

The cabbage webworm (*Hellula undalis*) on tickweed (*Cleome viscosa*) in Samoa

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Abstract

Cabbages (*Brassica* spp.) are important components of the diet of many South Pacific island people, but their production is often constrained by pests and diseases. Leaf-eating caterpillars, particularly *Crocidolomia pavonana*, *Plutella xylostella* and *Hellula undalis*, are the most important insect pest constraints in Samoa. In 2006, it was observed that *H. undalis* infests a wild plant, *Cleome viscosa*, in Samoa. Field surveys, laboratory and cage experiments were then conducted from 2007 to 2009 to investigate aspects of the ecology of *H. undalis* in Samoa. The study showed that *H. undalis* is present on *C. viscosa* throughout the year. Findings also suggest that parasitism of *H. undalis* in Samoa is either negligible or non-existent. Only *Brassica rapa chinensis*, *Brassica oleracea capitata* and *C. viscosa* were confirmed as hosts of *H. undalis*. Laboratory and cage experiments suggested that *C. viscosa* was more attractive for *H. undalis* larval feeding than the *Brassica* spp. However, overall indication from this study is that the main role of *C. viscosa*, under field conditions, is as source of recruitment of *H. undalis* onto cultivated hosts. We recommended that *C. viscosa* should be controlled in cabbage growing areas.

Key words: *Cleome viscosa*, Weed host, *Hellula undalis*, Samoa.

1 Introduction

Hellula undalis (Fabricius) (Lepidoptera: Pyralidae), commonly known as cabbage webworm, is native to Europe, Africa and most of Asia (Waterhouse and Sands, 2001). It is a pest of brassicas and other crucifers in warm regions (CABI, 2005), and serious outbreaks have been reported in some countries, including the Philippines where infestations of up to 100% have been observed in cruciferous crops (Kalbfleisch, 2006). The insect is important in cabbages in Malaysia (Sivapragasam and Abdul Aziz, 1992; Sivapragasam and Chua, 1997), Taiwan (Talekar *et al.*, 1981), India (Srihari and Satyanarayana, 1992), Guam (Muniappan and Marutani, 1992), and Australia (Waterhouse and Sands, 2001). It is present in Samoa (Taefu, 1977; Hollingsworth *et al.*, 1984; Waterhouse and Norris, 1989; Ebenebe *et al.*, 2006), Solomon Islands, Palau, New Caledonia, French Polynesia and Cook Islands (Pacific Islands Pest List Database), Fiji, Federated States of Micronesia (FSM), Niue, Papua New Guinea (PNG), American Samoa, Tokelau, and Tonga (Waterhouse, 1997).

Cleome viscosa L. (Capparaceae), commonly known as tickweed, originated from Asia (Smith, 1981), but it is now a widespread weed. In the Pacific Islands, it is present in Fiji, Micronesia, FSM, Nauru, New Caledonia, Samoa, Solomon Islands, French Polynesia, Northern Mariana Islands, PNG, and Vanuatu (Pacific Islands Pest List Database). It is described as an introduced invasive weed in Fiji (Smith, 1981), Kiribati (Space *et al.*, 2003), Nauru (Thaman *et al.*, 1994), and Niue (Whistler, 1988). Whistler (1988) describes it as "common as a weed of disturbed places in Samoa".

In Samoa, *H. undalis* is one of five lepidopterous leaf-eating pests recorded on cabbages (*Brassica* spp.), and along with *Crocidolomia pavonana* (Fabricius) and *Plutella xylostella* L., it is ranked among the top three most damaging insect pests of cabbages in the country (Ebenebe *et al.*, 2006).

In terms of impact of *H. undalis*, Hollingsworth *et al.* (1984) has reported up to 22% crop damage, and Ebenebe *et al.* (2006) reported a peak incidence of damage of 27.1% in head cabbage (*Brassica oleracea capitata*) at Alafua. These percentages are a good estimate of actual crop loss that can be caused, because the pest usually affects and destroys the growing point of a plant. Although the attacked plant may not die, the damage induces the formation of several growing points or multiple heads that usually fail to attain marketable quality. Tunnelling of growing points of young cabbage plants may result in plant death.

