INTERNATIONAL JOURNAL OF PLANT PROTECTION
VOLUME 7 | ISSUE 2 | OCTOBER, 2014 | 302-311 ● e ISSN-0976-6855 | Visit us : *www.researchjournal.co.in*

IJPP

RESEARCH PAPER

DOI : 10.15740/HAS/IJPP/7.2/302-311

Biology, feeding potential, standardization of mass production techniques and impact study of *Dipha aphidivora* Meyrick

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ARITCLE INFO

Received : 21.03.2014
Revised : 23.07.2014
Accepted : 07.08.2014

KEY WORDS :
Ceratovacuna laniger, *Dipha aphidivora*, Biology, Mass production, Feeding potential

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ABSTRACT

Experiments were conducted on the biology, feeding potential and standardization of the mass production of *Dipha aphidivora* Meyrick predator on sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner during 2005-2007, at Agricultural Research Station (ARS), Honnavile, Shimoga (district), Karnataka, India. The duration of the first instar was 2.5 to 3.5 days (average 2.95±0.90 days). The average duration of second, third, fourth and fifth instar, pupal period, adult female and male moth lasted for 4.57±1.33, 8.30±1.11, 11.37±2.96 and 6.10±0.77 days, 8.50±2.15 days, 4.5±0.50 days, 1.5±0.30 days, respectively and the total larval period lasted for 24.5 to 39.5 days. The daily consumption rate by *D. aphidivora* was 30.8 aphids per day. *D. aphidivora* or aphid multiplied faster on 7-month-old crop than 5, 6 and 8 month old crop. At the rate of 50 number of *D. aphidivora* pupae release, highest populations of 4230 per shade net *D. aphidivora* were harvested. Highest populations of *D. aphidivora* were harvested when the shade nets were irrigated once in two days with the population of 4123 *D. aphidivora* per shade net than irrigated once in week with the population of 1490 *D. aphidivora* per shade net. During the experiment, average temperature was 28^{0}C and relative humidity was 78 per cent.

How to view point the article : Mythri, Pradeep, S. and Hugar, S.V. (2014). Biology, feeding potential, standardization of mass production techniques and impact study of *Dipha aphidivora* Meyrick. *J. Plant Protec.*, **7**(2) : 302-311.

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is the main source of sugar and important commercial crops of India, which is cultivated all over the country from latitude 800°N to 330°N, except in the cold hilly areas like Kashmir valley, Himachal Pradesh and Arunachal Pradesh. Globally it is cultivated over an area of 20.1 million hectares with a production of 1318.1 million tonnes and productivity of 65.5 tonnes per hectare (Anonymous, 2004).

Sugarcane is ravaged by about 289 different pests affecting sugarcane. Out of which 213, are insects and 76 are non-insect pests. The winged and wingless forms of sugarcane woolly aphid (SWA), *Ceratovacuna lanigera* Zehntner are found on the ventral surface of the leaves. The nymphs and adults suck the sap resulting in tip and marginal yellowing initially, leading to drying of leaves. The excretion of honeydew causes development of sooty mould on upper surface of lower leaves with a reduction in photosynthetic area, resulting in reduction in cane internodal length, cane

girth and deterioration of juice quality and quantity, reducing yield by 30 per cent and sugar recovery by 24 per cent (Patil *et al*., 2003 and Kumarasinghe and Basnayake, 2009).

The sugarcane ecosystem is such that no methods of pest suppression would be more feasible than the biological control. A number of natural enemies of woolly aphid have been reported by several workers (Tripathi, 1995; Anonymous, 2002 and Rabindra *et al*., 2002). There are about seven parasitoids, 30 predators and four pathogens affecting woolly aphid. Among them, *Dipha aphidivora* Meyrick commonly known as pyralid webber, belonging to the family Pyralidae of the order Lepidoptera is considered as one of the potential predators. It was recorded from Dimapur in Nagaland (Tripathi, 1995). Though it was recorded as a predator on woolly aphid during 1978, serious efforts to multiply and use it for biological control were made only in 1997.

MATERIAL AND METHODS

Experiments were conducted during 2005-2007, at Agricultural Research Station (ARS), Honnavile, Shimoga (district), Karnataka, India.

Assessment of the impact of activity of *D. aphidivora* on the population dynamics of woolly aphid :

To assess the impact of *D. aphidivora* on the population dynamics of woolly aphid, an experiment was laid out in a Randomized Block Design with five treatments and four replications. Each treatment was imposed in a plot size of $10\times10m^2$ dimension with isolation distance of 10 m between the plots.

The following were the treatments :

Treatment 1: Initial infestation of SWA with *D. aphidivora*.

Treatment 2: Heavy infestation of SWA with *D. aphidivora*.

Treatment 3: Initial infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*.

Treatment 4: Heavy infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*.

Treatment 5: Heavy infestation of SWA without *D. aphidivora*.

