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Biology and biometrics of melon fly, *Bactrocera cucurbitae* Coquillett (Diptera: Tephritidae) on some cucurbitaceous crops

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Abstract
The studies pertaining to biology and biometrics of melon fly, *Bactrocera cucurbitae* were performed by rearing the insect on seven different cucurbitaceous crops (hosts) *viz*., ash gourd, bitter gourd, bottle gourd, cucumber, pumpkin, ridge gourd and snake gourd at mean temperature of 27.30 °C and relative humidity 86.39% in laboratory. The order of preference of hosts based on incubation period (hours) were: ash gourd (19.35) < bitter gourd (19.56) < snake gourd (19.91) < cucumber (19.99) < bottle gourd (20.08) < ridge gourd (20.63) < pumpkin (20.66). The order of hosts on the basis of fecundity (no. of eggs/female) were: bitter gourd (77.50) > snake gourd (63.90) > ash gourd (60.22) > ridge gourd (59.39) > cucumber (57.08) > pumpkin (48.55) > bottle gourd (48.06). Morphometric measurements of life stages of *B. cucurbitae* revealed that freshly laid eggs were glistening white, slightly curved, elongated and tapering at one end while rounded at the other end. The mean length and breadth of the eggs were 1.28 to 1.38 mm and 0.22 to 0.33 mm, respectively. The full grown larvae (maggots) were very mobile and measured 8.92 to 9.66 mm in length and 1.74 to 2.05 mm in breadth.

Keywords: Biometrics, incubation period, melon fly, morphometric, relative humidity

Introduction
The melon fly, *B. cucurbitae* Coquillett (Diptera: Tephritidae) is distributed widely in temperate, sub-tropical, and tropical regions of the world and India is considered as its native home (Dhillon *et al*. 2005a) [7]. It is a major pest of cucurbits in India and is uniformly widespread in the country. Its attack not only degrade the economic part of the plants but pose a serious threat to the horticulture industry as a whole. It has more than 81 host species but the family Cucurbitaceae is the most preferred (Allwood *et al*. 1999) [2]. The female fly puncture the skin of the fruit (mostly preferred) or flower and lay her eggs by inserting the pointed ovipositor. The maggots that hatch from the laid eggs remain inside the fruit and feed by boring into it. The damaged fruits are unmarketable for human consumption due to further attack by microorganisms which result in decaying. Due to its invasive nature and extensive damage to many fruits and vegetables especially cucurbits, melon fly is considered a federal quarantine pest (Mir *et al*. 2014) [15]. Their attack has been reported as the major limiting factor for profitable cucurbit production. Cucurbit crops are extensively grown in India including northeastern region and consist major portion of summer vegetables in the market.
The knowledge of the pest biology is a prerequisite for pest management methods compatible with Integrated Pest Management and organic pest management, which rather than eliminate insect pests aim to manage them. A successful management plan requires information about a species biology including its diet and life cycle. The present study was carried out to gain precise knowledge of the morphometrics of the various developmental stages, their durations, oviposition period, sex ratio, fecundity, adult longevity. The investigation was conducted under laboratory conditions.

Materials and Methods
A culture of *B. cucurbitae* was maintained in the laboratory, Department of Entomology, College of Agriculture, Central Agricultural University, Imphal during July to September, 2016. Adult fruit flies were placed inside rearing cages 30 x 25 x 30 cm. Food is supplied in the form of solution mixture which consists of protein hydrolysate, honey and water in the ratio 9:0.5:0.5. Cucumber slices were placed inside the cage for oviposition.

Eggs were collected from the cucumber slices and placed inside the petri dishes with moist filter paper. On hatching of the eggs, ten neonate larvae were released on slices of fruits of seven different cucurbitaceous host plants kept in petri plates over a moist filter paper. The experiment was conducted in a Completely Randomized Design (CRD) and replicated thrice. The maggots were transferred to fresh slices of different fruits after 3 days. The full grown larvae were transferred to sieved and sterilized sand in petri plates for pupation. The pupae were collected from the sand after four days and kept in glass vials individually. Observations were recorded on the larval duration, pupal duration, total developmental time, and sex-ratio. On the emergence of adults, one male and one female were released in a glass jar. A slice of fruits of seven different host plants were provided in the glass jar for egg laying from tenth day onwards after emergence of adults. The eggs laid on the fruit slices of different host plants were counted under stereo zoom binocular microscope. Observations were also recorded on size of eggs, oviposition period and adult longevity.

