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An insight into population dynamics of mango fruit borer, *Citripestis eutraphera* (Meyrick), in Gujarat, India

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ABSTRACT: The investigation on population dynamics of mango fruit borer, *Citripestis eutraphera* (Meyrick) based on fecundity per fruit, total number of larvae per fruit and per cent infestation was carried out at Agriculture Experimental Station, Navsari Agricultural University (NAU), Paria, Dist. Valsad (Gujarat) during 2022. Results revealed that the most preferred sites for oviposition by *C. eutraphera* was found to be the upper portion (1/3rd) of the fruit (1.24 eggs) and along the periphery at junction of peduncle and fruit (1.19 eggs). Larval density per fruit varied significantly with fruit developmental stage and infestation pattern. The highest larval densities at the limestone (4.0 larvae fruit^{-1}) and marble (4.7 larvae fruit^{-1}) stages were recorded under single-fruit and adjacent two-fruit infestations, respectively. However, at the mature fruit stage, infestation of multiple adjacent fruits resulted in a significantly greater larval density (7.4 larvae fruit^{-1}). The highest infestation levels were observed during the 16th–18th SMWs in standing fruits, whereas infestations in dropped fruits from individual trees peaked during the 18th–22nd SMWs.

Keywords: Mango fruit borer, *C. eutraphera*, Population dynamics

INTRODUCTION

Mango, *Mangifera indica* L. (Family: Anacardiaceae), is a tropical and subtropical fruit known as "King of Fruits". The states of Andhra Pradesh, Uttar Pradesh, Karnataka, Bihar, Gujarat and Maharashtra are major mango producers of the country. In Gujarat, Valsad, Navsari, Gir Somnath, Kutch and Surat are the major mango producing districts. In mango, about 492 species of insects, 17 species of mites and 26 species of nematodes have been reported from all over the world (Tandon and Verghese, 1985). Of these, 188 species have been reported from India (Butani, 1978; Tandon and Verghese, 1985) but only few are major importance which include hoppers, thrips, mealy bugs, stem borer, fruit flies and stone weevil. Climate change is considered a major driver in the transformation of several minor pests into economically important pests, including scales, thrips, mites, leaf webbers, stem borers, and fruit borers (Anderson and Tran-Nguyen, 2012; Jayanthi *et al*., 2014). The mango fruit borer, *Citripestis eutraphera* (Meyrick) (Lepidoptera: Pyralidae), exemplifies this trend, having expanded its distribution from the Andaman Islands to mainland India in recent years. Mango fruit borer, *C. eutraphera* which was originally described from Java, is a significant borer of mango fruits in South and South-East Asia and some parts of Australia (Anderson and Tran-Nguyen, 2012).

One of the most recent examples of intra-national invasion of an insect pest from the Andaman and Nicobar Islands to mainland India is the mango fruit borer, *C. eutraphera* (Meyrick). The pest was believed to have remained confined to the Islands for nearly two decades until its occurrence was reported in South India by Jayanthi *et al.* (2014). It was recorded from Karnataka and Tamil Nadu, where it caused extensive damage to immature mango fruits. Later, in Gujarat, during 2018, the infestation of *C. eutraphera* was reported for the first time, where it caused significant damage (Bana *et al*., 2018). This species recently invaded and spread to mainland India and infested mango crop in Karnataka, Tamil Nadu, Kerala, Gujarat, parts of Maharashtra and Odisha (Krull, 2004; Krull and Basedow, 2006; Jayanthi *et al.,* 2014; Singh and Kaur, 2014; Hiremath *et al*., 2017; Sunitha *et al*., 2020) and recently in Punjab (Singh *et al*., 2021). Chaudhary and Chavan (2025) documented a fruit borer complex consisting of *C. eutraphera* and *Conogethes punctiferalis* in South Gujarat. *Citripestis eutraphera* was the dominant species, representing 95.66% and 94.82% of the fruit borer population at the respective locations, while *C. punctiferalis* accounted for only 4.34% and 5.18%. It

also infested seedlings and grafts of cashew, *Anacardium occidentale* in Kerala (Jacob *et al*., 2004; Hiremath *et al*., 2017; Kori Nagaraj *et al*., 2020; 2022). Mango-growing pockets in the South-Western parts of Gujarat, as well as parts of Kerala and Tamil Nadu will remain moderately to highly suitable for *C. eutraphera* distribution in 2050 and 2070 (Choudhary *et al*.,2019).