While imposing treatments, initial infestation was considered as pest intensity rating (PIR) of one where the leaf area covered by SWA was 1 to 20 per cent and heavy infestation was considered as pest intensity rating four where 61 to 80 per cent of leaf was covered by SWA. For initial infestation of SWA with *D. aphidivora* and heavy infestation of SWA with *D. aphidivora* treatments, naturally infested patches of sugarcane were demarked into 10 mt×10 mt plots. For treatments 3, 4 and 5, artificial infestation of SWA was carried out to get pest intensity rating of 2 for treatment 3, and 4 for treatments 4 and 5. Artificial release of predators was carried out based on the feeding potential. For treatment 3, the numbers of predators released were three per plant and for treatment 4, the numbers of predators released were six per plant (Table A).

Table A : Scoring of pest intensity based on per cent leaf area covered by woolly aphid colonies

Area of leaf covered by SWA	Pest intensity rating
0 (%)	0 (Nil)
1-20 (%)	1 (Very low)
21-40 (%)	2 (Low)
41-60 (%)	3 (Moderate)
61-80 (%)	4 (High)
>80 (%)	5 (Severe)

Culture of SWA :

The stock culture of the aphids was maintained in a small patch of susceptible sugarcane variety (Co-8371) by artificially infesting the crop when it was six months old. The plot received 25 per cent more nitrogen and frequent irrigation to facilitate the build up of woolly aphid population. Measures were taken to keep the plot free from the predators.

Culture of *D. aphidivora* :

A culture of the predator, *D. aphidivora* was maintained in woolly aphid infested plot of sugarcane under shade net. The predators were collected form this source as and when required for the investigation.

Biology and feeding potential of *D. aphidivora* :

Biology :

Field collected pupae of *D. aphidivora* were kept in an emergence cage (17 cm diameter and 2 cm height) for collecting the emerging male and female adults. For egg laying, mated females were released on the SWA infested caged leaf. Neonate larvae were released into different SWA infested caged leaves. Later, the cage was fixed to the leaf and such ten sets were maintained. The same technique was used to rear different instars of larvae. Observations on the larval moulting and pupal period were recorded daily in the morning. The pupae were kept in a plastic cage (17 cm diameter and 7.5 cm length) for adult emergence. Freshly emerged male and female moths were released in the mating cage (17 cm diameter and 7.5 cm length) provided with 5 per cent sugar solution in a cotton wad for recording adult, longevity. The fecundity was studied by releasing a single gravid female moth provided with 5 per cent sugar solution in cotton wad into a SWA infested caged leaf. Ten cages were maintained for the study. The moth was allowed to lay eggs until its death and recorded the number of eggs laid.

The feeding potential of different larval instars of *D. aphidivora* was recorded daily in the caged leaf. Before releasing of predator, the total number of SWAs (all stages) within the cage was counted and later aphids were counted once a day. By deducting number of live aphids from the

total number of aphids, the feeding potential of larvae was recorded. Total feeding potential at different instars and daily feeding rates were recorded.

Standardization of mass production technique of *D. aphidivora* in shade net cages :

Three trials were taken up as mentioned below :

Trial 1 :

To find out the appropriate age of the crop for rapid multiplication of aphid as well as *D. aphidivora* under shade net cage, a non-replicated trial was laid out by selecting 5, 6, 7 and 8 months old crop on which shade nets were erected and SWA was artificially infested. When the infestation levels of SWA reached about 70 per cent, 50 numbers of *D. aphidivora*, II and III instar larvae were released.

Trial 2 :

To standardize the number of *D. aphidivora* pupae to be released per shade net cage, a non-replicated trial was laid out by releasing 50, 100 and 200 predators of pupal stage into three different shade net cages erected over seven months old crop. The predators were released when the woolly aphid infestation reached 70 per cent.

In Trial 1 and Trail 2, the crop received 25 per cent more nitrogen and irrigation at two days interval to encourage the woolly aphid.

Trial 3 :

To standardize the irrigation interval for sugarcane crop under the shade net for fast multiplication of *D. aphidivora*, a trial was laid out by giving irrigation once in 2 days and once in a week inside the shade net cage where 7-month-old crop was maintained with 60 to 70 per cent SWA infestation after releasing 50 numbers of *D. aphidivora* of II and III instar larvae.

In all the three trials, *D. aphidivora* was harvested up to three months where the predator completed two generation inside the shade net cages. Finally, number of predator harvested in each shade net was summed.

Specifications of shade net cages :

The specifications that were maintained for shade net cages are as follows :

Cover :

UV stabilized HDPE woven green colour 50 per cent shade nettings were used. All the joints of the shade nets were stitched with nylon threads and at the bottom, the nets buried into the soil up to a depth half a foot and on one side, provision was made for the entrance.

Dimensions :

5 mt × 5 mt × 4 mt height.

Structure :

Arecanut poles were used as pillars with GI wires.

Cost for one shade net :

Cost of areca poles	=	600
Cost of green colour shade net per 150 sq mt	=	3,330
Labour charges }		
Cost of GI wires }	=	500
Total	=	4,400

RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under the following heads :

Biology of *D. aphidivora* :

Egg :

Eggs were laid singly or in group or in a single/multiple rows at the lower surface of SWA infested leaves. The eggs were oval, white coloured which turned yellowish at hatching, similar to as reported by Shekharappa (2003). Average incubation period was 5.2±0.90 days (Table 1), however, Tripathi (1992) reported average of 1.10 days, which slightly differed from the present study. The variations may be due to the temperature and other climatic factors.

