Biological Forum – An International Journal **13(3): 64-70(2021)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Biophysical Traits as Resistance Sources in Bitter Gourd Genotypes Against Melon Fruit fly (*Bactrocera cucurbitae* Coquillett)

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(Received 10 May 2021, Accepted 15 July, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Melon fruit fly (*Bactrocera 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. Twenty-eight bitter gourd genotypes/hybrids were screened against fruit fly under field conditions at College of Horticulture, Kolar, Karnataka, India. The fruit damage was ranged from 18.10% to 83.38%. Maggot density per fruit ranged from 3.50 to 10.50 larvae/fruit. The maggot density increased with the increase in per cent fruit damage and showed significant positive correlation (r=0.89). Among the different genotypes/hybrids screened, Palee-1 and Leena were classified under resistant category, whereas the 22 genotypes/hybrids were categorized as moderately resistant. The Preeti and BG-13 were categorized into susceptible group and IC-541218-1 and Arka Harita were grouped into highly susceptible genotypes/hybrids. Fruit length, fruit diameter and exhibited positive correlation. Whereas, the number of longitudinal ridges, height of longitudinal ridges, fruit toughness, fruit rind thickness showed a negative correlation with fruit fly infestation. The maximum variation in fruit damage was explained by fruit toughness followed by fruit length and height of longitudinal ridges. Resistant genotypes found in the present study could be further used in breeding programme as sources for developing resistant bitter gourd varieties. Hence, the development of genotypes/varieties resistant to melon fruit fly is an important component of Integrated Pest Management.

Keywords: Bitter gourd, fruit infestation, melon fruit fly, biophysical traits.

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 (Rai *et al.*, 2008). It is variously known as Balsam pear, Bitter melon, Bitter cucumber or African cucumber. Bitter gourd is cultivated in an area of 95.00 lakh ha, with production of 1087 MT/ha and productivity of 10.87 MT/ha in India (Anonymous, 2018). It is used customarily as both food and medical importance as it is very effectual for various diseases *viz.*, diabetes, blood coagulation, cancer, menstrual stimulation, asthma and rheumatism (Thamburaj and Singh, 2001; Parray *et al.*, 2017). It is most influenced by several abiotic and biotic factors like diseases and insect pests. The insect pests *viz.*, Epilachna beetle, leaf miner, red pumpkin beetles and melon fruit fly. Among these, the melon fruit fly, *Bactrocera cucurbitae* Coquillett (Tephritidae: Diptera) has been recorded on more than 81 hosts. But bitter gourd is one of the most preferred hosts (Rabindranath and Pillai, 1986). 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 (Dhillon *et al.*, 2005b; Haldhar *et al.*, 2017).

The female fruit fly prefers to infest green, young and soft skinned fruits. It inserts the eggs at a fruit tissue depth of 2 to 4 mm and the larvae feed on the internal tissue of fruits causing decay of fruits and dropping of premature fruits (Ravindranathand Pillai, 1986). An affected fruits are misshapen and lose their market value. As the fly oviposits inside the fruit pulp and hatched maggots feed on the pulp, it becomes difficult to control with insecticides. The repeated usage of systemic toxic insecticides, the fruit fly has gained resistance and resurgence against new insecticides (Wang *et al.,* 2015) and involves huge additional management costs (25%) (Nasiruddin *et al.,* 2004). Integrated pest management practice, host plant resistance found to be an alternative to synthetic chemical pesticides for pest management (ElWakeil, 2013). Unfortunately the cultivars or genotypes resistant to the melon fruit flies infestation on the basis of biophysical fruit parameters have not still been identified in bitter gourd (Gogi *et al*., 2010a; Panda and Khush, 1995). Plants are generally exposed to a variety of biotic and abiotic factors that may alter their genotypic and/or phenotypic properties resulting in different mechanisms of resistance which enable plants to avoid, tolerate or recover from the effects of pest attacks (Gogi *et al.,* 2010b; Pedigo, 1996; Sarfraz *et al.,* 2006). Such mechanisms of plant resistance have been effectively used against insect pests in many field and horticultural crops (Dhillon *et al.,* 2005b; Gogi *et al.,* 2010a; Kogan, 1982; Sarfraz *et al.,* 2007). Mechanisms of resistance in plants are either constitutive or induced (Karban and Agrawal, 2002; Painter, 1951; Traw and Dawson, 2002) and are grouped into three main categories: antixenosis, antibiosis and tolerance (Painter, 1951). Therefore, there is a need to develop alternative management practices. One such alternative is using of resistant variety to manage the melon fruit fly infesting ridge gourd, which is a right choice as it do not have adverse effect on the ecosystem. Hence, present investigation was undertaken to identify biophysical traits as resistance sources in bitter gourd genotypes against fruit fly.