Insect population dynamics has played a prominent role in the development of basic ecology and in the understanding and management of serious pests over the landscape. The monitoring of the pest population and identification of the prevailing insects will need timely application, best methods and application rates relative to the economic threshold of each insect pest. A considerable research work has been carried out on bionomics, pest incidence, prediction level but its population dynamics based on ovipositional studies on different portions of fruits, larval population at different fruit development stages and crop phenology-based infestation have not been studied extensively. By considering this, the present studies on population dynamics of *C. eutraphera* based on fecundity per fruit, total number of larvae per fruit and per cent infestation were carried out at Valsad (Gujarat), India. The study thus helps mango grower to achieve with efficient, sustainable and environmentally sound management practices.

MATERIALS AND METHODS

The present investigation was conducted during 2022 at Agriculture Experimental Station, Navsari Agricultural University (NAU), Gujarat, India in mango orchard (4000 m^2) on *cv*. Kesar grown at 8m x 8m, spacing. All the recommended agronomical practices of NAU, Navsari were followed. The experimental area was kept free from insecticidal spray throughout the study period**.**

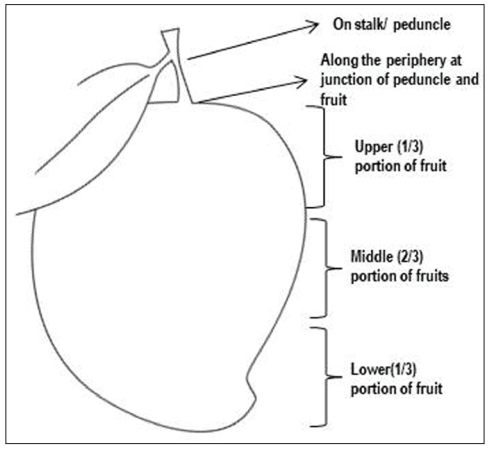

Fig. 1. Different portion of the fruit for ovipositional study

Population dynamics study based on fecundity per fruit by *C. eutraphera* was laid out in Randomized Block Design (RBD), to study the number of eggs laid on different portions of the fruit during each fruit development stage i.e. pea stage, marble stage, lime stone stage (stage when fruit attain hen's egg size) and full mature stage (Fig. 1). Five treatments *viz*., T_1 - Fecundity (eggs laid) on stalk/peduncle, T_2 - along the periphery at the junction of peduncle and fruit, T_3 - upper one third portions of the fruit, T_4 - middle two third portions of fruit and T_5 -lower one third portions of fruit (Fig. 1) were used with five replications (five fruits per replications). On each fruits fecundity on different portion of the fruit were counted with the help of 10X lens. Both, freshly laid eggs and hatched eggs were considered for recording fecundity. Un-hatched fresh eggs were red in colour whereas hatched eggs were characterized by white coloured marking after observed at the oviposition site on the fruit. White markings were also considered for counting the eggs laid by female of *C. eutraphera.*

Population dynamics study based on total number of larvae of *C. eutraphera* per fruit was laid out in RBD design in three different cases of infestation *viz*., single fruit infestation, adjacent couple of fruits infestation and adjacent cluster of fruits (> two fruits) infestation. Four treatments *viz*., T_1 - infestation at pea stage, T_2 - marble stage, T_3 – lime stone stage and T_4 - full mature stage were used with five replications (five infested fruits per replication). Each couple and each cluster of infestation were considered as single infestation. Infested fruits were observed on standing tree which were clearly visible from the ground and brought to the laboratory for dissection. In case of multiple fruit infestation (couple and cluster of fruits infestation) separate polythene bags were used to place all the infested couple or cluster of fruits separately. Total number of larvae per infestation (single fruit or couple of fruits or cluster of fruits) was also noted.