Larva :

The average duration of first, second, third, fourth and fifth instar lasted for 2.95±0.90, 4.57±1.33, 8.30±1.11, 11.37±2.96 and 6.10±0.77 days, respectively and the total larval period lasted for 24.5 to 39.5 days (Table 1). The observations of Tripathi (1992) on some aspects of larval morphology, duration and body size are in line with the present findings. However, the larval periods reported by Tirpathi (1992) and Mote and Puri (2003) were lower than the present findings, which may be due to change in climatic factors and host plant relationship.

Pupa :

The pupa was obtect type, dark reddish brown colored dorsally and light reddish ventrally, and tip of abdomen had short curved hairs. Sexual dimorphism was observed in the pupal stage. The female pupa was slightly bigger and stouter than male pupa with an inverted arrow mark inside the circle between 8th and 9th abdominal segments. In male pupa a triangular black mark was seen on 8th abdominal segment. Similar to the report of Shekharappa (2003), the average pupal period ranged from 7 to 10.5 days (Table 1), but was slightly higher compared to the pupal period (5.6 to 9.8 days) reported by Tripathi (1992), which may be attributed to the variations in climatic factors and crop variety.

Adult :

The adult moths were medium sized dull to brown coloured with setaceous antenna (present between brown eyes). The male moth was smaller and less darker than female moth. Similar to Tripathi (1992), mean longevity of adult female and male was 4.5±0.50 days and 1.5±0.30 days, respectively (Table 1). Similar to the observation of Shekrappa (2003), the fecundity varied from 88 to 116 eggs per female (Table 1).

The total life cycle :

The observations on total life cycle of *D. aphidivora* (47.32+10.07 days) (Table 1) in the present study are in agreement with the findings of (Shekhrappa, 2003). However, it was slightly higher than that observed by Mote and Puri (2003), which may be due to change in climatic factors and variety of the host plant.

Feeding potential of *D. aphidivora* :

The feeding potential of *D.aphidivora* in each instar varied with a mean of 31.45±4.97, 128.35±14.46, 293.70±1212, 493.70±15.40, and 425.45±10.09 aphids in I, II, III, IV and V instar, respectively (Table 2). The per day feeding potential varied with a mean of 10.66, 28.08, 35.38, 42.42 and 69.74 aphids in I, II, III, IV and V instar larvae, respectively. The percentage feeding potential of 2, 9, 21, 36, and 30 in I, II, III, IV and V instar larvae, respectively was observed. Average total feeding potential of *D. aphidivora* was 1372.65±54.85 aphids (Table 2). The daily consumption rate of 30.8 aphids per day in the present study are in agreement with the findings of Patil *et al.* (2003) and Mulimani *et al*. (2004). However, the total feeding potential of *D. aphidivora* (1372.65 aphids) in this study is slightly higher than the observations (1000 aphids) of Mulimani *et al*. (2004), which may be due to favourable climatic factors that prevailed in the study site.

Standardization of mass production techniques of *D. aphidivora* under shade net cages :

Trial 1 :

After erecting the shade net over an existing aphid infested crop with the pest intensity rating of 4 (60 – 80 % of leaf area covered by SWA) on 5, 6, 7 and 8 month old crop, the number of *D. aphidivora* harvested was 1572, 2438, 3940 and 2140, respectively per shade net. This revealed that *D. aphidivora* or aphid multiplied faster on 7-month-old crop than 5, 6 and 8 month old crop, when the average temperature was 28ºC and relative humidity was 78 per cent (Table 3).

Table 1 : Biology of *D. aphidivora* **(n=10)**

Sr. No.	Stage of the insect	Range(days)	Mean ± Sd (days)
1.	Egg	5.0-7.0	5.20+ 0.90
2.	I instar larvae	2.5-3.5	2.95+ 0.90
3.	II instar larvae	3.5-6.5	4.57+ 1.33
4.	III instar larvae	6.5 -9.5	8.30+ 1.11
5.	IV instar larvae	6.5 -13.5	11.37+ 2.96
6.	V instar larvae	5.5 - 6.5	6.10+ 0.77
7.	Total larval period	24.5 -39.5	
8.	Pupa	7-10.5	8.50+2.15
9.	Adult longevity of male moth	1.0-1.8	1.5+ 0.30
	Adult longevity of female moth	3-5	4.5+ 0.50
10.	Total	36.5-57	47.31+10.07
11.	Fecundity	88-116	105.2+12.2

Table 2 : Feeding potential of *D. aphidivora* **(n=10)**

Instars	Mean feeding rate (no. of aphids)	Feeding range (no. of aphids)	Daily feeding rate (no. of aphids)	Per cent of total aphids fed
I Instar	31.45 + 4.97	22-43	10.66	2
II Instar	128.35 + 14.46	103-160	28.08	9
III Instar	293.70 +1 2.12	210-465	35.38	21
IV Instar	493.70 + 15.40	341-980	42.42	36
V Instar	425.45 +10.09	312-812	69.74	30
Total	1372.65 + 54.85	988-2460		