MATERIALS AND METHODS

Twenty-eight genotypes/hybrids of bitter gourd were collected from different firms and sown at College of Horticulture, Kolar, Karnataka (13° 08’ 00.52” North latitude, 78° 10’ 32.59” East longitude) during *kharif* season of 2019. An experiment was laid out in a Randomized Complete Block Design (RCBD) with two replications. The area of experimental block was 30 m × 20 m and the spacing between rows and between the plants was 1.2m and 0.9m, respectively. The bitter gourd genotypes/ hybrids were grown in field by following recommended package of practices (POP) of UHS, Bagalkot and observations were recorded from date of fruit in (3rd week of October, 2019) to till the end of the harvest (1st week of January 2020).

Screening of bitter gourd genotypes against fruit fly infestation: The fruit infestation and density of fruit fly maggots present in the infested fruit recorded throughout the season. At weekly interval, fruits were harvested from five randomly selected plants of each genotypes/hybrids from each replication. Of which, total number of fruits and number of fruits infested by fruit fly were recorded. The per cent fruit damage was worked by following formula.

$$\text{Fruit damage (\%)} = \frac{\text{Number of fruits infested}}{\text{Total number of fruits observed}} \times 100$$

The susceptibility rating scale of the genotypes given by Nath (1966) was used to categorize genotypes/hybrids on the basis of per cent fruit infestation (Table 1).

At weekly interval, five fruit fly damaged fruits were randomly selected in each genotype/hybrid from each replication were harvested and brought separately to the laboratory in polythene bags. The damaged fruits were cut open to count the total number of fruit fly maggots present in the fruit.

Table 1: Susceptibility rating scale of the genotypes on the basis of per cent fruit infestation (Nath, 1966).

Scale	Fruit infestation (%)	Rating
1	No damage	Immune
2	1 – 10	Highly resistant
3	11 – 20	Resistant
4	21 – 50	Moderately resistant
5	51 – 75	Susceptible
6	76 – 100	Highly susceptible

Bitter gourd biophysical traits with fruit fly infestation: In order to correlate the biophysical basis of bitter gourd genotypes against fruit fly infestation, five plants of each genotype from each replication were selected randomly and collect one fruit per plant and these fruits were brought to the laboratory in paper bags. The biophysical traits such as fruit length, fruit diameter, number and height of longitudinal ridges, fruit toughness, and fruit rind thickness were recorded for all the genotypes. The fruit length was recorded from the base of the fruit to the tip with help of centimeter scale and the mean length was expressed in centimeters. The diameter of fruit was measured with the help of Digital Vernier Calipers (INSIZE, DIN862) and the mean diameter was expressed in millimeters. The number of longitudinal ridges was counted by selecting three square centimeter area of fruit at random with help of visual observations. Fruit rind thickness and height of the longitudinal ridges was measured by using Digital Vernier Calipers (INSIZE, DIN862) and it was expressed in millimeters. Fruit toughness was measured by using Penetrometer (Made in Italy) and the average toughness was expressed in kilogram per centimeter square (kg/cm^2).

Statistical analysis: Data obtained on percent fruit infestation and maggot density per fruit of all the tested bitter gourd genotypes/hybrids were subjected to suitable transformation before subjecting to statistical analysis and the data analyzed through one way ANOVA technique by using Statistical web tool (WASP-Web Agri Stat Package 2.0). The biophysical traits of tested genotypes/hybrids of bitter gourd were analyzed through one way ANOVA technique. The data obtained on biophysical traits of bitter gourd genotypes were analyzed through correlation and multiplestep-wise regressionswith fruit fly infestation and maggot density by using SPSS software (Version-2016).Among the screened genotypes, the means of significant parameters were compared by using Duncan's Multiple Range Test (DMRT) post hoc test.