Results and Discussion

The incubation, larval, pupal periods and total developmental time of *B. cucurbitae* reared on different cucurbitaceous crops are presented in Table 1. The data presented indicate that incubation period of *B. cucurbitae* varied from 19.35 to 20.66 hours. The result from present study showed that the incubation period was shortest in ash gourd and longest in pumpkin. Higher incubation period was recorded in pumpkin than in bitter gourd by Laskar (2013) [14]. It varied from 1.50 to 2.00 (mean ± S.D.= 1.85 ± 0.22) days and 1.50 to 2.25 (mean ± S.D.=1.90 ± 0.29) days when reared on bitter gourd and pumpkin, respectively; Gupta and Verma (1995) [9] stated that incubation period varied between 1.1 to 1.8 days on bitter gourd, cucumber and sponge gourd. The observation regarding oviposition period according to Shivayya (2005) [21] is 26.00 hours during March to April in bitter gourd which is little bit more than 19.56 hours in the same host in this study. Variations can be attributed to the different seasons during which these two studies were carried out. The present findings are almost in agreement with the reports of above authors. The incubation period was higher in the findings of above authors, but the variation is not too high. The total larval period varied from 3.83 to 4.94 days when the insect was reared on different cucurbitaceous hosts. The shortest larval duration was found on ash gourd and longest was on pumpkin. Depending on temperature and host the larval period lasts for 3 to 21 days (Renjhan, 1949; Narayanan and Batra, 1960; Hollingsworth *et al*. 1997) [19, 16, 11]. On different cucurbit species, the larval period varies from 3 to 6 days (Chawla, 1966; Chelliah, 1970; Doharey, 1983; Koul and Bhagat, 1994; Gupta and Verma, 1995) [5, 6, 8, 12, 9]. The findings of the present study are in close agreement with results of the above authors. Little deviations may be attributed to the different environmental factors such as temperature, relative humidity and fruit hosts. The pupal period was shortest on cucumber and longest on ash gourd. Pupal period worked out during present investigation resembles closely with the findings of earlier workers Narayanan and Batra (1960) [16] who reported pupal period to vary between 6 to 9 days during the rainy season. Longer pupal period of 7.2 days on pumpkin and squash gourd and shorter pupal period of 7 days on bitter gourd at 27 ± 1° C was reported by Doharey (1983) [8]. The above result is in corroboration with the findings of the present study which also states longer pupal period in pumpkin than bitter gourd. According to Hollingsworth *et al*. (1997) [11], the pupal period may vary between 7 to 13 days depending on temperature and the host. On different hosts, the pupal period varies from 7.7 to 9.4 days on bitter gourd, cucumber and sponge gourd (Gupta and Verma, 1995) [9], and 6.5 to 21.8 days on bottle gourd (Koul and Bhagat, 1994; Khan *et al*. 1993) [12, 10]. The findings of the present investigation are in close conformity with the above authors. Total developmental time did not vary significantly among the hosts.

Table 1: Incubation, larval, pupal periods and total developmental time of *B. cucurbitae* reared on some cucurbitaceous crops

Host plant	Incubation period (hours)	Larval period (days)	Pupal period (days)	Total developmental time (egg to adult emergence in days)
Ash gourd	19.35^{a}	3.83^{a}	9.35^{d}	13.99
Bitter gourd	19.56^{a}	4.72^{bcd}	8.43^{ab}	13.96
Bottle gourd	20.08^{ab}	4.77^{cd}	8.70^{abc}	14.31
Cucumber	19.99^{ab}	4.11^{ab}	8.40^{a}	13.34
Pumpkin	20.66^{b}	4.94^{d}	8.56^{abc}	14.36
Ridge gourd	20.63^{b}	4.66^{bcd}	9.06^{cd}	14.58
Snake gourd	19.91^{ab}	4.27^{abc}	9.02^{bcd}	14.12
S.E(d)	0.41	0.30	0.28	0.57
CD(p=0.05)	0.88	0.64	0.60	N.S.