Table 3 : Yield of predator, *D. aphidivora* as influenced by stage of the sugarcane crop

Non-replicated sugarcane crop	No. of predators harvested after three months per shade net cage
5 month	1572
6 month	2438
7 month	3940
8 month	2140

Trial 2 :

At the rate of 50 number of *D. aphidivora* pupae release, highest populations of 4230 per shade net *D. aphidivora* were harvested. The lowest population of 2740 and 931 was harvested when 100 and 200 pupae of *D. aphidivora*, respectively were released (Table 4). The variation in *D. aphidivora* population may be due to the infestation of SWA inside the shade nets. As the *D. aphidivora* is host dependent, second generation could not complete because of non-availability of the host or low infestation of SWA. So, less number of *D. aphidivora* pupae released corresponded with more number of *D. aphidivora* harvested.

Table 4 : Yield of predator, *D. aphidivora* as influenced by introduction of different numbers of *D. aphidivora* pupae per shade net cage

No. of *D. aphidivora* pupae released per shade net cage	Total no. of *D. aphidivora* harvested after two months per shade net cage
50	4230
100	2740
200	931

Trial 3 :

Highest population of *D. aphidivora* was harvested when the shade nets were irrigated once in two days with the population of 4123 *D. aphidivora* per shade net than irrigated once in week with the population of 1490 *D. aphidivora* per shade net. This revealed that frequent irrigation made the crop more suitable for aphid multiplication, which in turn is helpful for *D. aphidivora* to develop, as it is host dependent. However, this practice may accelerate growth and elongation of cane. When irrigation is given once in a week, the aphid multiplication will be slower. If the multiplication of SWA is slower, then *D. aphidivora* also multiplies slowly. The average temperature of 28^{0}C and average relative humidity of 76 per cent that prevailed under the shade net cages revealed that the *D. aphidivora* multiplied faster under the shade nets than in open condition in all the trials (Table 5).

Table 5 : Influence of irrigation intervals on build up of *D. aphidivora* populations

Irrigation levels	No. of *D. aphidivora* harvested after two months per shade net cage
Once in two weeks	4123
Once in a week	1490

It was reported that after erecting shade net over an existing SWA infested 7 months old crop yielded more out put than younger crop and 2,700 larvae or pupae can be obtained from 50 per cent shade net of 5 m×5 m within two months of establishment, which was little lower when compared with the present findings (Anonymous, 2005). This appears to be the first observation in respect of standardizing the mass production technique based on the irrigation levels.

To assess the impact of *D. aphidivora* on population dynamics of SWA :

The results on impact of *D. aphidivora* in suppression of SWA incidence revealed that highest SWA population (125.25) was noticed in treatment with heavy infestation of SWA without *D. aphidivora* which was followed by the treatments with heavy infestation of SWA with *D. aphidivora* with the population of 14.75 aphids per 2.5cm^2 leaf area and heavy infestation of SWA without *D. aphidivora* and where inoculative release of *D. aphidivora* was done, with the population of 11.96 aphids per 2.5cm^2 leaf area. The least population of 2.66 aphids per 2.5cm^2 leaf area was noticed in treatment with initial infestation of SWA without *D. aphidivora* and where inoculative release of *D. aphidivora* was done followed by the treatment with initial infestation of SWA with *D. aphidivora* with aphid population of 3.80 per 2.5cm^2 leaf area (Table 6).

The variation in the pest population in different treatments was mainly due to predatory activity of *D. aphidivora.*

The results (Table 6) on impact of *D. aphidivora* in suppression of SWA incidence revealed that in treatment with initial infestation of SWA with *D. aphidivora*, the population of SWA during I fortnight was 7.10 per 2.5cm^2 leaf area and it was reduced to 3.66 and 2.40 per 2.5 cm^2 leaf area during II and II fortnights. The population was nil during IV fortnight. The reduction in pest population was due to the activity of *D. aphidivora*. The population again increased during V fortnight with 6.10 aphids per 2.5cm^2 due to the insufficient numbers of *D. aphidivora* in suppression of SWA. This reveals that though the predator was active during early stages of infestation the natural population was not sufficient to suppress the aphids effectively.

In treatment with heavy infestation of SWA with *D. aphidivora*, population of SWA during I fortnight was 75.06 aphids per 2.5cm^2 leaf area. The population reduced during II, III, IV and IV fortnight with 50.26, 20.20, 6.66, 2.20 and 00.69 aphids per 2.5cm^2 leaf area, respectively. The reduction in pest population was due to the activity of *D. aphidivora*. Though the predator was active in suppressing the SWA

Table 6 : Impact of *D. aphidivora* on population of SWA at fortnightly intervals

