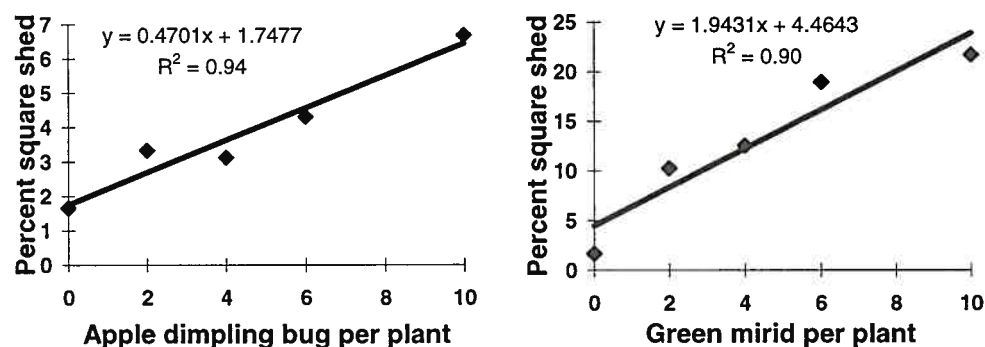


Figure 5 Relationship between damage and density of ADB and GM for squaring plants

Sampling

All the methods used in sampling ADB have both advantages and disadvantages. For example substantial amount of plants and fruits are damaged during sweepnetting. Also suction sampling with D-vac may be quicker than visual sampling, however, the efficiency of this method drop significantly at later stage of the growth of the cotton plant. On the other hand efficiency of visual counting will depend on the expertise of the bug checker and the time of the day checking is done. In shaking, most of the adult insects fly away.

The result of this study showed that irrespective of the cotton growth stage, visual counting is the most effective method to sample ADB followed by D-vac and sweepnetting (Figure 6). At seedling stage, any of the 3 sampling methods (visual, D-vac and sweepnetting) can be used to sample ADB. However, at squaring and flowering stages D-vac and sweepnetting are less effective than visual counting. This is mainly due to failure of sweepnetting and D-vac to penetrate deep into dense canopy at these stages and also the insects particularly the nymphs are hard to suck or dislodge from the plants especially when they are inside the squares. Shaking method was the least effective method. Early morning or late afternoon are the best times of the day to sample for ADB (Figure 7)

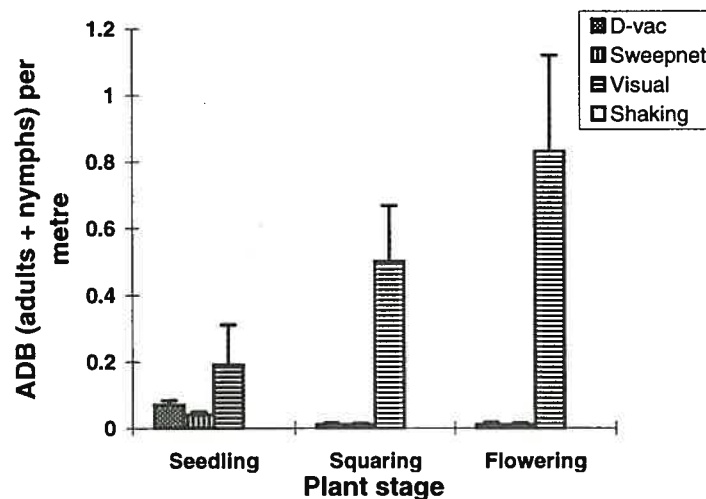


Figure 6. Comparison of sampling methods for apple dimpling bugs in cotton fields at Yarral, Narrabri, 1998-99.

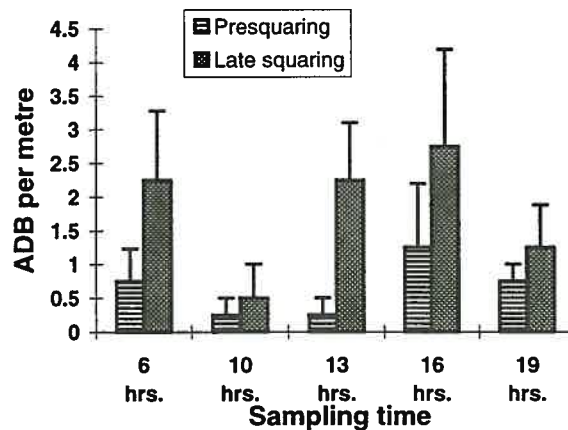


Figure 7. Number of apple dimpling bugs caught at different times of a day in cotton fields at Yarral, Narrabri, 1998-99