While working in a cabbage field at Alafua (Samoa) in 2006, Adama Ebenebe noticed leaf-rolling on *C. viscosa* plants growing near the field. The larvae responsible for the leaf-rolling were subsequently confirmed as *Hellula undalis*. Literature search revealed that this insect has been reported on *Cleome* spp. in the Caribbean, Guyana, Mexico (Alam, 1991), Malaysia (Sivapragasam and Abdul Aziz, 1992), and the Philippines where infestations of up to 60% was recorded on *C. viscosa* and *C. rufidosperma* (Kalbfleisch, 2006). Apparently, there is no previous report of *H. undalis* on *Cleome* spp. in Samoa and other South Pacific island countries.

Presently, management of *H. undalis* and other lepidopteran pests of cabbages in the Pacific Island Countries is mainly based on the preventive application of

chemical insecticides. However, most stakeholders around the region agree that the use of chemical pesticides must be minimized in the interest of safety and sustainability. In an effort to address this issue, a project funded by the Australian Centre for International Agricultural Research (ACIAR) (*PC/2004/063 - Integrated pest management in a sustainable production system for Brassica crops in Fiji and Samoa*), was started in Samoa and Fiji in 2005. According to the project description, it “seeks to understand the role played by natural enemies in pest population regulation and then to use participatory methods to develop more sustainable crop management strategies”. Apparently, the project did not include the investigation of uncultivated hosts among its objectives. Therefore, the observation of *H. undalis* on *C. viscosa* in 2006 triggered this present investigation, which was primarily aimed at finding out the role of this weed host in maintaining the population of this important cabbage pest in Samoa. The study provides information which has not been previously reported from Samoa or other island countries in the region. The investigation focused on the following objectives: (a) Occurrence of *H. undalis* larvae on *C. viscosa*, (b) Nature of infestation by *H. undalis* on *C. viscosa*, (c) Parasitism of *H. undalis* on *C. viscosa*, (d) Hosts of *H. undalis*, and (e) Host preference of *H. undalis* larvae.

2 Materials and Methods

2.1 Occurrence of *H. undalis* Larvae on *C. viscosa*

Monthly field observations were conducted at Alafua (15–17°S, 171–173°W) between 2007 and 2009 to monitor the presence of *H. undalis* on *C. viscosa* plants. Depending on the abundance of *C. viscosa* at the time of survey, 20–85 plants were randomly selected around the study area and inspected *in-situ* for the presence of *H. undalis* larvae. Plants were counted as infested only if *H. undalis* larvae were actually found on them. Occurrence was taken to mean the presence of *H. undalis* larvae on a *C. viscosa* plant, irrespective of the number of larvae present. *H. undalis* population densities and reasons for population fluctuations were not assessed during the surveys.

During the monthly field observations, data was also recorded on *C. viscosa* plants bearing signs (webbing, boring) which suggested having been infested by *H. undalis* larva. It was possible to attribute these signs to *H. undalis* without actually seeing the larvae, due to the characteristic way in which it infests the plants. In addition, none of the other insects (a lepidopteran larva that fed exposed on leaves and around shoot tips, and two unidentified hemipterans) which were frequently encountered on *C. viscosa* plants was observed to cause webbing or boring. Data collected from the Alafua monthly surveys were used to assess the seasonal occurrence of *H. undalis* on *C. viscosa* over the survey period (May 2007 to May 2009). *C. viscosa* plants growing along roadsides in various villages were occasionally inspected in order to note the presence or absence of *H. undalis* in areas where brassica vegetables were not grown.

2.2 Nature of Infestation by *H. undalis* on *C. viscosa*

The pattern of infestation by *H. undalis* on *C. viscosa* was studied through observations of infested plants at different growth stages occurring at the same time in the

study area. Plants for observation were uprooted at random and inspected to determine the presence, location, and number of larvae, on each plant.