Treatments	Population of SWA per 2.5cm2 at FN intervals								
	1st	2nd	3rd	4th	5th	6th	7th	8th	Pooled data
T_1	7.1ºCd (2.72)	3.66d (1.99)	2.40 d (1.63)	00.00e (0.70)	6.10 cd (2.84)	5.20 cd (2.17)	4.15 cd (2.03)	1.80 d (1.32)	3.80 d (1.94)
T_2	75.06ab (8.66)	50.26b (7.08)	20.20bc (4.49	6.66 cd (2.50)	2.20 d (1.48)	00.69 de (0.48)	00.00 e (0.70)	00.00 e (0.70)	14.75 b (3.84)
T_3	9.99 e (3.13)	6.32 cd (2.51)	4.10 cd (2.12)	0.54de (0.99)	00.00 e (0.70)	00.00 e (0.70)	00.00 e (0.70)	00.00 e (0.70)	2.66 e (1.63)
T_4	67.40ab (8.50)	21.32bc (1.311)	5.66 cd (2.37)	1.22 d (1.10)	00.10 de (0.31	00.00 e (0.70	00.00 e (0.70)	00.00 e (0.70)	11.96 c (3.45)
T_5	64.90ab (8.20)	81.4 a (9.03)	113.08a (10.63)	118.80a (10.8)	123.82a (11.12)	137.50a (12.19)	164.83a (12.80)	196.22 a (14.00)	125.25 a (11.19)
S.E. ±	0.27	0.84	0.23	0.16	0.22	0.21	0.24	0.20	0.29
C.D. (P=0.05)	0.78	0.29	0.67	0.46	0.64	0.61	0.71	0.59	0.64
CV (%)	16.44	15.75	13.53	10.93	15.28	14.08	14.91	12.16	14.13

Figures in parentheses are square root transformed values. Mean showing similar alphabets are on par with each other
FN=Fort night
Treatment 1: Initial infestation of SWA with *D. aphidivora.*
Treatment 2: Heavy infestation of SWA with *D. aphidivora.,*
Treatment 3: Initial infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora.,*
Treatment 4: Heavy infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*
Treatment 5: Heavy infestation of SWA without *D. aphidivora.*

population but it took time to suppress the populations under natural conditions (Table 6).

In treatment with initial infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*, the population of SWA before the release of the predator was 9.99 aphids per 2.5 cm^2 leaf area during I fortnight. The population reduced during II, III and IV fortnights with 6.32, 4.10 and 0.54 aphids per 2.5 cm^2 leaf area, respectively. The population was reduced due to the predatory activity of *D. aphidivora*. The population was nil from V fortnight up to VIII fortnights due to activity of *D. aphidivora.* This revealed that artificial release of predator during early stages in newly infested sugarcane fields is required for quick and effective suppression of the pest (Table 6).

In treatment with heavy infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*, the population of SWA before release of the predator was 67.40 aphids per 2.5 cm^2 leaf area during I fortnight. The population was reduced to 21.32, 5.66, 1.22 and 00.10 aphids per 2.5 cm^2 leaf area during II, III, IV and V fortnights. The pest population was reduced due to the activity of *Dipha*. This revealed that artificial releasing of *Dipha* in more number to newly heavy infested sugarcane fields will effectively suppress the pest.

In treatment with heavy infestation of SWA without *D. aphidivora*, the population of SWA during I fortnight was 64.90 aphids per 2.5cm^2 leaf area. The population increased from II fortnight onwards up to VIII fortnights. The absence of the predator encouraged the pest to multiply. This revealed that for suppression of SWA, *D. aphidivora* required to control the infestation (Table 6).

In treatment with initial infestation with *D. aphidivora*, there was reduction in pest population by 51.54 pre cent, in treatment with heavy infestation with *D. aphidivora*, the pest population was reduced by 66.95 per cent, in treatment with initial infestation without *D. aphidivora* and heavy infestation without *D. aphidivora* where inoculative release of *D. aphidivora* was done the pest population reduced by 63.26 and 31.63 per cent, respectively with in 15 days. It reached zero level during VI fortnight. This was due to the activity of *D. aphidivora* in initial stages. The infestation again appeared due to insufficient number of *D. aphidivora* in suppression of SWA under natural condition. Where as in treatment with heavy infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*, the per cent reduction in population SWA was more in each fortnight, due to the activity of *D. aphidivora*. This revealed that artificial release of predator was required to suppress the population of SWA in newly infested fields.

Similarly in treatment with heavy infestation of SWA with *D. aphidivora*, the per cent reduction in population, of SWA was more when compared to treatment with heavy

Table 7 : Activity of *D. aphidivora* population in suppression of SWA

Treatments	Population of Dipha/plant at FN intervals								
	1st	2nd	3rd	4th	5th	6th	7th	8th	Pooled data
T_1	2.2cd (1.40)	2.5 cd (1.58)	1.8 cd (1.30)	0.0e (0.70)	0.3de (0.76)	0.2 de (0.56)	0.3 de (0.76)	0.1 de (0.31)	0.88 d (0.93)
T_2	2.3 cd (1.51)	3.2c (1.78)	4.1b (2.02)	3.2 c (1.78)	1.8 cd (1.34)	0.4 de (0.85)	0.2 de (0.56)	0.0 e (0.70)	1.91 de (1.38)
T_3	0.0 e (0.70)	3.0 c (1.82)	3.0 b (1.87)	2.2 de (1.48)	1.26 cd (1.10)	0.0 e (0.70)	0.0 e (0.70)	0.0 e (0.70)	1.22 cd (1.10)
T_4	0.0 e (0.70)	6.0b (2.54)	4.0 b (2.0)	7.0a (3.02)	5.10 b (2.34)	7.5 a (2.86)	3.5 c (1.98)	0.8d (1.10)	4.23 b (2.26)
T_5	0.0 e (0.70)	0.0 e (0.70)	0.0 e (0.70)	0.0 e (0.70)	0.0 e (0.70)	0. 0 e (0.70)	0.0 e (0.70)	0.0 e (0.70)	0.00 e (0.70)
S.E. ±	0.02	0.02	0.06	0.04	0.06	0.03	0.04	0.04	0.10
C.D. (P=0.05)	0.06	0.07	0.18	0.11	0.17	0.10	0.14	0.11	0.30
CV	9.25	5.71	17.09	11.24	17.90	9.40	14.70	14.86	19.19

