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Biophysical basis of resistance in bitter gourd against melon fruit fly, *Zeugodacus cucurbitae* Coquillett (Diptera: Tephritidae)

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Abstract
Melon fruit fly (*Zeugodacus cucurbitae* Coquillett) is one of the most important pests of cucurbits and bitter gourd (*Momordica charantia* Lin.) is highly prone to damage by this pest worldwide. Field and laboratory experiments were conducted to screen the bitter gourd accessions for their reaction to melon fruit fly. Screening was carried out with 50 bitter gourd accessions (wild types and commercial cultivars) and among these, 12 accessions (2 resistant, 6 moderately resistant, 3 susceptible and 1 highly susceptible) were selected to study the influence of morphological traits on larval density and reaction to melon fruit fly. The fruit weight, fruit length, spine length and spine density were positively correlated with fruit damage while the fruit width was negatively correlated (-0.2427 and -0.2621) at phenotypic and genotypic levels. The fruit hardness had a significant negative correlation (-0.9046 and -0.9205) to fruit damage at the phenotypic and genotypic levels.

Keywords: Bitter gourd, fruit fly, biophysical, screening, correlation

Introduction
Bitter gourd (*Momordica charantia* L.) is the most important tropical and sub-tropical vegetable among the cucurbitaceous crops which occupies a predominant place in Indian vegetables and cultivated throughout the world [17]. The tender fruit is found to have steroidal compound saponins (charantin) and insulin like peptide [2]. Bitter gourd is cultivated in an area of 95.00 lakh ha, with 1087 MT/ha and 10.87 MT/ha production and productivity, respectively in India [3]. The melon fruit fly (*Zeugodacus cucurbitae* Coquillett) damages over 81 plant species, however plants belonging to Cucurbitaceae family are more preferred hosts [1]. The fruit fly infests a wide range of cucurbitaceous crops with yield loss from 30 to 100 per cent, based on crop growth stages and season [4]. Generally the female fruit flies prefer young, soft and tender fruits for egg laying at 2 to 4 mm depth inside with its sharp ovipositor [18]. The repeated usage of systemic toxic insecticides, the fruit fly has gained resistance and resurgence against new insecticides [20] and involves huge additional management costs (25%) [13]. In integrated pest management practice, host plant resistance found to be an alternative to synthetic chemical pesticides for pest management [6]. Screening of bitter gourd accessions/ genotypes for resistance to fruit fly species and identifying morphological factors governing resistance is important for the management of fruit fly. The morphological factors can provide a source of resistance [12]. Hence, the development of genotypes/varieties resistant to melon fruit fly is an important component of Integrated Pest Management [16].

Materials and Methods
Preliminary screening
A preliminary screening was carried out with 50 bitter gourd accessions (wild types and commercial cultivars). Among these, 12 accessions (2 resistant, 6 moderately resistant, 3 susceptible and 1 highly susceptible) were selected to study the influence of morphological traits on larval density and reaction to melon fruit fly.

Raising of bitter gourd accessions
The bitter gourd accessions were raised in a plot of 3.0 m ×1.5 m with 0.5 m (plant to plant) and 2.5 m (row to row) spacing from August to November in a farmer’s field at Kotappatti

village, Tiruchirappalli District. Each accession was replicated thrice with four plants in each replication using Randomized Block Design (RBD) and recommended package of practices were followed according to TNAU crop production guide except plant protection measures

Damage assessment

The marketable mature fruits were collected at weekly intervals to observe larval density and fruit fly infestation. Based on fruit infestation, the accessions were grouped as per the rating system of immune (no damage), highly resistant (1-10%), resistant (11- 20%), moderately resistant (21-50%), susceptible (51-75%) and highly susceptible (76-100%) [14]. The infested fruits were cut open to observe the number of melon fruit fly maggots in each fruit. The healthy fruits were collected from each replication of selected accessions for morphological observation. The morphological characters of the fruits were observed on three randomly selected fruits in three replications. The length (cm), width (cm) and diameter (cm) were measured with the help of a Vernier calliper, length of the spine was measured using a scale, density of spine per cm^2 was observed under magnifying lens and fruit toughness (kg/cm^2) was measured using hand penetrometer.

Statistical analysis

Graphical work was done through the Microsoft Excel program. The morphological traits of bitter gourd accessions were correlated with the fruit damage by using TNAUSTAT Software.