2.3 Parasitism of *H. undalis* on *C. viscosa*

Fourth and fifth instar larvae of *H. undalis* were collected from field-infested *C. viscosa* plants around Alafua. These were kept at normal room conditions in transparent jars covered with pieces of fabric. Jars were monitored daily for possible emergence of parasitoids from larvae, or until pupation. Larvae were provided with fresh pieces of *C. viscosa* plants as often as necessary. Upon pupation, they were transferred singly into petri-dishes for further observation for possible emergence of parasitoids from pupae, or until emergence of *H. undalis* adults. Sex ratio of emergent adults was also determined.

2.4 Hosts of *H. undalis*

Weeds growing near and within Chinese cabbage (*B. rapa chinensis*) and head cabbage crops around Alafua were regularly examined for alternative hosts of *H. undalis*.

2.5 Host Preference of *H. undalis* Larvae

Two sets of experiments were conducted at the University of the South Pacific, Alafua Campus, Samoa, to assess the host preference of *H. undalis* larvae. Larvae were provided with three hosts and their dispersal onto the hosts was recorded. One study was a cage experiment and the other was a tray experiment in a laboratory. Both were done under normal ambient conditions.

2.5.1 Cage experiment

This study was done in a screen house during 2008 (preliminary experiment) and 2009. Cages measuring 1.5 m x 1 m x 1 m were constructed from timber (frame) and fine mesh wire (sides). Eight seedlings (5 weeks old) each of Chinese cabbage, head cabbage and *C. viscosa* were transplanted into garden bags and placed in an alternating manner inside each cage, ensuring that adjacent plants did not touch each other. In the preliminary study of 2008, 30 to 45 third and fourth instar *H. undalis* larvae, which were collected from field-infested *C. viscosa* plants, were released into each of three cages. Larvae were distributed across the floor of the cages so that they could move on to their plants of choice. Seven days after the introduction of larvae into cages, the plants were observed for incidences of damage and infestation, and number of larvae present. The same procedure was followed in the 2009 experiment, except that 30 third and fourth instar larvae were introduced into each of eight cages. Only the result from the 2009 experiment was analysed statistically using analysis of variance.

2.5.2 Tray experiment

This study was conducted in a laboratory during 2009. Fresh pieces of Chinese cabbage and head cabbage (about 5 cm x 5 cm) and an equivalent bunch of *C. viscosa* shoot tips were placed on a plastic tray (51 cm x 36 cm x 2.5 cm). The plant pieces were arranged by type towards the outer edge of the tray in a more or less triangular manner. Ten third and fourth instar larvae of *H. undalis*, collected from field-infested *C. viscosa* plants, were placed in the

middle of the tray. Observations were made to identify the whereabouts of the larvae at 1 hour, 6 hours, and 24 hours after the introduction of larvae. There were 10 trays (replications) altogether, and the experiment was repeated once. Data on the number of larvae that moved to the different types of plant pieces were analysed using analysis of variance.

3 Results

3.1 Occurrence of *H. undalis* Larvae on *C. viscosa*

Monthly surveys of *C. viscosa* around Alafua revealed that *H. undalis* larvae, and symptoms of infestation, were present throughout the year (Figures 1 and 2), except in January 2008. However, larvae were observed on *C. viscosa* along a roadside at Tafaigata village during January 2008. Peak incidence of infestation during the 2007/2008 survey period was 41% (in September 2007), and 53.2% for the 2008/2009 survey period (in September 2008).