Figures in parentheses are square root transformed values. Mean showing similar alphabets are on par with each other
FN=Fortnight
Treatment 1: Initial infestation of SWA with *D. aphidivora*
Treatment 2: Heavy infestation of SWA with *D. aphidivora*
Treatment 3: Initial infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*
Treatment 4: Heavy infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*
Treatment 5: Heavy infestation of SWA without *D. aphidivora*.

Table 8 : Pest intensity rating of SWA per leaf area at fort night intervals due to activity of *D. aphidivora*

Treatments	Pest intensity rating at FN intervals								
	1st	2nd	3rd	4th	5th	6th	7th	8th	Pooled data
T_1	1.9 (1.48)	1.6 cde (1.38)	1.2 (1.18)	0.0 e (0.70)	1.6cde (1.38)	1.1 d (1.36)	0.5 d (0.81)	0.3 d (0.76)	1.05 cd (1.02)
T_2	4.6 ab (2.30)	4.1b (2.04)	3.01 (1.76)	1.4 cde (1.32)	1.0 d (1.22)	0.9d (1.00)	0.8 d (0.89)	0.3 (0.54)	1.97 bcd (1.40)
T_3	2.0bcd (1.58)	2.0 bcd (1.58)	2.0bcd (1.8)	0.8 d (2.34)	0.0 e (0.70)	0.0 e (0.70)	0.0 e (0.70)	0.0 e (0.70)	0.85 d (0.92)
T_4	4.1b (2.02)	3.2bc (1.75)	3.0 bc 1.63)	2.6c (1.58)	1.4 cde (1.34)	0.0 e (0.70)	0.0 e (0.70)	0.0 e (0.70)	1.17 cde (1.08)
T_5	2.8 c (2.09)	4.2 b (2.27)	4.8 a (2.30)	5.0a (2.34)	5.0 a (2.34)	5.0 a (2.34)	5.0 a (2.34)	5.0 a (2.34)	4.67 a (2.16)
S.E. ±	0.01	0.02	0.02	0.05	0.03	0.06	0.06	0.03	0.08
C.D. (P=0.05)	0.05	0.14	0.07	0.15	0.10	0.18	0.17	0.10	0.20
CV (%)	3.36	3.37	4.52	11.29	8.21	13.70	12.48	7.82	14.26

Figures in parentheses are square root transformed values. Mean showing similar alphabets are on par with each other
FN=Fortnight
Treatment 1: Initial infestation of SWA with *D. aphidivora*.
Treatment 2: Heavy infestation of SWA with *D. aphidivora*.
Treatment 3: Initial infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*.
Treatment 4: Heavy infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*
Treatment 5: Heavy infestation of SWA without *D. aphidivora*.

infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*. Though the per cent reduction was high in treatment with heavy infestation of SWA with *D. aphidivora*, the time taken for reduction was more when compared to treatment with heavy infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*, where the population was zero during VI fortnight itself. This revealed that under natural condition of heavy infestation of SWA with *D. aphidivora* the number of *D. aphidivora* was insufficient to suppress the pest population. Therefore, artificial release of *D. aphidivora* to newly heavy infested fields is necessary.

Whereas in treatment heavy infestation of SWA without *D. aphidivora*, there was increase in population from each fortnight. This was due absence of the activity of *D. aphidivora*. This revealed that to control the pest, the predator *D. aphidivora* to be released necessarily. The present findings are comparable with Anonymous (2005) in which it was reported that field studies in Maharastra and Karnataka revealed that *D. aphidivora*, if released during early stages of infestation could check the population (Bambawale *et al*., 2009).