To study the population dynamics study based on infestation**,** paired t-test was used with ten replications (each replication with five trees). Two treatments were selected *viz*., T_1- infestation on standing tree and T_2 - infestation under tree in terms of dropped fruits due to damage by *C. eutraphera*. Observations were recorded at weekly interval as per Standard Meteorological Week (SMW) from pea stage to the harvest. For recording observations on standing tree, 25 fruits per tree clearly visible from the ground were observed and fruit borer

damaged fruits were noted. Based on which per cent infestation was worked out. For recording observation under tree in terms of dropped fruits due to damage by *C. eutraphera*, total number of dropped fruits under each tree were collected and counted. The total numbers of fruit borer infested fruits were separated. Based on this, per cent infestation was worked out. After taking observations, all the dropped fruits were destroyed. The data obtained (egg and larval population, per cent fruit infestation) from the present study were statistically analysed. Statistical analyses were performed using OPISTAT statistical software.

RESULTS AND DISCUSSION

The data presented in Fig. 2A–D on the population dynamics of *C. eutraphera*, based on oviposition preference at different fruit portions and developmental stages, revealed distinct egg-laying patterns. During the pea stage, the highest fecundity was recorded along the periphery at the junction of the peduncle and fruit (0.84 eggs fruit^{-1}), which was statistically at par with the upper one-third portion of the fruit. This was followed by the middle portion (0.32), fruit stalk (0.12), and lower one-third portion (0.04) (Fig. 2A). The number of eggs ranged from 0-0.4 on the fruit stalk, 0.6-1.2 at the peduncle–fruit junction, 0.4-1.2 on the upper portion, 0-0.6 on the middle portion, and 0–0.2 on the lower portion.

At the marble stage, significantly higher fecundity was observed on the upper portion of the fruit (1.32 eggs fruit^{-1}), which was statistically comparable with that at the peduncle–fruit junction (1.20 eggs fruit^{-1}), followed by the middle portion (0.44), fruit stalk (0.12), and lower portion (0.08) (Fig. 2B). Egg numbers ranged from 0-0.4, 0.6-1.8, 0.6-2.2, 0-0.8, and 0-0.4 on the fruit stalk, peduncle–fruit junction, upper, middle, and lower portions, respectively.

A similar trend was observed during the egg stage, wherein the upper portion of the fruit recorded the highest fecundity and remained statistically at par with the peduncle-fruit junction (1.48 eggs fruit^{-1}), followed by the middle portion (0.28), lower portion (0.12), and fruit stalk (0.08) (Fig. 2C). Egg numbers ranged from 0-0.2 on the fruit stalk, 0.8-2.0 at the peduncle–fruit junction, 1.2-2.0 on the upper portion, 0-0.6 on the middle portion, and 0-0.4 on the lower portion.

Likewise, at the mature fruit stage, significantly higher fecundity was recorded on the upper portion of the fruit (1.32 eggs fruit^{-1}), which was statistically comparable with that observed at the peduncle–fruit junction (1.24 eggs fruit^{-1}), indicating a consistent preference of *C. eutraphera* females for oviposition on the upper fruit surface and near the peduncle across fruit developmental stages (Fig. 2D).

