Pakistan J. Zool., vol. 45(6), pp. 1563-1572, 2013.

Phenology, Population Dynamics and Within Tree Distribution of *Dasineura amaramanjarae* Grover, 1965 (Diptera: Cecidomyiidae) in Punjab, Pakistan

Hafiz Mahmood ur Rehman,[1,2]* Riaz Mahmood[1] and Muhammad Razaq[2]
[1]*CABI Central and West Asia, Opposite 1-A, Data Gunj Bukhsh Road, Satellite Town, Rawalpindi, Pakistan.*
[2]*Department of Entomology, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan, Pakistan*

Abstract.- Gall midges are major pests in all of the mango areas of the world. They damage many parts of the plant including the bark, shoots, leaves, pre and post flowering shoot buds, inflorescence buds, axillaries, flowers, newly formed fruit and twigs. A complex of gall midges damages mango in Pakistan. *Dasineura amaramanjarae* Grover, 1965, one such midge pest that feeds on mango inflorescence, has been first time recorded here. In this study, we report its phenology, population dynamics and within tree distribution from Punjab Pakistan. The gall midge was active from February to April with a population peak in March. The flower buds were the only parts for oviposition and the larvae moved to soil for pupation after feeding inside the buds. No stage of the pest was observed from mango trees from May to January when flowers were not available. Studies on within tree distribution through trapping of the larvae with funnel rings indicated that *D. amaramanjarae* was not uniformly distributed vertically and horizontally in mango tree canopy. Highest numbers of *D. amaramanjarae* larvae were found at the height 1.5m from ground and southern side of tree canopy.

Key words: *Dasineura amaramanjarae* Grover, phenology, *Mangifera indica.*

INTRODUCTION

Mango, *Mangifera indica* L. is grown in lowland tropical and sub-tropical areas throughout the world. It is one of the foreign exchange earning crops that ranks second in the fruit industry of Pakistan (Asif *et al.,* 2011). The production of mango is undermined by more than 250 insect pests in the world (Peña and Mohyuddin, 1997; Pena *et al.*, 1998). Among these, about 20 species of gall midges are known worldwide associated with various parts of mango plant including bark, shoots, leaves, pre and post flowering shoot buds, inflorescence buds, axillaries, flowers, newly formed fruit and twigs (Srivastava, 1998).

Dasineura amaramanjarae Grover, 1965 is one of the midge pests of mango which feeds on flower buds. Female lays eggs near the stamens, larvae feed inside the flower buds and full grown larvae drop to the soil for pupation. In the case of severe infestation, the reduction in yield can reach 100% (Grover and Prasad, 1966; Prasad, 1966). In India, *D. amaramanjarae* has been reported as a pest in Saharanpur, Dehradun, Delhi, Aligarh, Allahabad and Varanasi. The adults emerge from the soil and immediately pair at the start of the flowering season. A single female lays 40-50 eggs which are hatched in 30-36 hours, depending upon the temperature and humidity. There are four larval instars and the second and third instars cause the most of the damage. Pupation and diapause take place in soil under mango tree (Prasad and Gorver, 1966).

Farmers apply insecticides and cultural practices for the control of *D. amaramanjarae*. Wetting the soil at the time of flowering under the mango tree delays the emergence of adults from the soil and slows down the build-up of the pest population, enabling the inflorescence buds to escape the damage of gall midges. Literature reports the effectiveness of insecticides in the past available at that time in India where it was reported as pest in 1980s. For example, the treatment of aldrin on the soil and spray of 0.02% phosphamidon + 0.03% diazinon, 0.25% demeton-S-methyl + 0.03% malathion, phosphamidon and demeton-S-methyl on

* Corresponding author:hafizmehmood83@gmail.com
hafizmehmood83@hotmail.com.uk
0030-9923/2013/0006-1563 $ 8.00/0

mango trees at the peak of population proved to be effective in controlling *D. amaramanjarae* (Grover, 1985).

Pesticide sprays which are the most common control measure used to suppress insect pests of mango have been reported to be toxic to some hymenopterans parasitoids (Saifullah *et al.*, 2007; Prabhaker *et al.*, 2007). Moreover, the intensive use of pesticides has led to problems such as insecticide resistance, loss of natural enemies, secondary pest outbreaks and environmental contamination (Zadocks, 1993; Dent, 1995). Estimating population abundance or density is necessary to understand the population dynamics of a species for making decisions in developing successful pest management programs (Krebs, 1978; Ekbom and Xu, 1990; Dent, 1997).

The problem of mango gall midges is recent in the Pakistan. Anecdotal reports of damage due to this pest were among the mango growers since last decade. However, it was not clear whether the damage was due to mango gall midges because of unawareness of identification of the pest. We initiated study and confirmed the presence of the complex of the gall midges in mango orchards. We identified, explored population trends and natural enemies of *Procontarinia matteiana* Kieffer and Cecconi, a gall midge forming galls on mango leaves from the complex of mango gall midges (Rehman *et al.,* 2013). In extension of the further research we report here identification, phenology/life cycle and within tree distribution of *D. amaramanjarae* from the gall midge complex. Nothing has been published about this pest species earlier than this study from Pakistan.