Data presented are mean of 3 replications (10 individual/ replication)
Means in columns followed by same letter(s) are not significantly different
Means are separated by LSD test

Oviposition period, fecundity, sex ratio and adult longevity of *B. cucurbitae* reared on some cucurbitaceous crops are presented in Table 2. Oviposition period of *B. cucurbitae* varied from 22.55 to 34.00 days when reared on different hosts. Shortest oviposition period was recorded in bottle gourd and longest in ash gourd. The oviposition period of melon fly reared on different hosts during the course of present investigations are mostly in agreement with the findings of Ullah *et al*. (2008) [24], who reported oviposition period in days as 35.33, 26.67, 35.00, 21.31 and 24.62 in squash, bottle gourd, sweet gourd, bitter gourd and snake gourd, respectively.

There was a significant (p=0.05) impact of different hosts on the fecundity of the females. Bottle gourd was at par with pumpkin but differed significantly with rest of the hosts. Cucumber was at par with pumpkin on one side and with ridge gourd, ash gourd and snake gourd on the other side of the order. During the research period, under laboratory condition, the fecundity of melon fly was found to be 48.06 to 77.50 i.e., (48 to 78) eggs per female. The present findings are

in close agreement with those of Lanjar *et al*. (2013) [12] who recorded it ranging from 50 to 91 eggs in musk melon and Indian squash, during entire life span. Mir *et al*. (2014) [15] who recorded it ranging from 58 to 92 eggs in cucumber and little variation in fecundity may be attributed to the environmental factors such as temperature, relative humidity, diet, etc.

The sex ratio did not vary significantly among the hosts. The sex ratio of *B. cucurbitae* which was found to be generally female oriented during the course of the investigation which is almost in agreement with the findings of Chelliah (1970) [6], Sisodiya (2007) [23], Prasad (2012) [17], who also reported that sex ratio is female biased. The difference in sex ratio may be due to the interplay of factors like seasonal fluctuation and type of availability of food material. The present investigation indicated adult survivability of male and female flies varied between 24.67 to 34.33 days and 37.33 to 54.22 days, respectively, when provided with adult diet of water: honey: protein hydrolysate in the ratio 9:0.5:0.5. The adults survived from 27.5, 30.71 and 30.66 days at 27 ± 1 °C on pumpkin, squash gourd and bitter gourd, respectively, as per Doharey (1983) [8]; Rahaman *et al*. (2015) [18] reported average longevity of the adult as 27.67 days when fly was reared on bitter gourd. The above reports are almost similar in case of male longevity but differs with the female longevity which is recorded slightly higher in the present study. Reports of Khan *et al*. (1993) [10] and Mir *et al*. (2014) [15] confirm the longer female longevity of 27.5 to 133.5 days, 30 to 42 days, which is almost in agreement with the findings of the present study.

Table 2: Oviposition period and fecundity of *B. cucurbitae* reared on some cucurbitaceous crops

Host plant	Oviposition period (days)	Fecundity female^{-1}	Sex-ratio (male:female)	Adult longevity	
				Male	Female
Ash gourd	34.00^{c}	60.22^{c}	1:1.63	34.33^{d}	49.66^{bc}
Bitter gourd	23.00^{a}	77.50^{d}	1:1.42	27.00^{ab}	40.00^{a}
Bottle gourd	22.55^{a}	48.06^{a}	1:1.05	24.67^{a}	37.33^{a}
Cucumber	24.66^{ab}	57.08^{bc}	1:1.60	29.22^{bc}	41.00^{a}
Pumpkin	24.00^{ab}	48.55^{ab}	1:1.06	29.00^{bc}	41.66^{ab}
Ridge gourd	26.11^{b}	59.39^{c}	1:1.19	31.00^{cd}	44.00^{ab}
Snake gourd	31.66^{c}	63.90^{c}	1:1.64	32.22^{cd}	54.22^{c}
S.E(d)	1.38	4.14	0.36	1.84	3.94
CD(p=0.05)	2.96	8.88	N.S.	3.94	8.45

Data presented are mean of 3 replications (10 individual/ replication)
Means in columns followed by same letter(s) are not significantly different
Means are separated by LSD test