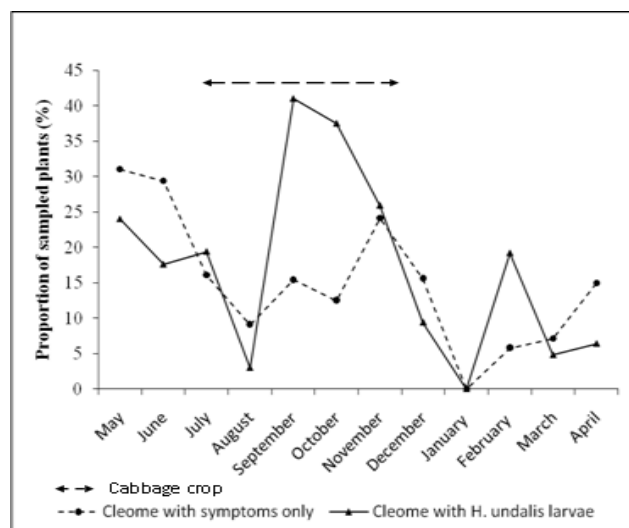


Figure 1. Occurrence of *H. undalis* larvae and symptoms of damage on *C. viscosa* at Alafua during the 2007/2008 sampling period.

Larvae were present on *C. viscosa*, both in the presence and absence of cultivated brassica at Alafua (Figures 1 and 2). Larvae were also observed on *C. viscosa* along roadsides at various locations including Alafua, Lotopa, and Tafaigata villages.

Correlation analysis for incidence of *H. undalis* larvae on *C. viscosa* and total monthly precipitation at Alafua area during the sampling period of 2008/2009 revealed no significant relationships ($R^2 = 0.002$). The result was similar in relation to mean monthly temperature (extreme) which ranged between 26.6 °C and 31.8 °C during the same period ($R^2 = 0.123$). Correlation analysis could not be done for the 2007/2008 data because the recording of meteorological data at Alafua started in March 2008 (Sunny Seuseu, Samoa Meteorology Division, personal communication, 2009).

3.2 Nature of Infestation by *H. undalis* on *C. viscosa*

Observations of *C. viscosa* of different growth stages in the same vicinity showed that *H. undalis* larvae occurred more frequently on pre-flowering, flowering, and fruiting

stages, and less on mature plants (Table 1). A 2-way contingency table analysis of the data strongly indicates that younger *C. viscosa* are more attractive to *H. undalis* than mature plants.

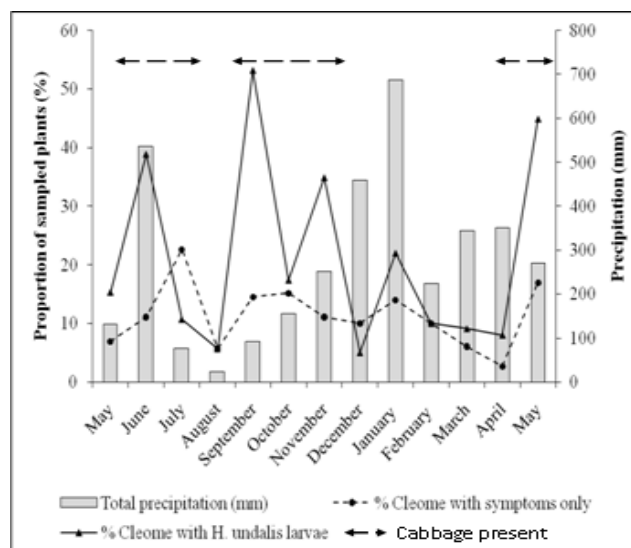


Figure 2. Occurrence of *H. undalis* larvae and symptoms of damage on *C. viscosa*, and monthly total precipitation recorded at Alafua during the 2008/2009 sampling period.

Table 1. Occurrence of *Hellula undalis* larvae on *Cleome viscosa* of different growth stages.

Cleome growth stage	No. of plants not infested	No. of plants infested	Total
Pre-flowering/	512	161	673
flowering/fruiting	(68.0%)	(21.4%)	(89.4%)
Maturity (pods still green, very few flowers present)	76	4	80
	(10.1%)	(0.5%)	(10.6%)
Total	588	165	753
	(78.1%)	(21.9%)	(100%)

Chi Square = 14.963; d.f. = 1; p-value = 0.000

Out of 335 infested sites examined on *C. viscosa* of all growth stages occurring in the same general vicinity, most infestations (290, or 86.6%) occurred around the shoot tip area inside folded leaves or leaves joined with flower buds. First instars were generally more difficult to locate, but those encountered occurred in folded leaves or inside flower buds. Infestation of side leaves (i.e. leaves attached directly to main stem or branch) was low but not uncommon (7.2%), whereas infestations of all other possible sites (pods, flowers, stem, etc.) were seldom (<2%) or not encountered.