Integrated pest management (IPM) encompasses multiple control tactics to reduce pest status while minimizing economic and environmental costs. The model of IPM is organized into three steps i.e. avoidance tactics that delay or prevent the pest to achieve economic status, sampling and selective chemical application provide effective control (Naranjo, 2011). Outcome of the research will provide information about designing of cultural control practices (avoidance of the pest), the timing of the insecticide application and parts of the mango trees to be sprayed. In India, based upon the phenology of this pest the optimum time to apply the insecticides on mango trees at a peak of population and 13 days later effectively controlled *D. amaramanjarae* (Grover, 1985). Only due to the timing of insecticide application 50% chemicals can be reduced (Metcalf and Luckmann, 1994). Moreover, the data on spatiotemporal distribution of the pest will be the foundation for future research to develop forecasting system, evaluation of pesticide alternatives and selective chemicals for fine tuning of pest management strategies (Castle and Naranjo, 2009).

MATERIALS AND METHODS

Floral sampling of mango trees at different localities for presence of D. amaramanjarae

In order to determine the presence of *D. amaramanjarae*, surveys were conducted in mango orchards at different localities in Punjab; Tranda Sway Khan (District Rahim Yar Khan, three commercial orchards), Regional Agricultural Research Institute (District Bahawalpur, two commercial orchards), near Bahaudin Zakaria University at Bosan Road, (District Multan, three commercial orchards) and Thokar Niaz Beig (District Lahore, two small orchards) from 2008 to 2010. During February to April of each year, ten inflorescences were examined at least once a month from 10-12 mango trees in each orchard at all locations. The flower buds were opened with needle to determine the presence of larvae of *D. amaramanjarae.*

Biology and life cycle

During the first year of the research larvae of the gall midge complex were collected from different parts of mango tree like flowers and axillaries. However, we separately reared the larvae collected from above said parts in the laboratory developed by CABI-Central and West Asia at Rahim Yar Khan. The adults emerging from the pupae were preserved in 70-75% ethanol (Gagné, 1994). The larvae collected from the flowers were of the species of *D. amaramanjarae.* Their identification was confirmed from experts at Natural History Museum U. K. Voucher specimens were deposited at CABI – Central and West Asia, Rawalpindi.

Inflorescences were brought in plastic bags to laboratory to study the biology of *D. amaramanjarae*. Flowers were removed from the axillaries of inflorescences and placed in petri dishes lined with moist blotting papers. When the larvae reached to final instar they came out from the flowers, were collected with camel hair brush and transferred to small round jars (length 12.7cm and diameter 5cm) containing a thin layer of moist soil at bottom for pupation. Observations were made daily in the morning and evening for larvae reaching to pupal stage from the flowers and adults emerging from pupae in the jars (Temperature 20-25ºC and R.H. 60-75%). Duration for larvae in the flowers, pupae and adults was noted. The experiment was repeated every year in the flowering seasons 2008-10.

Phenology and population dynamics of D. amaramanjarae

Phenology and population dynamics of *D. amaramanjarae* were investigated in a mango orchard at Taranda Saway Khan, Rahim Yar Khan. For the collection of larvae of *D. amaramanjarae*, plastic sheet method previously employed was used with some modifications (Rehman, unpublished). Three mango trees of varity Fajri having a uniform flowering were selected and 12 plastic sheets (2x2m) were spread and fixed on ground under the canopies of these trees. Four sheets were spread under a mango tree and this individual tree considered a replicate. Mature larvae of *D. amaramanjarae* falling on plastic sheets were counted daily and pooled to weekly basis. The experiment was continued throughout the study period starting from January 2008 to April 2011, however damaged plastic sheets were changed when required.

D. amaramanjarae passes summer or undergo hibernation in soil under the mango trees in India (Prasad and Gorver, 1966). There was the possibility of presence or hibernation of the pest in soil, malformed inflorescence and other available plants in the orchards. To investigate hibernation place, soil samples (2kg) under the canopy of three mango trees were also taken in plastic bag to the laboratory and examined under microscope (60X) for the presence of its development stages in the soil each month from April 2009 to February 2010. Malformed inflorescences on mango tree and flowers of other trees in/surrounding areas of experimental orchard were observed once in a month during the same time period as for above part. To determine the emergence time and place of adult of *D. amaramanjarae*, the soil under a mango tree canopy was covered with a cloth cage (1x1x1m) from December 2009 February 2010 and a yellow sticky trap (15 X15cm) was put in the cage to collect the *D. amaramanjarae* adults emerging from soil after the completion of diapauses/hibernation. Numbers of adult were recorded once per week on the yellow sticky trap inside the cage.

In order to determine the association/ synchronization of appearance of inflorescence and its growth to the population development of *D. amaramanjarae*, the numbers of flowers present on inflorescence were counted and length of inflorescence (cm) was measured with scale at weekly intervals from February to April of 2010 and 2011. For this purpose, five mango trees were selected and measurements were taken from four inflorescences of each tree.