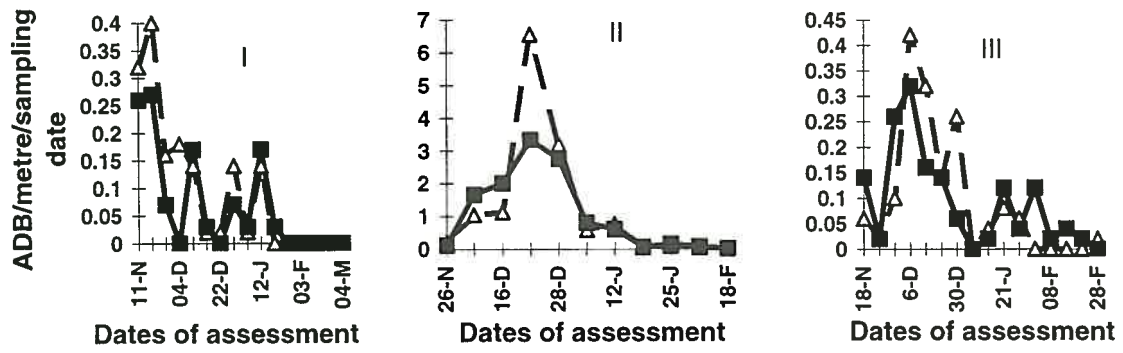
Seasonal phenology of ADB on cotton

Results on seasonal phenology of ADB are presented in figure 8. There was no significant difference ($P < 0.05$) in ADB numbers between normal and INGARD cotton. The population trend of ADB was also the same in both cotton types. Apple dimpling bug migrate to cotton crops, possibly from surrounding wild host plants, during early cotton season to establish on cotton crops. The peak ADB population occur during the mid-cotton season and coincided with the peak squaring period of the cotton crop. This could indicate that ADB prefer squaring plants and also squaring plants possibly provide a good source of food and shelter. Sometimes high ADB numbers may occur on cotton plants early in the season. This may happen if rainfall during winter or prior to the cotton season has been good resulting in the growth of weeds and other host plants which enhances ADB development and high population build up. The high population then migrate in to cotton crops. ADB populations on cotton usually declines during the late cotton season. This may be due to increase late season insecticide spray to control *Helicoverpa* spp. and also the high summer temperature. In seasons with mild summers, low *Helicoverpa* spp. pressure and low insecticide use, ADB populations during late season may be same as mid-season (for example during the 1999-00 season).

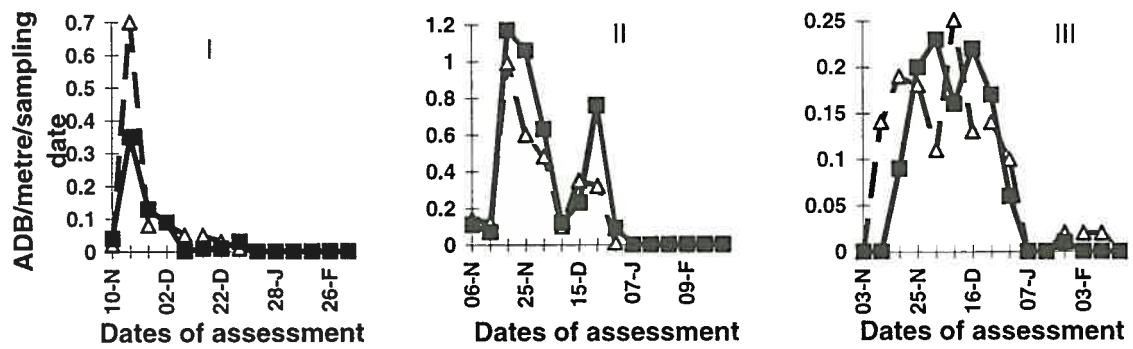
Sources of ADB

Considerable number of crops and weeds serve as host to ADB. These alternative crops can support the development of ADB adults and nymphs (Table 2). It is therefore possible that ADB found in cotton fields early in the season might have migrated to cotton crops from weeds and other crop hosts surrounding cotton fields. During late September and or early October, large numbers of ADB are found on weeds and other host plants. In October these host plants dry up or are cultivated and or grazed resulting in the movement of ADB from these host plants to cotton.