Results and Discussion

Screening of bitter gourd accessions for the resistance to melon fruit fly *Z. cucurbitae*

The results of fruit damage in different genotypes and variety/local types are presented in (Table 1). The maximum number of fruits was recorded in variety CO-1 (31.67 no. /plant) and minimum in accession/local type viz, TCR 393 and Ucha small (22.33 no. /plant). The fruit damage was maximum in susceptible genotype MC-41 (21.00 no. /plant) and minimum in TCR-393 (4.00 no. /plant). The maggot population and fruit infestation was lowest in TCR-393 (6.33 no. /fruit and 17.90 %) followed by Musiri local-1 (6.50 no. /fruit and 20.00 %) and CO-1 (9.33 no. /fruit and 49.50 %). According to [19] reported Twenty eight genotypes of bitter gourd were evaluated for their resistance to fruit fly. However, six cultivars showed moderate resistance. Two cultivars, ACC-16-3 and Kalyanpur Sona were found to be highly susceptible with more than 20 per cent damage.

Influence of morphological traits of bitter gourd on infestation of melon fruit fly, *Z. cucurbitae*

The results indicated that the accessions/variety/local type showed a wide variation in their resistance to the fruit fly damage (Table 2). The CO-1 fruit recorded maximum weight and length (111.33 g and 18.50 cm) followed by MC-10 (103.33 g and 14.33 cm) and MC-41 (101.33 g and 15.57 cm). The fruit width and spine length were maximum in MC-10 (4.60 and 4.00 cm), MC-41 (4.17 and 4.17 cm) and TCR 393 (4.10 and 3.17 cm). The minimum spine density was recorded in resistant accession TCR 393 (4.67 no. /cm^2) followed by Musiri local-1 (5.00 no./cm^2) and MC-10 (5.67 no./cm^2). The maximum spine density was recorded in susceptible accession MC-41 (8.67 no. /cm^2). The fruit hardness was high in TCR 393 (9.30 kg/cm^2) followed by Musiri local-1 (8.97 kg/cm^2) and MC-10 (8.83 kg/cm^2). The fruit weight and fruit length were positively correlated with fruit damage (0.1776 and 0.1488) and (0.1662 and 0.2178) at phenotypic and genotypic level while the fruit width was negatively correlated (-0.2427 and -0.2621) at phenotypic and genotypic level (Table 3). The fruit hardness had a significant negative correlation (-0.9046 and -0.9205) to fruit damage at the phenotypic and genotypic level. The fruit width (-0.2979 and -0.3010), fruit length (-0.2544 and 0.4175) and spine length (-0.4540 and -0.4698) were negatively correlated to fruit hardness and spine density was highly significant with a negative correlation (-0.8445 and -0.9156) to fruit hardness in phenotypic and genotypic level. Similar results were reported by [10] who showed fruit infestation with a significant positive correlation with fruit weight and length. The maximum weight and length of fruits carried maximum eggs and preference for oviposition [9]. The spine density and depth were negatively correlated with fruit damage and more number of spine density and spine length unit/area/fruit was less preferred by the melon fruit fly [6]. The larval density (2.4 to 9.35 larvae per fruit) was significantly lower in resistant genotypes as compared to susceptible genotypes [7]. The fruit thickness influenced the fruit damage by fruit fly [15] and infestation also has been a significant positive correlation (0.971) of larval density per fruit [8].

The results clearly reiterated that the morphological traits directly or indirectly influenced the fruit damage by fruit fly (Table 4). The fruit weight (-0.066), fruit length (-0.1404), fruit width (-0.0212) and fruit hardness (-0.3485) had a negative direct effect on fruit damage. However, spine length and spine density showed a positive direct effect (0.047 and 0.6821) on fruit damage. Physical characters of the fruit hardness, firmness, chewiness and gumminess contribute to ovipositional preference of fruit fly. Among this, less hardness and firmness have higher infestation and high preference for oviposition [11]. The resistance varieties are an important component to manage fruit flies. The resistant cultivars are limited, because of a lack of information on genetic variability and sources of resistance against fruit fly [4]. The biophysical traits will help identify the resistance genotypes for the development of resistance cultivars. The antixenotic and antibiotic effect of resistance cultivars reduced the oviposition, host preference and feeding deterrents of melon fruit flies [12].

Conclusion

Infestation of bitter gourd by melon fruit fly has been found to be influenced by morphological traits of fruits. The accessions having high spine density and fruit hardness showed less fruit fly damage. These traits can be well utilized in the development of varieties of conferring melon fruit fly resistance in the near future.