Vertical and horizontal distribution of D. amaramanjarae *on mango tree canopy*

To study the distribution of midges at different vertical and horizontal strata of the mango trees, funnel rings of 1 meter diameter with plastic jars fixed below were suspended on each side of the four strata/all four sides of the tree i.e. east, west, north and south (variety Chounsa) at 1.5, 3 and 6 meters above from ground. It was replicated on three trees. There were 12 traps total per tree. Number of larvae of *D. amaramanjarae* trapped in these funnel rings were counted weekly. This study was started at Rahim Yar khan from July 2009 and continued to June 2010.

Statistical analysis

A simple linear correlation was worked out between the mean weekly population of *D. amaramanjarae* and weekly mean, maximum and minimum temperatures, relative humidity and rainfall in January, February and March of 2008 to 2011 for Rahim Yar Khan location only. The significance of association of the weather factors

and numbers of pest was determined from absolute co-efficient of correlation (r-value) by the method of Gomez and Gomez (1984). The numbers of gall midges of four sides and three heights were converted to percentage for each side and height, respectively. Sides and heights where funnel rings were tied were considered as treatments. As there were four rings attached on each horizontal side (South, North, East and West) and three rings on vertical side (heights of 1.5, 3 and 6m) on each tree and there were total three trees for the experiment. Each tree was considered as a block. Analysis of variance (ANOVA) for RCBD was carried out to determine the significance of treatments. Differences among the numbers of *D. amaramanjarae* among the treatments were calculated by LSD test at 5% level of significance. All the statistical analysis was carried out with software Statistix 8.1.

RESULTS

Occurrence of D. amaramanjarae

D. amaramanajarae was first time recorded from Pakistan. It was found in all the areas surveyed in Punjab including Rahim Yar Khan, Bahawalpur Multan and Lahore. The specimens were identified by the experts from Natural History Museum (NHM) London, UK.

Life cycle of D. amaramanjarae

We examined 1249 flower buds with magnifying glass and found more than 76% of total flowers infested with creamy white larvae feeding inside the buds, at the base of stamen and carpel. Variable numbers of the larvae feeding per flower were observed ranging from 1 to11. However, we did not maintain the data of all the flowers examined pertaining to frequency of flowers containing the larvae between 1 and 11. They became pinkish red at final stage and pupated in the soil within 1-2 days and red colored adults emerged in 4-7 days which survived for 2-3 days (data not shown). Males were smaller than females in size.

Phenology and population dynamics of D. amaramanjarae

In the four years (2008-11) of this study, *D. amaramanjarae* was observed in the months of February, March and April. The active span was 63, 70, 63 and 35 days (Mean 57.75±7.76) in 2008, 2009, 2010 and 2011, respectively. The highest numbers of larvae were found in March (88%) followed by April (10%) and February (2%). During research period of all years, peaks of population of *D. amaramanjarae* were observed in March. Maximum numbers were recorded in second week of March during 2008-09 and in third and fourth week in 2010 and 2011, respectively.

Studies on population dynamics in 2008 indicated that the larvae of *D. amaramanjarae* were first observed on 3rd week of February (mean temp. 22.01°C and RH 53.42). Their numbers increased steadily and reached at peak in 3rd week of March (mean temp. 29.535°C and RH 60.33). After that, numbers of larvae decreased suddenly and reached at minimum level in the 3rd week of April. They were not found on mango trees from May 2008 and onwards. In next year (2009), small numbers of larvae started falling from flowers onto the ground in the 2nd week of February (mean temp. 18.87°C and RH 75.01). Highest numbers were recorded in 2nd week of March (mean temp. 25.57°C and RH 52.86%). They gradually decreased to zero in 4th week of April (mean temp. 33.86°C and RH 56.2). Damage was not observed after April 09 till the 3rd week of February 2010 when population of *D. amaramanjarae* again emerged (mean temp. 19.32°C and RH 72.85%) and reached at peak in 3rd week of March (mean temp. 30.31°C and RH 56.85) then reduced to zero in 4th week of April (mean temp. 32.48°C and RH 51.5). In 2011, a delay was observed in falling of larvae from flowers to ground due to frequent rainfall from 3rd week of February to 2nd March. Its emergence commenced during second week of March (mean temp. 27.28°C and RH 73.43). The peak period of pest was recorded in last week of March (mean temp. 28.5°C and RH 59.2). Thereafter, their numbers decreased gradually and were not observed after second week of April 11(Table I).

D. amaramanjarae was noted only when flowers were available and it was not found from May to January on mango tree even on remaining parts of malformed inflorescences present on mango trees (Figs. 1, 2). Its pupae were found in soil under

Table I.- Mean weekly populations of *D. amaramanjarae* and weather factors at Rahim Yar Khan in the months of February, March and April from 2008 to 2011.