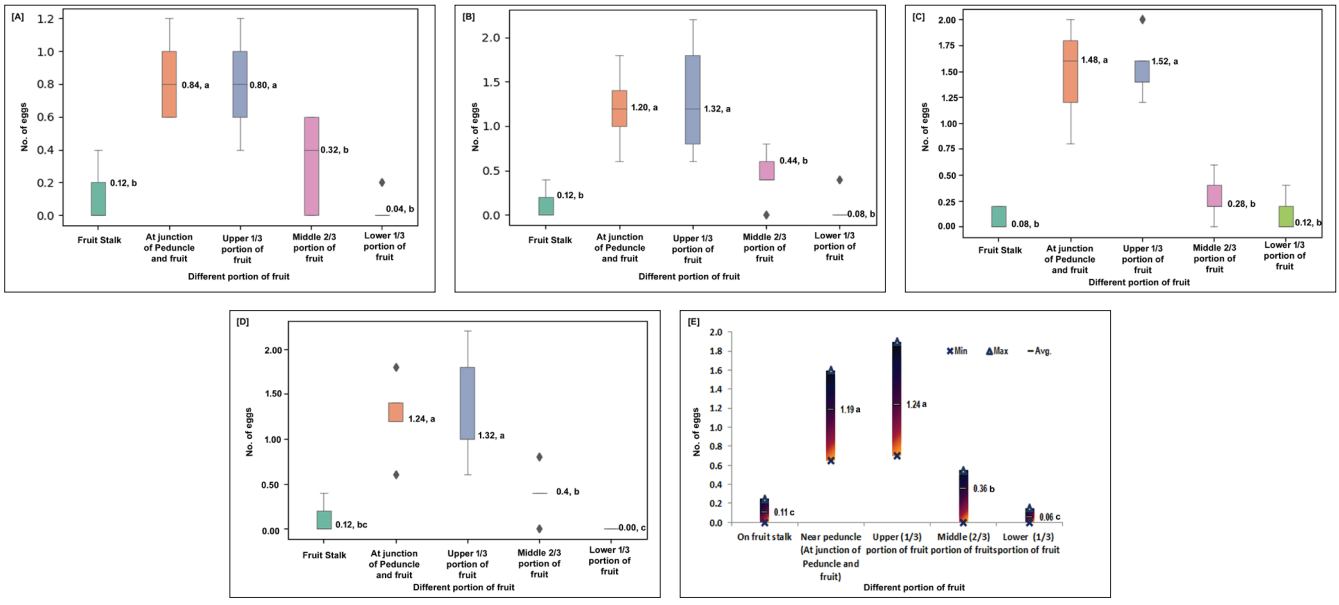

Fig. 2. Population dynamics of *C. eutraphera* based on mean number of eggs laid on different parts of fruit **[A]-** at pea stage, **[B]-** at marble stage, **[C]-** at lime stone stage, **[D]-** at mature stage, [**E**] Pooled of all stages. Values are mean of replicates +S.E. Bars followed by same letters are not significantly different at P= 0.01 Duncan's Multiple Range test. Stage (S) x Treatment (T) is non-significant.

Pooled results of all the stages depicted in Fig.3E showed that significantly highest fecundity was on upper portion (1.24) which statistically at par with eggs laid at junction of peduncle and fruit (1.19) followed by middle portion (0.36), on fruit stalk (0.11) and lower (1/3) portion of fruit (0.06). By considering the overall egg laying behaviour of female adults of *C. eutraphera*, it is evident that upper (1/3) portion of fruit and junction of peduncle and fruit are the most preferred sites for oviposition. The least preferred sites were lower (1/3) portion of the fruit and on the stalk or peduncle. Additionally, it was also observed that, concave portion of dried sepals which remain attached with fruit stalk is the most preferred site (Fig. 5d) by female adult of *C. eutraphera* (Fig. 5r) for egg laying on upper portion of fruit.

Several studies have focused on infestation level, damaging potential of *C. eutraphera*, but most of them have focussed on population dynamics in terms of ovipositional studies, so present results on this aspect were discussed based on other fruit borer species in different crops. According to Murugan and Thirumurugan (2001) and Karuppuchamy *et al*. (1998), some of chemical cues present in young fruits might have induce the lepidopterans to fecundity more. Patil (2022) revealed that leaves and flowers were rarely preferred site for oviposition by pomegranate fruit borer, *Deudorix isocrates* Fab. and mostly the fruits of varying stages were preferred to oviposit. These findings are in accordance with the present results. But, the calyx end of fruit is the highly preferred site of egg laying than other parts like lower half, stalk base, upper half and middle region of the fruit. The similar ovipositional behaviour of female *D. isocrates* has been reported earlier in pomegranate (Shevale and Khaire, 1999), however are not in line with the present results. This might be due to different fruit structure of pomegranate and mango fruits. Sajad Mohi-ud-din *et al.* (2018) studied the ovipositonal preference of females of Anar butterflies (*D. epijarbas*) under laboratory condition and revealed that adult female laid eggs on flowers, fruits and also on stalk and leaves within the vicinity of fruiting parts. Other plant parts *viz*., flower buds, fully opened flowers, leaves, stalk and fruit let stage were least preferred by *D. epijarbas* adults for oviposition. Recently, Chaudhary and Chavan (2025) studied biology and morphometrics of *C. eutraphera* and revealed that adult females laid an average of 41.15 ± 7.22 white coloured eggs on upper 1/3 portion of fruit *viz*., junction of peduncle and fruit which turned red after 1-2 days.