A



B



C

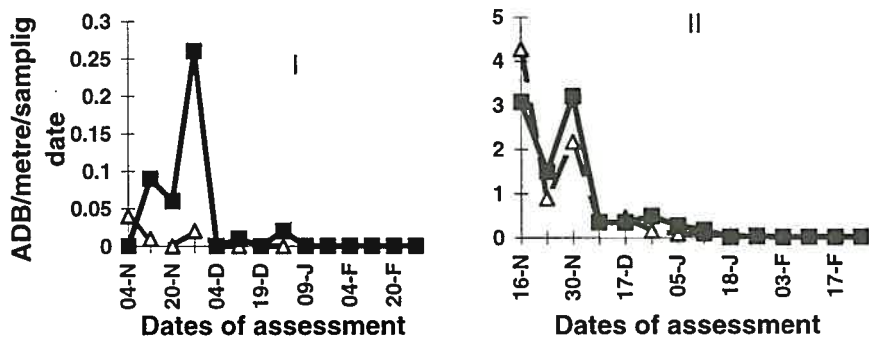


Figure 8. Apple dimpling bug population densities on cotton at (A) ACRI, (B) Nrwood and (C) Yarral during (I) 1997-98, (II) 1998-99 and (III) 1999-00 seasons. — — Δ — — normal cotton; —■— INGARD cotton.

Common Name	Scientific Name	Support ADB stage
Crop Hosts		
Lucerne	<i>Medicago sativa</i>	Adult and Nymph
Sunflower	<i>Helianthus annuus</i>	Adult and Nymph
Safflower	<i>Carthamus tinctorius</i>	Adult
Sorghum	<i>Sorghum bicolor</i>	Adult
Mungbean	<i>Vigna radiata</i>	Adult and Nymph
Bean	<i>Phaseolus vulgaris</i>	Adult and Nymph
Fababean	<i>Vicia faba</i>	Adult and Nymph
Vetch	<i>Vicia villosa</i>	Adult and Nymph
Pigeonpea	<i>Cajanus cajan</i>	Adult and Nymph
Weed Hosts		
Burr medic	<i>Medicago polymorpha</i>	Adult
Cat head	<i>Tribulus terrestris</i>	Adult
Common joyweed	<i>Alternanthera nodiflora</i>	adult
Gluaca	<i>Haloragis glauca</i>	Adult and Nymph
Hairy carpet weed	<i>Glinus lotoides</i>	Adult and Nymph
Noogoora burr	<i>Xanthium spp.</i>	Adult and Nymph
Paterson's curse	<i>Echium plntagineum</i>	Adult and Nymph
Salt bush	<i>Atriplex spp.</i>	Adult and Nymph
Variegated thistle	<i>Silybum marianum</i>	Adult
Wild turnip	<i>Brassica spp.</i>	Adult and Nymph

Table 2. List of crop and weed hosts that support ADB population

Conclusions

- ADB passes through an egg and 5 nymphal stages before becoming on adult
- ADB take 18.1 days to complete their development from egg to adult
- Development of ADB is temperature dependent
- The optimum temperature for ADB development is 30-32°C

- ADB (both adults and nymphs) can cause damage to both seedling and squaring plants
- Damage caused by ADB is similar to GM damage
- ADB's feeding on seedling cotton plants cause terminals, tips of folded and unfolded leaves to burn and blacken.
- ADB's feeding on young cotton plants particularly seedling cotton can cause about five days delay in squaring, flowering and boll maturity
- Damage and delay in maturity of cotton plants as a result of ADB feeding increases with density
- Squaring stage is the most favourable stage for ADB development in the field
- ADB feeding can cause pinhead squares to shed; shedding increases with ADB density
- The economic threshold of ADB for seedling and squaring cotton is 11.3 and 9.8 per metre respectively. During the squaring stage of cotton, the economic threshold of 9.8 ADB per metre and 50% square retention should be used for management decisions of this insect.
- Population trend in both Ingard[®] and normal cotton are similar
- Visual count or D-vac are the two most effective methods for sampling ADB
- Early morning and late afternoon are the best times of the day to sample ADB

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