Years/months		Population		Weather factors (Temperature °C)				
Years	**Months/Weeks**	**Mean larvae**	**SE**	**Max.**	**Min.**	**Mean**	**RH(%)**	**Rain (mm)**
2008	Feb $_{(1)}$	0.00	0.00	21.56	3	12.28	74.5	1.3
	Feb $_{(2)}$	0.00	0.00	26	8.68	17.34	62	0.00
	Feb $_{(3)}$	0.70	0.2	28.92	15.1	22.01	53.42	0.00
	Feb $_{(4)}$	1.90	0.6	30.66	16.75	23.705	58.3333	0.00
	Mar$_{(1)}$	20.3	2.9	33.57	16.57	25.07	57.42	0.00
	Mar$_{(2)}$	132.0	18.2	36.21	16.78	26.495	59.28	0.00
	Mar$_{(3)}$	237.0	24.0	37.91	21.16	29.535	60.33	0.00
	Mar$_{(4)}$	196.0	23.6	39.8	23.2	31.5	51.8	0.00
	Apr$_{(1)}$	42.7	6.2	34.64	20.71	27.675	54.28	6.9
	Apr$_{(2)}$	11.80	3.4	37.57	22.5	30.035	54.33	0.00
	Apr$_{(3)}$	3.8	1.1	41.37	28.5	34.935	52.85	0.00
	Apr$_{(4)}$	0.00	0.00	45.2	29	37.1	52	0.00
	Not found on mango from May 08 to January 09							
2009	Feb $_{(1)}$	0.00	0.00	26.5	8.75	17.625	80.5	0.00
	Feb $_{(2)}$	1.4	0.00	27.62	10.12	18.87	75.01	0.00
	Feb $_{(3)}$	11.9	1.1	29.5	14.89	22.195	65	0.00
	Feb $_{(4)}$	52.2	7.2	34.42	14.33	24.375	57.33	0.00
	Mar$_{(1)}$	533.3	25.8	32.71	12.29	22.5	57.43	0.00
	Mar$_{(2)}$	578.5	32.3	35.71	15.43	25.57	52.86	0.00
	Mar$_{(3)}$	400.7	25.8	31.25	16.83	24.04	53.5	0.00
	Mar$_{(4)}$	154.2	9.8	32	20.03	26.015	51.3	0.00
	Apr$_{(1)}$	30.7	1.4	35.21	20.64	27.925	54	0.00
	Apr$_{(2)}$	23.1	1.8	38.43	20.29	29.36	58	0.00
	Apr$_{(3)}$	1.6	0.4	39.62	21.75	30.685	56	0.00
	Apr$_{(4)}$	0.00	0.00	42.62	25.1	33.86	56.2	0.00
	Not found on mango from May 09 to January 10							
2010	Feb $_{(1)}$	0.00	0.00	27.07	9.21	18.14	82.28	0.00
	Feb $_{(2)}$	0.00	0.00	26	7.15	16.575	78.7	0.00
	Feb $_{(3)}$	1.5	0.2	28.78	9.85	19.32	72.85	0.00
	Feb $_{(4)}$	5.4	0.4	30.35	15.4	22.875	62.78	0.00
	Mar$_{(1)}$	16.4	5.2	30	18.64	24.32	63.14	0.00
	Mar$_{(2)}$	61.0	16.5	35.1	19.55	27.325	59.5	0.00
	Mar$_{(3)}$	459.3	25.8	38.85	21.78	30.315	56.85	0.00
	Mar$_{(4)}$	174.0	12.5	39.92	21.86	30.89	50	0.00
	Apr$_{(1)}$	46.3	1.6	39.07	21	30.035	54.28	0.00
	Apr$_{(2)}$	21.7	1.5	42.6	23.7	33.15	51.9	0.00
	Apr$_{(3)}$	1.3	0.2	44.28	24.71	34.495	52.28	0.00
	Apr$_{(4)}$	0.00	0.00	41.37	23.59	32.48	51.5	0.00
	Not found on mango from May 10 to January 11							
2011	Feb $_{(1)}$	0.00	0.00	26.64	10	18.32	79.25	0.00
	Feb $_{(2)}$	0.00	0.00	22.71	11.14	16.925	90	0.00
	Feb $_{(3)}$	0.00	0.00	26.43	11	18.715	86.86	14.5
	Feb $_{(4)}$	0.00	0.00	22.14	10.86	16.5	78.29	2.2
	Mar$_{(1)}$	0.00	0.00	29.64	14.36	22	76	0.5
	Mar$_{(2)}$	4.1	1.7	36.71	17.86	27.285	73.43	8.5
	Mar$_{(3)}$	80.3	8.6	36.29	18.71	27.5	68.86	0.00
	Mar$_{(4)}$	149.4	17.3	36.1	20.9	28.5	59.2	0.00
	Apr$_{(1)}$	94.7	15.4	31.43	20.21	25.82	58	0.00
	Apr$_{(2)}$	15.0	2.1	36.25	23.44	29.845	56.75	0.00
	Apr$_{(3)}$	0.00	0.00	41.64	27.29	34.465	53.14	3.00
	Apr$_{(4)}$	0.00	0.00	41.81	28.31	35.06	57.75	0.00