Observations to assess the role of mature *C. viscosa* plants in maintaining the populations of *H. undalis* through pod infestation were done on five occasions (7/9/2007, 11/7/2008, 30/4/2009, 11/5/2009, and 16/7/2009). These were during periods when only mature plants carrying a lot of pods but very few young leaves and buds were present in the area. Results showed that pod infestation was rare (9 pods out of a total of 2689 pods examined, or 0.3%). This was in spite of the fact that overall incidence of infestation of observed plants ranged from 11% to 44.9% on these

sampling dates. This confirms that pod infestation is not common.

Examination of 378 infested *C. viscosa* plants of all ages revealed that most plants (82.8%) carried only one larva, although two larvae per plant was not too infrequent (12.2%). Up to eight larvae per plant was recorded (0.3% of infested plants). It is worth noting that *H. undalis* pupae were not encountered on *C. viscosa* plants during this study.

No parasitoids were reared from 371 *H. undalis* larvae collected from field-infested *C. viscosa*. The male:female ratio of adult *H. undalis* reared from the field-collected larvae was 1:1.44.

Surveys of weeds and eggplant near or within Chinese cabbage and head cabbage crops around Alafua found no additional hosts of *H. undalis*.

More *C. viscosa* plants were damaged by *H. undalis* larvae than Chinese cabbage, which had a higher incidence than head cabbage, but the differences were not significant (Table 2). Similar trends were observed for proportion of infested plants and number of *H. undalis* larvae recovered from plants, but differences were significant for these parameters (Table 2).

Table 2. Mean incidence of damage, infestation and number of *H. undalis* larvae recovered per plant on three hosts (Cage experiment - 2009).

Host	% plants with damage (with or without larvae present)	% plants with larvae	Number of larvae recovered per plant
Head cabbage	45	9c	1c
Chinese cabbage	53	13b	1.5b
<i>Cleome viscosa</i>	58	23a	3.5a
P-value	0.648n.s.	0.032	0.014

Means in the same column having different letters are significantly different ($P \leq 0.05$). n.s. means not significant.

Total numbers of *H. undalis* larvae that had moved to each of the three types of plant material at 1 hour after introduction of larvae were 8, 7 and 58 to Chinese cabbage, head cabbage, and *C. viscosa*, respectively. After 6 hours, the numbers were 12, 12 and 45 larvae to Chinese cabbage, head cabbage, and *C. viscosa*, respectively. By 24 hours after introduction, all the larvae had moved onto the plant pieces provided. Statistical analysis of total counts at 24 hours showed that *C. viscosa* had significantly higher numbers than both cabbages in both trials, but there was no significant difference between the two cabbages (Table 3).

Table 3. Total number of *H. undalis* larvae on hosts at 24 hours after introduction onto trays.

Host	Number of larvae:	
	Trial 1	Trial 2
Chinese cabbage	10b	20b
Head cabbage	10b	10b
<i>Cleome viscosa</i>	80a	70a
P-value	0.000	0.001

4 Discussion

This study has revealed that *H. undalis* occurs on *C. viscosa* throughout the year in Samoa, even in the absence of cultivated brassica. In addition, all growth stages of *C. viscosa* harbour the insect. These observations suggest that *C. viscosa* plays a role as a wild reservoir of this insect pest in Samoa. Kalbfleisch (2006) also drew the same conclusion with respect to *H. undalis* on *C. viscosa* and *C. rutidosperma* in the Philippines. Larvae of different instars were usually present during sampling exercises, suggesting the occurrence of overlapping generations. Talekar *et al.* (1981) have reported overlapping generations of *H. undalis* in Taiwan.