Population dynamics studies based on the number of larvae per fruit revealed that, during the pea stage, infestation ranged from one to three larvae per fruit, with an average of 1.7 larvae per fruit (Fig.3A). Thereafter, mean larval population were increased up to the lime stone size and further declined at mature stage. This may be due to hardening of mango seed kernel at mature stage as soft seed kernel is the preferred by the larvae. At marble stage 1 to 7 larvae per fruit were observed with an average of 3.2 larvae per fruit. Likewise, at lime stone stage 1 to 8 larvae (avg. 4.0) and at mature stage 1 o 7 larvae (avg. 2.8) were observed. Results also illustrated that significantly highest larvae per fruit (4.0) were observed at lime stone stage followed by marble stage (3.2) and mature stage (2.8) when single fruit was infested by *C. eutraphera* (Fig.3A).

The similar trend was noted when adjacent paired fruits were infested. The results depicted in Fig.3B revealed that at pea stage, 1 to 4 larvae per fruit (avg. 2.6) were observed. Thereafter, mean larval population was found to increase up to the mature stage. At marble stage, 1 to 6 larvae per fruit (avg. 3.6) was observed. Likewise, at lime stone and mature stage maximum 9 (avg. 4.7) and 6 (avg. 3.4) larvae per fruit were observed, respectively. Moreover, results also showed that significantly highest larvae per fruit (4.7) was observed at lime stone stage followed by marble stage (3.6) and mature stage (3.4) when adjacent paired fruits were infested by *C. eutraphera* (Fig.3B).

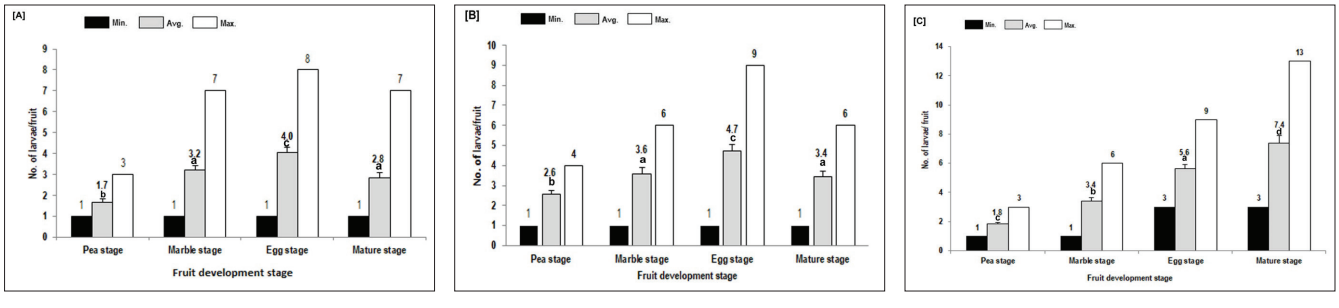

Fig. 3. Population dynamics of *C. eutraphera* based on **[A]** mean number of larvae per fruit when single fruit was infested **[B]** mean number of larva per fruit when adjacent couples of fruits were infested (each couple consider as single infestation) **[C]** mean number of larva per fruit when adjacent multiple fruits (more than two fruits wherein each cluster of multiple fruits considered as single infestation) were infested at different fruit development stages. Values are mean of replicates +S.E. Bars followed by same letters are not significantly different at P= 0.01 Duncan's Multiple Range test

At pea stage maximum 3 larvae per fruit (avg. 1.8) were observed when adjacent multiple (more than two) fruits were infested (Fig.3C). Thereafter, mean larval population was found increasing up to the mature stage. At marble stage, maximum 6 larvae per fruit (avg, 3.4) was observed. Likewise, at lime stone and mature stage maximum 9 (avg, 5.6) and 13 (avg. 7.4) larvae per fruit were observed, respectively. Significantly maximum larvae per fruit (7.4) were observed at mature stage followed by lime stone stage (5.6) and marble stage (3.4) when adjacent multiple fruits were infested by *C. eutraphera* (Fig. 3 C).