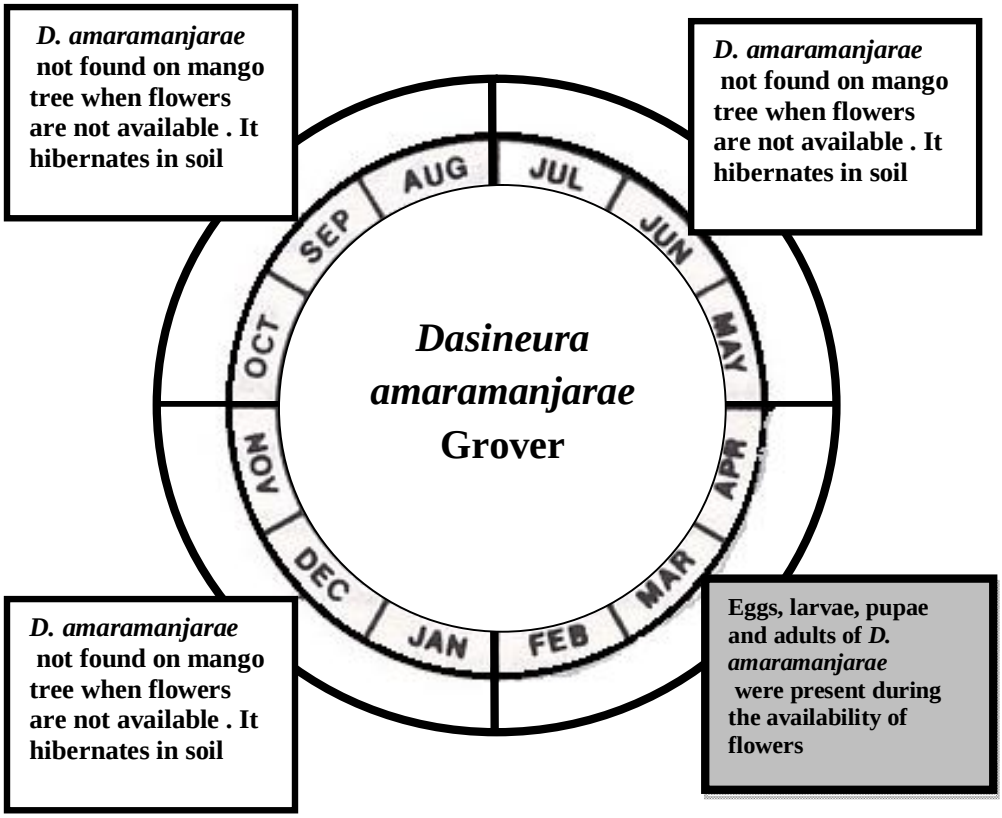

Fig. 1. Seasonal activity of *D. amaramanjarae* at Rahim Yar Khan

the mango tree canopy during this period. No adults were trapped on yellow sticky trap placed in cloth cage from December 2009 January 2010. They emerged from the soil and trapped on yellow sticky trap in February 2010.

A simple linear correlation between the mean weekly population of *D. amaramanjarae* and weekly mean, maximum and minimum temperatures, relative humidity and rainfall (Table I) in January, February and March of 2008 to 2011 for Rahim Yar Khan location revealed non significant association of the weather factors and numbers of larvae (Fig. 3).

Vertical and horizontal distribution of D. amaramanjarae *on mango tree canopy*

The larvae were collected in funnels from February to first fortnight of April and they were not found in the remainder of the year between April to January during 2009-10. Though they were found all over tree canopy and their numbers varied on different aspects of canopy. In 2009, vertical distribution of the pest on tree canopy was statistically significant ($F = 7.84$; $df = 2, 35$; $P < 0.00$). About 38.69% population of *D. amaramanjarae* was found at the height of 1.5m of tree canopy from ground level while 34.86 and 26.44% was recorded at 3 and 6m, respectively. Pair wise comparison of population at various heights with least significant difference test (LSD at $\alpha = 0.05$) indicated that the mean numbers of larvae at 1.5 and 3m were similar but higher than at 6 m.

Population of *D. amaramanjare* was not equally found ($F = 7.31$; $df = 3, 35$; $P < 0.00$) on the four horizontal sides (South, North, East and West) of tree. More numbers of larvae were found on the southern side (31.24%) followed by east, west and north sides with 23.42, 22.95 and 22.37 %, respectively. LSD test ($\alpha=0.05$) showed that they were significantly higher at the southern side as

compared to other three sides and there was no statistically significant difference among other three horizontal strata.