Morphometric observations revealed that the length of egg varied from 1.28 to 1.38 mm, and the breadth varied from 0.22 to 0.33 mm when reared on different cucurbitaceous hosts. The freshly laid eggs of *B. cucurbitae* were glistening white, slightly curved, pointed in one end and rounded on other side. The eggs were laid singly or in clusters of 4 to 7. The findings of the present investigations are in close conformity with those of Laskar (2013) [14], Mir *et al*. (2014) [15], Bhowmik *et al*. (2014) [4], who reported average length and breadth of melon fly eggs varied from 1.22 to 1.36 mm (1.28 ± 0.059) and 0.18 to 0.32 mm (0.26 ± 0.057) in bitter gourd and 1.20 to 1.35 mm (1.26 ± 0.060) and 0.17 to 0.31 mm in pumpkin, 0.98 to 1.28 mm (1.13 ± 0.14) and 0.21 to 0.34 mm (0.28 ± 0.05) in cucumber, 0.75 to 1.5 mm (1.06 ± 0.25) and 0.1 to 0.3 (0.21 ± 0.08) in bottle gourd. Variation in size of eggs could be due to the interplay of different environmental factors and hosts in which the insect was reared.

Pupal size on different hosts also varied significantly and measured 5.38 to 6.03 mm in length and 2.36 to 2.66 mm in breadth (Table 3). Maximum pupal length was observed in snake gourd and minimum in bottle gourd. Breadth of pupa was found maximum in ash gourd and minimum when reared in bottle gourd. Pupal size of present findings are in close conformity with the reports of Barma and Jha (2011) [3], Mir *et al*. (2014) [15], Vigneswaran *et al*. (2015) [25], who reported pupal length and breadth of melon fly to vary between 5.25 to 5.88 mm and 2.09 to 2.59 mm, 5.46 to 5.91 mm and 2.32 to 2.68 mm, 4.86 to 5.83 mm and 1.90 to 2.20 mm in pointed gourd, cucumber and four different cultivars of pointed gourd, respectively.

Table 3: Morphometrics of eggs and pupae of *B. cucurbitae* reared on some cucurbitaceous crops

Host plant	Egg size (mm)		Pupal size (mm)	
	Length	Breadth	Length	Breadth
Ash gourd	1.38	0.33	5.95^{e}	2.57^{d}
Bitter gourd	1.37	0.28	5.66^{c}	2.49^{c}
Bottle gourd	1.28	0.29	5.38^{a}	2.36^{a}
Cucumber	1.37	0.27	5.57^{b}	2.43^{b}
Pumpkin	1.31	0.29	5.68^{cd}	2.41^{b}
Ridge gourd	1.31	0.22	5.75^{d}	2.53^{cd}
Snake gourd	1.35	0.27	6.03^{e}	2.66^{e}
S.E(d)	0.05	0.04	0.04	0.02
CD(p=0.05)	N.S.	N.S.	0.08	0.04

Data presented are mean of 3 replications (10 individual/ replication)
Means in columns followed by same letter(s) are not significantly different
Means are separated by LSD test
N.S.- Non significant

The first instar larvae were apodous, translucent and glistening white in colour. The length of first instar larva was minimum in snake gourd and maximum in ash gourd whereas ash gourd, bitter gourd, bottle gourd and cucumber recorded the shortest and ridge gourd the longest breadth measurement, respectively. Morphometric observations on size of first instar larva are in close conformity with the reports of Narayanan and Batra (1960) [16], Shivarkar and Dumbre (1985) [20], Rahaman *et al.* (2015) [18]. The observations are in corroboration with the result of Rahaman *et al.* (2015) [18], who measured the length and breadth of first instar larva as 1.48 mm and 0.26 mm, respectively, in bitter gourd. The size of second instar larva varied from 5.00 to 5.78 in length and 0.99 to 1.30 mm in breadth. The second instars were translucent, elongated with ellipsoidal shape and creamy white in colour. Similar findings have been reported by Mir *et al.* (2014) [15]. The length of second instar larvae were found to be shortest in bitter gourd and longest in snake gourd. The size of second instar found in this investigations are in close conformity with earlier reports of Narayanan and Batra (1960) [16], Sivarkar and Dumbre (1985) [20], Agarwal (1987) [1], Rahaman *et al.* (2015) [18]. Second instar size did not vary significantly among the hosts. Whereas, length and breadth of third instar varied from 8.92 to 9.66 mm and 1.74 to 2.05 mm, respectively. The colour of third instar larva was deep yellow and possessed a unique way of throwing itself by curving and springing to a short distance of few centimeters probably to find a pupation site *viz*., soil or sand. Same observations were made by Mir *et al.* (2014) [15]. The length is found to be significantly different in the test hosts (Table 4), which is in close agreement with the observations made by Narayanan and Batra (1960) [16], Koul and Bhagat (1994) [12], Shivayya *et al.* (2007) [22] and Mir *et al.* (2014) [15].