RESULTS AND DISCUSSION

Screening of bitter gourd genotypes against fruit fly infestation

Fruit infestation (%) and maggot density

The results presented in Table 2 revealed that none of the genotypes showed free from infestation by fruit flies. However, fruit infestation varied significantly in the screened bitter gourd genotypes. On the basis of seasonal average, fruit infestation was ranged from 18.10 to 83.38 per cent in different genotypes. However, fruit infestation varied significantly in the screened bitter gourd genotypes. The lowest fruit infestation was recorded with Palee-1(18.10%) followed by Leena (18.11%). While significantly highest fruit infestation was recorded in the genotypes such as, Arka Harita (83.38%) and followed by IC-541218-1(78.61%).

The density of fruit fly maggot per fruit in infested fruits was ranged from 3.50 to 10.50. The genotype, Palee-1 reported the lowest mean maggot density of 3.50 per infested fruit and followed by Leena (3.70 larvae/ fruit). The highest mean maggot density was reported in the genotype Arka Harita (10.50 larvae/ fruit) followed by IC-541218-1(10.40 larvae/fruit).The present investigation is in agreement with the findings of Nath *et al.* (2017b) in bitter gourd; Duradundi *et al.* (2017) in ridge gourd genotypes and Maharjan *et al.*, (2015) evaluated six different varieties of cucumber against fruit flies and recorded that the fruit infestation was ranged from 41.04 to 51.95%.

Table 2: Fruit infestation by melon fruit fly, *B. cucurbitae* in different bitter gourd genotypes/hybrids.

Sr. No.	Genotypes/ Hybrids	Fruit damage (%)	Maggots density
1.	Pallavi	37.89 (38.00)[b]	6.80
2.	MAHY-102	43.60 (41.34)[lm]	6.80
3.	Rider	44.18 (41.53)[mn]	6.70
4.	Rathna	40.49 (39.26)[c]	6.80
5.	Abhishek	42.09 (40.36)[fg]	6.90
6.	Balee	43.18 (41.02)[ijk]	6.80
7.	Araya	42.82 (40.72)[hi]	6.60
8.	Sida	45.17 (42.24)[o]	6.70
9.	Pragathi 065	42.83 (40.83)[hij]	6.90
10.	Palee 1	18.10 (25.06)[a]	3.50
11.	Teja	44.09 (41.61)[n]	6.80
12.	Leena	18.11 (25.10)[a]	3.70
13.	Sakata-7045	41.81 (40.06)[def]	6.90
14.	Monolisa	42.99 (41.06)[kl]	7.00
15.	Monika	42.50 (40.74)[hi]	6.90
16.	Lavanya	43.00 (40.90)[ij]	6.90
17.	BG-5	44.69 (42.05)[o]	7.00
18.	Meghana-2	41.13 (39.84)[de]	6.90
19.	Supergreen	42.20 (40.56)[gh]	7.00
20.	BG-2	44.29 (41.69)[n]	6.90
21.	BG-4	43.40 (41.13)[jkl]	7.00
22.	DEB-505	43.87 (41.37)[lm]	6.90
23.	BG-12	42.65 (40.85)[hij]	6.90
24.	BG-1	44.98 (42.04)[o]	6.90
25.	ArkaHarita	83.38 (65.94)[s]	10.50
26.	BG-13	62.57 (52.37)[q]	8.60
27.	Preeti	61.59 (51.86)[p]	8.70
28.	IC-541218-1	78.61 (62.47)[r]	10.40
SEm ±		**0.11**	**0.40**
CD (p=0.05)		**0.29**	**1.16**

Figures in parentheses are arcsine transformed values; Figures with same alphabet in the column are not significantly different (p=0.05) from each other following DMRT

Categorization of bitter gourd genotypes based on fruit infestation: The categorization of bitter gourd genotypes based on the seasonal average of the fruit infestation (Table 3). Out of twenty-eight genotypes, none of the genotypes was found to be highly resistant. While, two genotypes *viz*., Palee-1 (18.10%) and Leena (18.11%) were categorized as resistant group. Whereas, 22 genotypes such as BG-2, Sida, BG-12, BG-4, BG-5, Meghana-2, Monika, Monolisa, Sakata-7045, Araya, BG-1, Pallavi, Abhishek, Balee, DEB-505, Lavanya, Rathna, Supergreen, MAHY-102, Rider, Teja and Pragathi-065 were categorized as moderately resistant group and two genotypes such as Preeti (61.59%) and BG-13 (62.57%) were categorized into susceptible. However, IC-541218-1(78.61%) and Arka Harita (83.38%) were grouped into highly susceptible genotypes. The results of present investigations were close conformity with findings of Nath (1966) on ridge gourd.