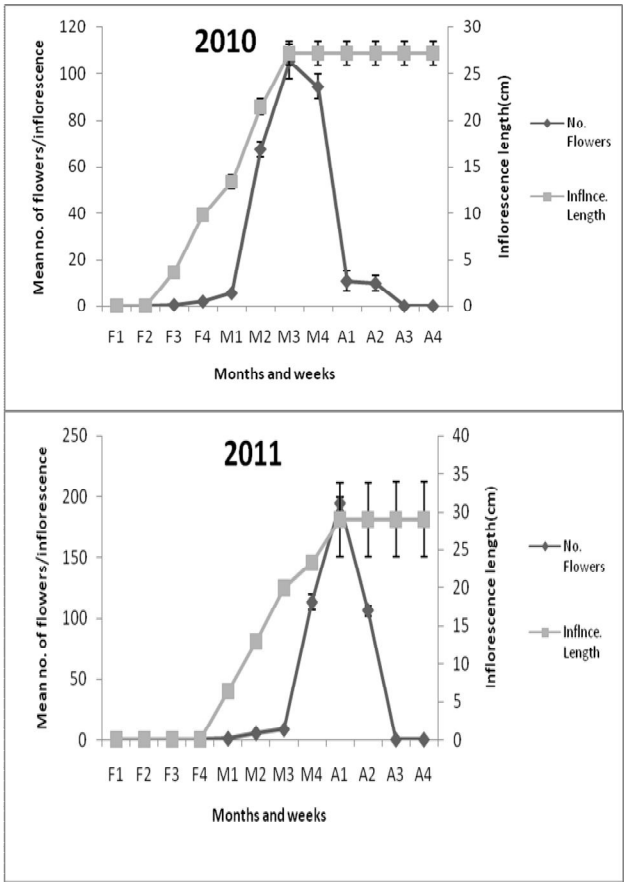

Fig. 2. Mean length (cm) and numbers of flower buds of an inflorescence at Rahim Yar Khan in 2010 and 2011.

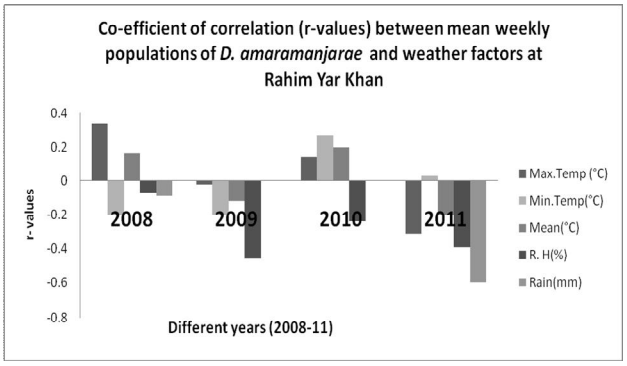

Fig. 3. Co-efficient of correlation between mean populations of *D. amaramanjarae* and weather factors at Rahim Yar Khan in 2008-11.

In 2010, analysis of variance of numbers of *D. amaramanjarae* larvae among the different vertical strata (1.5, 3 and 6m) of mango tree showed that its distribution was significantly different ($F = 8.11$; $df = 2, 35$; $P < 0.00$). Highest numbers of larvae were recorded in the funnels at 1.5m (44.41%) followed by 3m (41.93%) and 6m (13.65%). LSD (α=0.05) indicated no significant difference among the populations at 1.5 and 3m though slightly more larvae were caught at lower areas. However population at 6m was significantly lower than other two strata. Population differed considerably among the four horizontal strata of the tree ($F = 4.51$; $df = 3, 35$; $P < 0.01$). Funnel rings at the southern part of tree received higher numbers of the larvae (42.15%) as compared to east (20.47%), north (18.95%) and west (18.42%). The aggregation of the pest on southern side was statistically significant from other three strata. However, there was no substantial variation in among east, north and west sides (Fig. 4).

DISCUSSION

The adults of *D. amaramanjarae* emerged from the soil in February. Larvae fed inside the buds at the base of stamen and carpel. Numbers of the larvae feeding per flower ranged from 1 to11. They dropped on to the soil under the mango tree for pupation. *D. amaramanjarae* was noted from February to April when flowers were available and was not found from May to January on of mango trees. During inactive period (May to January) they were not recorded on malformed inflorescences on mango trees and flowers of other trees in/surrounding areas of experimental orchard. Their pupae were found in the soil under mango tree canopy. In India, larvae of *D. amaramanjarae* damaged mango trees by feeding on buds and flowers. Numbers of larvae observed were 3-4 in a flower which increased to 6-8 or even 10-12 in severe infestation. Although emergence of adults varied in different years yet was synchronized with flowering on mango (Prasad, 1966; Grover, 1986). Larvae of *D. amaramanjarae* hibernated in soil under mango trees (Prasad and Grover, 1966).

In present findings, *D. amaramanjarae* followed aggregated pattern of distribution.