The highest incidences of infestation by *H. undalis* on *C. viscosa* in the Alafua area during the two survey periods (2007/2008 and 2008/2008) were in September, which falls within the dry season period in Samoa. However, although Kalbfleisch (2006) reported a significant negative correlation between rainfall and *H. undalis* larval infestation in the Philippines, such was not found in this present study.

It was found that higher incidences of infestation of *C. viscosa* by *H. undalis* coincided with the presence of cultivated brassicas in the field. This seems to suggest that the presence of brassica crops somehow encouraged the infestation of *C. viscosa* by *H. undalis*. However, an abundance of young *C. viscosa*, which always developed following land preparation for crop cultivation in the study area, was probably the likely influence which encouraged the higher incidences of infestation of *C. viscosa* during those times. It was observed that flushes of *C. viscosa* which appeared following land preparation in the study area were quickly infested with *H. undalis* even in the absence of brassica crops.

Most *H. undalis* infestations on *C. viscosa* involved leaves. However, unlike infestations in cabbages, whereby early instars usually mine leaves (Talekar *et al.*, 1981; Kalbfleisch, 2006), larvae, including first instars, did not mine into *C. viscosa* leaves. One possibility for this difference in behaviour may be because *C. viscosa* leaves are smaller and softer and, therefore, more readily folded, even by young larvae, to provide the protection that mines in cabbage plants afford. However, where infestations involved only a flower bud, a pod, or a petiole, *H. undalis* larvae were observed in holes bored into these plant parts.

Although it has been reported that *H. undalis* may pupate on cabbage plants (Sivapragasam and Chua, 1997), pupae of *H. undalis* were not encountered on *C. viscosa* plants during the present study. Therefore, it may be concluded that the insect pupates off *C. viscosa* plants, possibly in the soil or on plant debris. Talekar *et al.* (1981) have reported pupation in the soil, and Sivapragasam and Chua (1997) on plant debris.

Larval parasitoids of *H. undalis* have been reported in other countries (CABI, 2005; Kalbfleisch, 2006), but none was found during this study. In a previous study on head cabbage crops at Alafua during 2006 - 2008, no parasitoids were reared from field-collected larvae of pest Lepidoptera, including *H. undalis* (Ebenebe *et al.*, 2010). This suggests that larval parasitism of *H. undalis* is either non-existent or rare in Samoa.

Although *H. undalis* has been reported elsewhere on *Portulaca* sp. (Romm, 1937 cited by Waterhouse, 1993),

Amaranthaceae and eggplant (Waterhouse and Sands, 2001), all of which were surveyed during this study, *C. viscosa* was the only non brassica host found to harbour the insect.

In the host preference studies, *H. undalis* larvae were found to be significantly more attracted to *C. viscosa* than Chinese cabbage and head cabbage. However, it is not certain from this study whether this observed trend was a reflection of ecological preference for *C. viscosa*, or whether prior feeding experience on *C. viscosa* in the field played a role in the observed behaviour. The possibility of influence of prior dietary experience in host selection by some leaf-feeding lepidopterans has been reported by Campo and Renwick (1999) and Renwick and Lopez (1999).

The 1.44:1 female:male sex ratio recorded in this study differs from the 1.28:1 reported by Talekar *et al.* (1981) in Taiwan, 1.22:1 and 1.31:1 by Wang *et al.* (undated) in northern Taiwan for field and laboratory populations, respectively, and 1:1 by Sivapragasam (2005) under field and laboratory conditions in Malaysia.

5 Conclusion

This study has demonstrated that *C. viscosa* is an important uncultivated host of *H. undalis* in Samoa as it appears to be a year-round reservoir of this important pest of cultivated *Brassica* spp. However, further research is needed to gain a better understanding of the relationships between *H. undalis* and each of the three hosts. A practical pest management question to answer is whether the attraction to *C. viscosa* observed in the laboratory and cage experiments is also exhibited in the field, and if so, whether it is strong enough to divert *H. undalis* away from cultivated brassicas (i.e. as trap plant). Until this is investigated, we recommend that *C. viscosa* plants should be removed in areas where Chinese and head cabbages are to be grown.

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