Table 1: Screening of bitter gourd accessions for resistance to melon fruit fly *Z. cucurbitae*

S. No.	Bitter gourd accessions/variety/ local types	Biological attributes			Fruit fly infestation* (%)	Resistance Index
		Total fruits* (no. /plant)	Damaged fruit* (no. /plant)	Maggots/ fruit* (no.)		
1	TCR-393	22.33	4.00	6.33	17.90	Resistant
2	Musiri local-1	25.00	5.00	6.50	20.00	Resistant
3	MC-10	24.67	5.67	7.25	23.00	Moderately Resistant
4	Ucha small	22.33	6.67	7.40	29.80	Moderately Resistant
5	Bikaner-2	30.33	11.67	7.80	38.50	Moderately Resistant
6	Musiri local-2	28.33	12.33	8.17	43.50	Moderately Resistant
7	Pkm local	24.33	11.67	9.16	47.90	Moderately Resistant
8	Co-1	31.67	15.67	9.33	49.50	Moderately Resistant
9	MC-39	23.67	15.67	10.10	66.20	Susceptible
10	MC-105	25.67	15.33	10.67	59.70	Susceptible
11	Paravai local	27.33	17.00	11.87	62.20	Susceptible
12	MC-41	27.00	21.00	13.89	77.79	Highly Susceptible

*Mean of three replications

Table 2: Influence of morphological traits of bitter gourd on infestation of melon fruit fly, *Z. cucurbitae*

S. No.	Bitter gourd accessions/variety/ local collection	Morphological Traits*						Fruit infestation (%)
		fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Spine length (cm)	Spine density (no./cm^2)	Fruit hardness (kg/cm^2)	
1	TCR-393	93.33	15.50	4.10	3.17	4.67	9.30	17.9
2	Musiri local-1	80.67	12.77	3.90	3.43	5.00	8.97	20.0
3	MC-10	103.33	14.43	4.60	4.00	5.67	8.83	23.0
4	Ucha small	67.67	12.33	4.17	3.13	6.33	8.63	29.8
5	Bikaner-2	90.33	9.87	3.80	3.73	6.67	8.33	38.5
6	Musiri local-2	101.33	15.83	4.03	3.97	7.33	8.53	43.5
7	PKM local	70.67	11.87	3.47	3.57	6.33	8.43	47.9
8	CO-1	111.33	18.50	3.73	3.47	7.67	7.23	49.5
9	MC-39	81.67	13.47	4.13	3.77	7.33	7.43	66.2
10	MC-105	83.67	13.67	3.93	3.60	8.00	7.67	59.7
11	Paravai local	97.33	14.73	3.67	3.83	8.33	7.87	62.2
12	MC-41	101.33	15.57	4.17	4.17	8.67	6.87	77.79

*Mean of three replications

Table 3: Influence of morphological traits on resistance in bitter gourd accessions/variety/local types to melon fruit fly, *Z. cucurbitae*

S. No.	Fruit character		Fruit morphological traits of bitter gourd fruits						
			FW	FL	FWD	SL	SD	FH	FD
1.	FW	P	1.000	0.5631*	0.2055	0.5035	0.2867	-0.2979	0.1776
		G	1.000	0.9044**	0.2143	0.5145	0.3186	-0.3010	0.1488
2.	FL	P		1.000	0.1563	0.1272	0.1728	-0.2544	0.1662
		G		1.000	0.1429	0.1405	0.3944	-0.4175	0.2178
3.	FWD	P			1.000	0.2106	-0.2150	0.1554	-0.2427
		G			1.000	0.2247	-0.2272	0.1789	-0.2621
4.	SL	P				1.000	0.5074	-0.4540	0.5513
		G				1.000	0.5937*	-0.4698	0.5576
5.	SD	P					1.000	-0.8445**	0.8631**
		G					1.000	-0.9156**	0.9577**
6.	FH	P						1.000	-0.9046**
		G						1.000	-0.9205**
7.	FD	P							1.000
		G							1.000

FW-Fruit Weight; FL-Fruit Length; FWD-Fruit Width; SL-Spine Length; SD-Spine Density; FH-Fruit Hardness;
FD-Fruit Damage, *Significant at 5% level, ** Significant at 1% level, r = 0.576 (5%), 0.708 (1%), P-Phenotypic level; G-Genotypic level

Table 4: Estimation of direct and indirect effects of morphological traits on fruit damage at genotypic level in bitter gourd accessions / variety / local types

S. No.	Fruit characters	Fruit morphological traits of bitter gourd fruits						
		FW	FL	FWD	SL	SD	FH	Correlation
1	FW	-0.0664	-0.1269	-0.0045	0.0245	0.2173	0.1049	0.1488
2	FL	-0.0600	-0.1404	-0.0030	0.0067	0.2690	0.1455	0.2178
3	FWD	-0.0142	-0.0201	-0.0212	0.0107	-0.1550	-0.0624	-0.2621
4	SL	-0.0341	-0.0197	-0.0048	0.0476	0.4050	0.1637	0.5576
5	SD	-0.0211	-0.0554	0.0048	0.0282	0.6821	0.3191	0.9577
6	FH	0.0200	0.0586	-0.0038	-0.0223	-0.6245	-0.3485	-0.9205

FW-Fruit Weight; FL-Fruit Length; FWD-Fruit Width; SL-Spine Length; SD-Spine Density; FH-Fruit Hardness
Residual effect = 0.4764

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