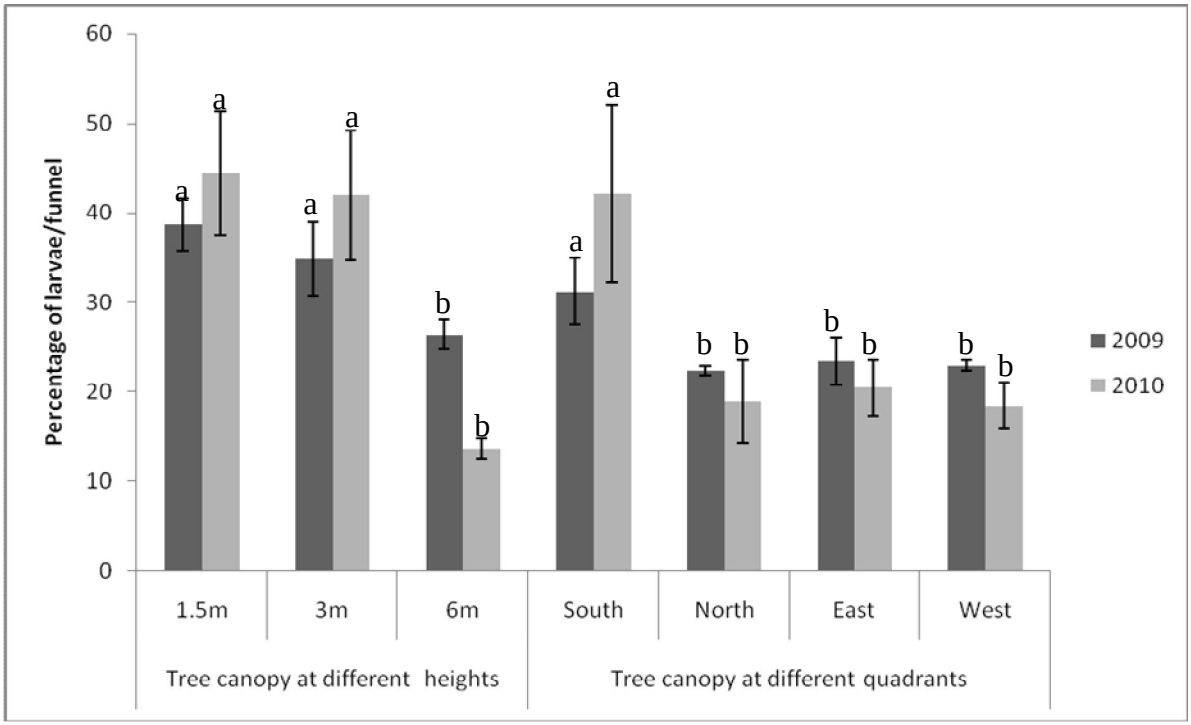

Fig. 4. Percent mean of larvae of *D. amaramanjare* collected in funnels hanged on mango trees at different vertical and horizontal strata at Rahim Yar Khan in 2009 and 2010. **Note:** Bars topped with different letters are significantly different for the same year (LSD Test, $\alpha = 0.05$).

Numbers of the larvae were significantly higher on the southern side of the trees than all other horizontal sides and significantly less at 6m height of tree canopy as compared to 3m and 1.5m. In India, a mango gall midge, *Procontarnia matteiana* followed an aggregated distribution (Verghese and Rao, 1988). Another mango gall midge species, *Erosomyia indica* (now *Procontarinia mangiferae*) showed a random pattern of distribution in a mango orchard. It was not aggregated on some of the horizontal and vertical sections of mango tree (Verghese *et al.*, 1988). This random pattern of distribution in *E. indica* may be due to seasonal variation in flushing and blooming of mango trees which changes the distribution of inflorescences, a feeding and ovipostion site for pests on a mango tree and might be the species preference. In a study at Faisalabad Pakistan, it was observed that April flushes were more important for blooming, while April based May, June and July flushes showed more vegetative growth with less blooming percentage. The bloomed panicles on April and April based May, June and July flushes were 31.50, 0.25, 27.99 and 10 %, respectively (Anwar *et al.*, 2006). Mature flushes with high starch contents would bloom readily (Chacko, 1984). The variations in growth patterns of flushes have an impact on blooming of mango tree which may induce the changes in distribution patterns of various mango gall midges species.

In conclusions, midge was found in all surveyed areas of Rahim Yar Khan, Bahawalpur and Multan. Females lay eggs on flower buds and larvae feed inside the buds and pupate in the soil in April. Phenology showed that activity of *D. amaramanjarae* mostly started in February and reached a peak in March. It was not found on mango trees from May to January. Present studies also revealed that the association between population of midge and weather parameters was not significant. Its distribution was not uniform on vertical and horizontal strata of mango tree. It was more abundant on 1.5m and on south side of mango tree.

This piece of research is an initiative in

understanding eco-biology of *D. amaramanjarae* for developing its eco-friendly management tactics in Pakistan. The pest causes damage to flower buds from February to April with a peak in March. Its attack is significantly higher on lower and southern sides of tree canopy, therefore, insecticides can be applied at or near peak on mango trees canopy. We recognize that there is lot to do on its biology for the development of comprehensive phenogram showing the occurrence and duration of all life stages of the pest. As the pest remains active for three months, there is need to determine the losses by applying insecticides at varying intervals. More over the economic threshold level should be determined to avoid economic and environmental costs due to over use of insecticides. Role of cultural practices like hoeing and irrigating the orchards and natural enemies also demands evaluation for reducing midge population. These components are essential for developing any IPM program as recognized since late 1950s (Metcalf and Luckmann, 1994).

ACKNOWLEDGEMENTS

This study was supported by Pakistan Agriculture Research Council under Agriculture Linkage Program, Pakistan. Thanks are due to Department of Agriculture (Extension), Rahim Yar Khan for providing us with the meteorological data.

We specially thank Dr M. Ashraf Poswal, Global Director, CABI Central and West Asia, Rawalpindi for his consistent support and encouragement during the course of studies. This paper forms a part of Ph. D. research work of the first author.

REFERENCES

ANWAR, R., ZAHOOR, H., SAEED, A. AND FAKHARUDDIN, R., 2006. Vegetative and Reproductive Physiology of April Flush in Mango (*Mangifera indica L.*) cv. Dusehri. *Int. J. Agric. Biol*., **8**:452-454.

ASIF, I., FAISAL, F. S., MUNAWAR, K. R., CHRYS, A.N., GUL BHAR, P. AND NAZIM, L. H., 2011. Trend of mango sudden death syndrome (MSDS) in relation to fungal microflora and nematodes fauna in Punjab, Pakistan. *Pak. J. Nematol*., **29** : 45-51.