The present studies on population dynamics of *C. eutraphera* based on number of larvae per fruit is a new report. Thorough scanning of published literature revealed no published report on the population dynamics study of indigenous restricted fruit borer, *C. eutraphera* based on number of larvae per fruit at different fruit developmental stages.

Population dynamics of *C. eutraphera* based on per cent infestation:

The population dynamics of *C. eutraphera* based on per cent infested fruits on standing tree and dropped fruits under tree revealed that mango fruit borer infestation was found at all the growth and development stages of mango fruit during summer 2022 (Table 1). The infestation commenced from pea stage (11th SMW) and continued up to the harvesting (22nd SMW). In case of infestation on standing tree, the peak activity of *C. eutraphera* was observed during 16th to 18th SMW coincided with marble to lime stone stage, wherein damage percentage ranged between 10.72 and 12.16 per cent. Whereas, in case of infested dropped fruits under tree, maximum fruit drop due to infestation by *C. eutraphera* was observed during 18th to 22nd SMW which coincided with lime stone to mature stage and damage percentage ranged between 34.70 and 53.80 per cent. Significantly maximum fruit damage was observed in case of dropped fruits under tree as compared to damage on standing tree (Table 1) during all the observational period. The maximum fruit infestation of 12.16 per cent and 53.8 per cent was recorded during 17th and 19th SMW on standing tree and dropped fruits under tree, respectively.

The mango fruit borer, *C. eutraphera* has been recorded to cause infestation ranging from 2.46 to 64

Table 1: Population dynamics of *C. eutraphera* based on per cent infested fruits on standing tree and dropped fruits under tree

SMW	Development stage	Damaged fruits by *C. eutraphera* (%)		T - Statistic
		On standing tree	Dropped fruits under tree	
11	Pea	2.08	5.54	-4.537**
12	Pea	4.16	9.90	-4.537*
13	Pea	4.80	13.60	-5.788**
14	Marble	6.72	14.30	-10.488**
15	Marble	7.68	21.70	-8.839**
16	Marble	10.88	29.40	-4.129*
17	Lime stone	12.16	31.40	-4.253*
18	Lime stone	10.72	35.80	-7.211**
19	Lime stone	9.76	53.80	-7.506**
20	Mature	7.84	52.20	-4.938**
21	Mature	6.24	48.70	-17.41**
22	Mature	4.48	34.70	-8.022**
	Average	7.29	29.25	-4.991**

* Significant at 5 % level ** Significant at 1 % level, For individual week, 2.776 (T 0.05) and 4.604 (T 0.01), For average of 12 week, 2.201 (T 0.05), 3.106 (T 0.01)

per cent in Karnataka and Tamil Nadu (Jayanthi *et al.,* 2014; Soumya *et al.,* 2017). Bana *et al.* (2018) observed that *C. eutraphera* caused extensive damage of 5.00 to 45.00 per cent at farmer's field in South Gujarat during 16th to 25th SMW when fruits were at marble to maturity stages. The maximum infestation was observed in 18th SMW (19.04 & 14.42%) followed by 19th (18.46 & 12.88%) and 20th SMW (16.92 & 8.65%) during 2015 and 2016, respectively. The infestation range of 23.33 to 46.67 per cent caused by *C. eutraphera* was reported by Khan *et al.* (2020) in Bangladesh. Soumya *et al*. (2016) noted that there was no infestation of *C. eutraphera* at pea size fruits. The first infestation with low incidence commenced at marble size of fruit. At lime stage, infestation was increased. Thereafter at maturity stage, infestation decreased. Moreover, at full-grown stage and in harvested fruit, there was no infestation. Average 6.83 and 8.58 per cent infestation was observed during 2014 and 2015, respectively. Soumya *et al*. (2017) also reported incidence of *C. eutraphera* during flowering, wherein the infestation was mostly seen during April and May, when the fruits were at marble and lime size. Recently, Singh *et al*. (2021) reported that *C. eutraphera* is the emerging insect pest of mango in Punjab causing infestation level ranging from 2.50 to 10.80 per cent, starting from marble to maturity stage. They also showed the level of adaptation of this borer to varying climatic conditions. Hiremath *et al*. (2017) reported widespread infestation on mango fruits in the third week of September in Kerala. Though, the results of the present study are in agreement with most of the previous studies, while it is also not in agreement with few earlier reports, perhaps because of different fruiting season and climatic condition at various locations.