Table 4: Morphometrics of larval instars of *B. cucurbitae* reared on some cucurbitaceous crops

Host Plant	Larval size (mm)					
	Instar I		Instar II		Instar III	
	Length	Breadth	Length	Breadth	Length	Breadth
Ash gourd	1.83^{d}	0.26	5.58	1.22	9.66^{d}	2.03
Bitter gourd	1.43^{ab}	0.26	5.00	1.12	9.33^{cd}	1.99
Bottle gourd	1.62^{bcd}	0.29	5.28	1.19	9.13^{abc}	1.95
Cucumber	1.50^{abc}	0.26	5.33	1.02	9.29^{bc}	1.85
Pumpkin	1.56^{abc}	0.27	5.17	1.01	8.96^{ab}	1.74
Ridge gourd	1.67^{cd}	0.29	5.42	0.99	8.92^{a}	1.78
Snake gourd	1.40^{a}	0.27	5.78	1.30	9.28^{abc}	2.05
S.E(d)	0.10	0.02	0.24	0.10	0.17	0.10
CD(p=0.05)	0.21	N.S.	N.S.	N.S.	0.36	N.S.

Data presented are mean of 3 replications (10 individual/ replication)
Means in columns followed by same letter(s) are not significantly different
Means are separated by LSD test
N.S. - Non significant

Adult flies are moderate in size, having reddish brown with lemon yellow curved markings (vittae) on the thorax and fuscous shading in outer margins of wings; the average length (expanded wings) and breadth of male varied from 7.22 to 7.66 mm and 11.36 to 11.82 mm, respectively. Female length varied from 9.70 to 10.05 mm while females when expanded measured 15.12 to 15.67 mm in breadth. The female flies are bigger in size than their male counterparts and possess predominant ovipositors. Present investigations are in close conformity with earlier works of Laskar (2013) [14], Mir *et al.* (2014) [15]. Laskar (2013) [14] measured the length and breadth of adult male in the range of 5.50 to 7.20 mm and 10.10 to 12.65 mm in bitter gourd and pumpkin, whereas, the length and breadth of female flies were ranged between 7.40 to 9.50 mm and 12.00 to 16.50 mm in the same hosts. Mir *et al.* (2014) [15] reported the length and breadth of adult male and female in cucumber to range between 8.05 to 8.74 mm and 10.00 to 12.69 mm and 9.50 to 10.2 mm and 14.88 to 16.90 mm, respectively. The little difference in the size of adult flies could be due to sex differences and innate character of the female as they had to develop through different reproductive stages like mating, pre-oviposition, oviposition and post oviposition periods. The size of both adult male and female flies were insignificant among the hosts.

Table 5: Morphometrics of adults of *B. cucurbitae* reared on some cucurbitaceous crops

Host plant	Adult male size (mm)		Adult female size (mm)	
	Length	Breadth	Length	Breadth
Ash gourd	7.66	11.77	9.97	15.35
Bitter gourd	7.38	11.53	9.77	15.28
Bottle gourd	7.22	11.67	9.70	15.12
Cucumber	7.40	11.36	9.75	15.16
Pumpkin	7.42	11.46	9.83	15.14
Ridge gourd	7.55	11.75	9.99	15.22
Snake gourd	7.62	11.82	10.05	15.67
S.E(d)	0.11	0.30	0.36	0.16
CD(p=0.05)	N.S.	N.S.	N.S.	N.S.

Data presented are mean of 3 replications (10 individual/replication)
Means in columns followed by same letter(s) are not significantly different
Means are separated by LSD test
N.S. - Non significant

Conclusion

The study revealed pronounced effects of hosts on some of the biological parameters of the melon fly, *B. cucurbitae* Coquillett. Ash gourd was found to be more suitable host and bottle gourd was less preferred by the melon fly for its growth and development under laboratory condition. The biology and biometrics of melon fly have been extensively investigated in India and other parts of the world on some of the cucurbit species by several researchers but literatures pertaining to the same set of test hosts, biological parameters and environmental conditions are very limited.

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