CASTLE, S. AND NARANJO, S.E., 2009. Sampling plans, selective insecticides and sustainability: the case for IPM as 'informed pest management'. *Pest Manage. Sci*., **65**:1321-8.

CHACKO, E.K., 1984. Physiology of vegetative and reproductive growth in mango (*Mangifera indica* L.) tree. *Proc. 1St Australian Mango Research Workshop*. Qyueensland, pp. 54–70.

DENT, D., 1995. *Integrated pest management*. Chapman and Hall, Wallingford, pp. 356.

DENT, D., 1997. Quantifying insect populations: Estimates and parameters. In: *Methods in ecological and agricultural entomology* (eds. D. R. Dent and M.P. Walton), CAB International, New York, pp. 57-109.

EKBOM, B.S., XU RUMEI. 1990. Sampling and spatial patterns of whiteflies. In: *Whiteflies: their bionomics, pest status and management* (ed. D. Gerling), Intercept Ltd., UK, pp. 107-121.

GAGNÉ, R.J., 1994. *The gall midges of the neotropical region*. Cornell University Press, Ithaca, N Y.

GOMEZ, K. A., AND GOMEZ, A. A., 1984. *Statistical procedures for agricultural research*, 2nd Ed. John Wiley and Sons, NY. Call No. S540.S7 G65 1984

GROVER, P., 1985. Protection of mango crop against newly discovered midge pests. *Cecidol. Int.*, **6**: 35-40

GROVER, P., 1986. Population fluctuation of *Erosomyia indica* and *Dasineura amaramanjarae* and extent of damage. *Cecidol. Int.,* **7**: 1-57.

GROVER, P. AND PRASAD, S. N., 1966. Studies on Indian gall midges XVI. Four species of gall midges (Cecidomyiidae: Diptera) affecting inflorescence of mango. *Cecidol. Int.,* **1**: 1-19.

KREBS, C J., 1978. *Ecology: the experimental analysis of distribution and abundance*. Harper & Row, New York.

METCALF, R.L. AND LUCKMANN, W.H. 1994. *Introduction to insect pest management*, 3rd edn. John Wiley & Sons, New York, pp 1-34

NARANJO, S. E., 2011. Impacts of Bt transgenic cotton on integrated pest management. *J. Agric. Fd. Chem*., **59**: 5842–5851.

PEÑA J. E. AND MOHYUDDIN., A. I., 1997. Insect pests. In: *The Mango — botany, production and uses* (ed. R.E. Litz), CAB International, Oxfordshire, UK, pp. 327-362.

PENA, J.E., MOHYUDDIN, A. I. AND WYSOKI, M., 1998. A review of the pest management situation in mango agroecosystems. *Phytoparasitica,* **26**: 1-20

PRABHAKER, N., MORSE, J. G., CASTLE, S. J., NARANJO, S. E., HENNEBERRY, T.J. AND TOSCANO, N. C., 2007. Toxicity of seven foliar insecticides to four insect parasitoids attacking citrus and cotton pests. Entomological Society of America, Lanham, USA. *J. econ. Ent.*, **100** : 1053-1061.

PRASAD, S. N., 1966. The relation of mango blossom midge (*Dasineura amaramanjarae*) to the yield of mango. *Cecidol. Int.,* **3**: 171-184.

PRASAD, S. N.; GROVER, P., 1966. Gall-midges of economic importance IV. Biology of gall-midges (Cecidomyiidae: Diptera) affecting mango inflorescence. *Cecidol. Int.,* **1**: 51-66

REHMAN, H. M., R. MAHMOOD AND M. RAZAQ., 2013. Phenology, distribution, biology and population trends of *Procontarinia matteiana* Kieffer and Cecconi (Diptera: Cecidomyiidae) in Punjab, Pakistan. *Pakistan J. Zool.,* **45:** 941-947

SAIFULLAH , M., MUHAMMAD, S. AND. LODHI, T. E., 2007. Communication gap regarding plant protection, harvesting and post-harvest technologies among the mango growers. *Pak. J. agric. Sci.,* **44**: 654-59.

SRIVASTAVA, R. P., 1998. *Mango cultivation.* International Book Distributing, Charbagh, Lucknow, India. pp. 175–299.

VERGHESE, A., TANDON, P. L. AND RAO, P.G.S., 1988. Spatial distribution pattern and sampling plan for the blister midge, *Erosomyia indica* Grover (Cecidomyiidae: Diptera) in India. *Insect Sci. Appl.,* **9**: 515-518

VERGHESE, A., AND. RAO, S. P., 1988. Spatial distribution of the mango leaf gall, *Procontarinia matteiana* Kief. Gand Cocc. on mango cv. Dashehari. *Indian J. Horticul.,* **42**: 139-143.

ZADOCKS, J.E., 1993. Crop protection: why and how. In: *Crop protection and sustainable agriculture.* (eds. D.1. Chadwick and I. Marsh), John Wiley and Sons, Chichester, pp. 48-60.

(Received 27 May 2013, revised 16 September 2013)