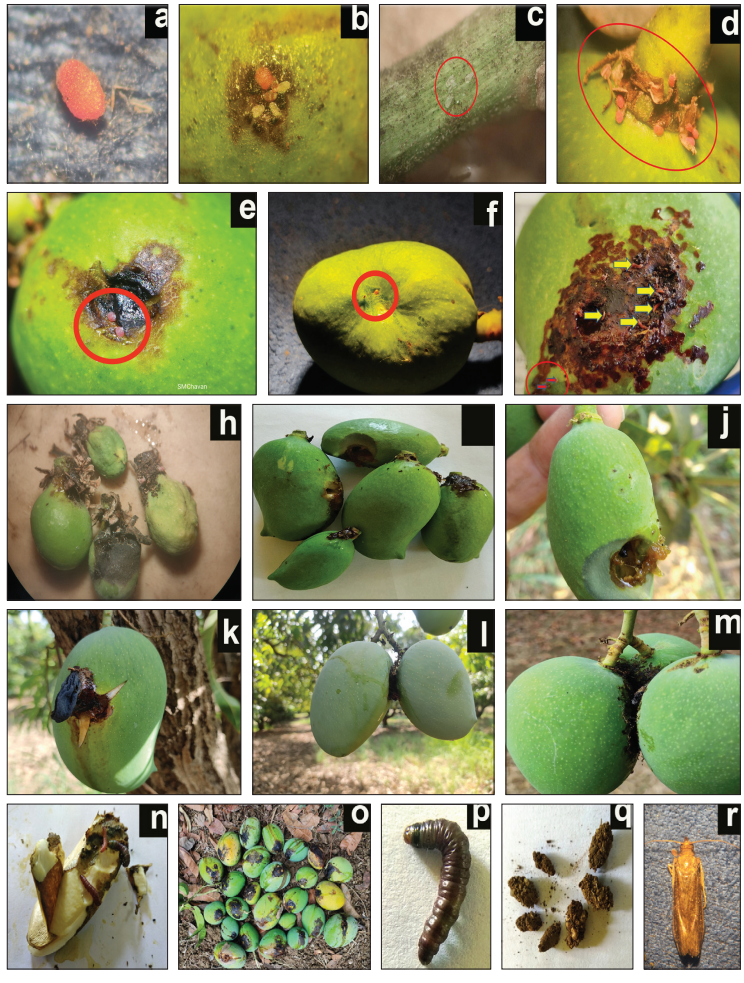

Fig. 4. Different life stages of *C. eutraphera* with Ovipositional and damage pattern a. Freshly laid egg (microscopic view), **b**. Eggs laid in groups on upper portion of fruits showing fresh (red) and hatched eggs (white), **c.** Eggs laid on stalk (hatched eggs-microscopic view), **d**. Eggs laid on upper portion of fruits (within dried sepals), **e.** Eggs laid on rough surfaces generated by larval damage on fruit skin, **f.** Eggs laid on middle portion of fruit, **g.** Eggs laid on lower surface of fruit, **h.** Damage at pea stage, **i.** Damage at marble stage, **j.** Damage at lime stone stage, **k.** Damage at mature stage with fruit cracking, **l.** Infestation at couple of fruit, **m.** Infestation at multiple (more than two) fruits, **n**. Damage on seed kernel, **o**. Damaged fruits dropped under tree, **p.** Mature larva, **q**. Earthen pupa, **r**. Adult in resting stage

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AUTHORS CONTRIBUTION

ANC- Designing and implementation of the experiments and MS preparation implementation of the experiments; SMC- planning, supervising and formal analysis and MS finalisation.

CONFLICT OF INTEREST

The authors do not have any conflict of interest with respect to the content of the article.

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