Activity of *D. aphidivora* in predation of SWA

Similarly, the population of *D. aphidivora* in suppressing the population of SWA, was highest in treatment with heavy infestation of SWA without *D. aphidivora* and where inoculative release of *D. aphidivora* was done with the mean population of 4.23 *D. aphidivora* larvae per plant due to multiplication of *D. aphidivora*. Since the pest was present, the *D. aphidivora* population increased in this treatment, as *D. aphidivora* is host dependent. *D. aphidivora* population was decreased in treatment with initial infestation without *D. aphidivora* and inoculative release of *D. aphidivora* with mean population of 1.22 per plant and treatment with initial infestation of SWA with *D. aphidivora* under natural condition with mean population of 0.88 *D. aphidivora* per plant, because of predation of SWA in initial stages, there was reduction in pest population. Therefore, *D. aphidivora* population also decreased. This implies that the predator is host dependent. Therefore, the population of *D. aphidivora* decreased in treatment with initial infestation of SWA with *D. aphidivora* under natural condition and initial infestation without *D. aphidivora* and inoculative release of *D. aphidivora* followed. The population was nil in treatment with heavy infestation of SWA without *D. aphidivora* due to the absence of activity of *D. aphidivora* under natural condition (Table 7). Though the predator is active during early stages of infestation and can be seen in sufficient numbers compared to *D. aphidivora*, the natural population is not sufficient to suppress the aphid effectively. Artificial release of predator is newly infested sugarcane fields is required for effective suppression of the pest.

These findings are comparable with the reports of Sanveerappanavar *et al*. (2005) who reported that though the predator is active during early stages the natural population is not sufficient to control the pest and artificial release of *D. aphidivora* is required for effective suppression of SWA.

Pest intensity rating and the extent of infestation of SWA :

Similarly, high pest intensity rating of 4.67 was observed in treatment with heavy infestation of SWA without *D. aphidivora* due to absence of predator, *D. aphidivora*. In all other treatments with initial infestation of SWA with *D. aphidivora* under natural condition and initial infestation without *D. aphidivora* and inoculative release of *D. aphidivora* followed, the pest intensity rating was low with 1.05 and 0.85, respectively. The pest intensity rating has reduced in these treatments due to the activity of *D. aphidivora* in predating the population of SWA. Similarly, in treatment with heavy infestation of SWA with out *D. aphidivora* and inoculative release of *D. aphidivora* followed and heavy infestation of SWA with *D. aphidivora*, the pest intensity rating has reduced drastically due to predation of SWA by *D. aphidivora* as it is a potential predator of SWA with pest intensity rating of 1.17 and 1.97, respectively (Table 8).

Table 9 : Extent of infestation of SWA by suppression of *D. aphidivora*

Treatments	Extent of infestation of SWA at fortnightly intervals							
	1st	2nd	3rd	4th	5th	6th	7th	8th
T_1	Low	Low	Low	Nil	Low	Low	Low	Low
T_2	High	Moderate	Low	Low	Low	Low	Low	Low
T_3	Low	Low	Low	Nil	Nil	Nil	Nil	Nil
T_4	High	Moderate	Low	Low	Nil	Nil	Nil	Nil
T_5	High	High	Severe	Severe	Severe	Severe	Severe	Severe

Treatment 1: Initial infestation of SWA with *D. aphidivora*
Treatment 2: Heavy infestation of SWA with *D. aphidivora*
Treatment 3: Initial infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*
Treatment 4: Heavy infestation of SWA without *D. aphidivora* and inoculative release of *D. aphidivora*
Treatment 5: Heavy infestation of SWA without *D. aphidivora.*

The extent of infestation of SWA was low in the treatments, where *D. aphidivora* was present and was severe in treatment with heavy infestation of SWA without *D. aphidivora* under natural condition because of the absence of *D. aphidivora*, it was congenial for the pest to multiply. Whereas in treatments with heavy infestation of SWA with *D. aphidivora* and with heavy infestation of SWA without *D. aphidivora* and where inoculative release of *D. aphidivora* was done, the extent of infestation of SWA was low compared to treatment with heavy infestation of SWA without *D. aphidivora* due to predatory activity of *D. aphidivora*, on SWA (Table 9).

The present findings revealed that *D. aphidivora* has been active predator in bringing down the sugarcane woolly aphid (Horne *et al*., 2001).

Conclusion :

The average duration of first, second, third, fourth and fifth instar, pupal period, adult female and male moth lasted for 2.95±0.90, 4.57±1.33, 8.30±1.11, 11.37±2.96 and 6.10±0.77 days, 8.50±2.15 days, 4.5±0.50 days, 1.5±0.30 days, respectively and the total larval period lasted for 24.5 to 39.5 days. Average feeding potential and daily consumption rate by *D. aphidivora* was 1372.65±54.85 aphids and 30.8 aphids per day, respectively. *D. aphidivora* or aphid multiplied faster in shade net cages than open field on 7-month-old crop at pest intensity rating of 4. At the rate of 50 number of *D. aphidivora* pupae release and when the shade nets were irrigated once in two days, highest populations of *D. aphidivora* were harvested.

Studies made on impact of *D. aphidivora* on the population dynamics of SWA indicated that higher SWA population was noticed in treatment with heavy infestation of SWA without *D. aphidivora* under natural conditions with 125.25 aphids per 2.5 cm^2 leaf area followed by all other treatments where the population of SWA was less due to absence of predatory activity of *D. aphidivora*. Whereas least population of SWA was noticed in treatment with initial infestation of SWA without *Dipha* and inoculative release of *D. aphidivora* was done with mean of 2.66 aphids 2.5sqcm^2 leaf per area due to the predatory activity of *D. aphidivora*. The highest population of *D. aphidivora* per plant was seen in treatment with heavy infestation of SWA without *D. aphidivora* and where inoculative release of *D. aphidivora* was followed with mean of 4.23 *D. aphidivora* larvae per plant due to multiplication of *D. aphidivora* as the pest was present. The lowest population of *D. aphidivora* per plant in suppressing SWA was seen in the treatment with initial infestation without *D. aphidivora* and where inoculative release of *D. aphidivora* was done due to the absence of pest that was very essential for multiplication of predator, as it is host dependent. The population was nil in treatment with heavy infestation of SWA without *D. aphidivora*. The pest intensity rating was highest in treatment with heavy infestation of SWA without *D. aphidivora* under natural condition. The pest intensity rating was lowest in all other treatments where *D. aphidivora* was present, due to predation of SWA by *D. aphidivora*. The extent of infestation was very low in treatment with initial infestation without *D. aphidivora* and where inoculative release of *D. aphidivora* was done due to the activity of *D. aphidivora*. The extent of infestation was more in treatment with heavy infestation of SWA without *D. aphidivora*.

REFERENCES

Anonymous (2002). Sugarcane pests and their control. In: The Philippines recommendations for sugarcane. Sugarcane Research Foundation, Philippines, pp. 139-186.

Anonymous (2005a). Proc. workshop on sugarcane woolly aphid, *Ceratovacuna lanigera*, PDBC, Banglore, p. 31.

Anonymous (2005b). All India co-ordinated research project on biological control of crop pests and weed. Annual progress report, Project Directorate of Biological Control, Bangalore, pp. 1-296.

Bambawale, O.M., Tanwar, R.K. and Chander, S. (2009). IPM strategies and orientation towards changes in pest scenario due to climatic change. In: V.V. Ramamurthy, G.P. Gupta and S.N. Puri (eds) Proc. Natn. Symp. IPM strategies to combat emerging pests in the current scenario of climate change. Pasighat, Arunachal Pradesh, pp.14- 24. December, 2003, pp. 16-17.

Horne, P.A., Ridland, P.M. and New, T.R. (2001). *Micromus tasmaniae*: A key predator on aphids on field crops in Australia. In: *Lacewings in the Crop Environment.* Horne, P. A., Ridland, P. M. and New, T. R. 2001. (McEwen, P. K., New, T. R. and Whittington, A. E. eds.). Cambridge University Press, Cambridge, Pp. 388-394.

Kumarasinghe, N.C. and Basnayake, B.R.S.B. (2009). Influence of monsoonal weather on sudden establishment of the sugarcane woolly aphid in Sri Lanka. *Sugar Tech.*, **11**(3): 267-273.

Lingappa, S., Patil, R.K., Vidya, M. and Ramegowda, G.K. (2004). Brown lacewing, *Micromus igorotus* Banks – a potential predator of sugarcane woolly aphid. *Curr. Sci.*, **87**: 1056-1057.

Mote, U.N. and Puri, S.N. (2003). Present status of sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner, a new pest problem on sugarcane in Maharashtra. Paper presented at brain storming session on sugarcane woolly aphid, 10 June, 2003, AHMEDNAGAR, M.S. (INDIA). pp. 16-18.

Mulimani, V., Patil, R.K., Lingappa, S. and Malthesh, S.P. (2004b). Sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner and its predators. *Insect Environ.*, **10**: 116-117.

Patil, R.K., Ramegowda, G.K., Rachappa, V., Lingappa, S. and Tippannavar, P.S. (2003). Record of woolly aphid, *Ceratovacuna lanigera* Zehntner (Homoptera: Pemphigidae) on sugarcane in Northern Karnataka. *Insect Environ.*, **9**: 57-58.

Rabindra, R.J., Mohanraj, P., Poorani, J., Jalali, S.K., Joshi, S.S. and Ramani, S. (2002). *Ceratovacuna lanigera* Zehntner (Homoptera: Aphididae), a serious pest of sugarcane in Maharashtra and attempts at its management by biological means. *Indian J. App.Entomol*., **16**: 171-172.

Sannaveerappanavar, V.T., Rajanna, Pradeep, S., Swamy Gowda, S.N. and Keshavaiah, K.V. (2005). Management of sugarcane woolly aphid, *Ceratovacuna lanigera* in Karnataka. ORP on management of sugarcane woolly aphid *Ceratovacuna lanigera* Zehntner in Southern Karnataka. 9 pp.

Shekharappa (2003). Biological control of sugarcane woolly aphid with special reference to *Dipha aphidivora*. Paper presented in MOA, GOI sponsored state level collaborative training course on woolly aphid management in sugarcane organised by the University of Agricultural Sciences, Dharwad, KARNATAKA (INDIA).

Tripathi, G.M. (1992). Biology of *Conobathra aphidivora* Meyrick, a pyralid predator of sugarcane woolly aphid in Nagaland. *J. App. Zoological Res.*, **3**: 99-100.

Tripathi, G.M. (1995). Record of parasite and predator complex of sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner in Nagaland, *Indian Sugar*, **44**: 883-885.

WEBLIOGRAPHY

Anonymous (2004). FAO (Food and Agriculture Organization of the United Nations), statistical database (internet website: *www.fao.org*)