Table 3: Grouping of genotypes on the basis of per cent fruit infestation by fruit fly.

Scale	Fruit damage (%)	Rating	Number of genotypes	Genotypes/ Hybrids	Fruit damage (%)
1	No damage	Immune	Nil	Nil	Nil
2	1 – 10	Highly resistant	Nil	Nil	Nil
3	11 – 20	Resistant	2	Palee-1	18.10
				Leena	18.11
4	21 – 50	Moderately resistant	22	Pallavi	37.89
				Rathna	40.49
				Meghana-2	41.13
				Sakata-7045	41.81
				Abhishek	42.09
				Supergreen	42.20
				Monika	42.50
				BG-12	42.65
				Araya	42.82
				Pragathi 065	42.83
				Monolisa	42.99
				Lavanya	43.00
				Balee	43.18
				BG-4	43.40
				MAHY-102	43.60
				DEB-505	43.87
				Teja	44.09
				Rider	44.18
				BG-2	44.29
				BG-5	44.69
				BG-1	44.98
				Sida	45.17
5	51 – 75	Susceptible	2	Preeti	61.59
				BG-13	62.57
6	76 – 100	Highly susceptible	2	IC-541218-1	78.61
				Arka Harita	83.38

Influence of bitter gourd biophysical traits on fruit fly infestation: The correlation co-efficient (r) was worked out to identify the nature of relationship between fruit infestation (per cent fruit damage and maggots/fruit) and its biophysical fruit traits for all the genotypes (Table 4). The per cent fruit infestation showed positively significant correlation (r = 0.89) with maggot density per fruit. Fruit length was positively non-significant correlation (p = 0.05) with fruit infestation (r = 0.34) and maggot density (r = 0.21) (Table 4). Similarly, fruit diameter was positively non-significant correlation (p = 0.05) with fruit infestation (r= 0.15) and maggot density per fruit (r = 0.07). An influence of number of longitudinal ridges was negatively (r = -0.22, -0.26) correlation and influence of height of longitudinal ridges was negative (r = 0.41, 0.37), but non-significantly on fruit infestation and maggot density.

Fruit toughness was found to be highly significant (p = 0.01) negative correlation with fruit infestation (r = -0.94) and maggot density (r = -0.81). Fruit rind thickness had negatively significant (p=0.01) correlation with fruit infestation (r = -0.71) and maggot density per fruit (r = -0.48). Fruit toughness and rind thickness can be used as markers to develop resistant variety against fruit fly in bitter gourd. The present investigation are well study with findings in bitter gourd (Singh, 2007; Mawtham *et al.*, 2020; Gogi *et al.*, 2010a) and in ridge gourd (Haldhar *et al*., 2015a; Duradundi *et al*., 2017).

Table 4: Influence of biophysical traits of bitter gourd genotypes on fruit infestation.

Parameters	Fruit damage (%)	Maggot density	Biophysical traits					
			Fruit length (cm)	Fruit diameter (mm)	Number of longitudinal ridges /cm^2	Height of longitudinal ridges (mm)	Fruit toughness (kg/cm^2)	Fruit rind thickness (mm)
Fruit damage (%)	1							
Maggot density	0.89**	1						
Fruit length(cm)	0.34^{NS}	0.21^{NS}	1					
Fruit diameter (mm)	0.15^{NS}	0.07^{NS}	-0.28^{NS}	1				
Number of longitudinal ridges	-0.22^{NS}	-0.26^{NS}	-0.08^{NS}	-0.26^{NS}	1			
Height of longitudinal ridges (mm)	-0.41^{NS}	-0.37^{NS}	-0.05^{NS}	0.62**	0.24^{NS}	1		
Fruit toughness(kg/cm 2)	-0.94**	-0.81**	0.18^{NS}	0.23^{NS}	-0.16^{NS}	0.39*	1	
Fruit rind thickness (mm)	-0.71**	-0.48**	0.17^{NS}	0.47*	0.13^{NS}	0.38*	0.73^{NS}	1

*Significant at p=0.05; ** Significant at p=0.01, NS; Non-significant at p=0.05

Table 5: Backward stepwise regression models showing effect of different biophysical fruit traits on fruit infestation.

Regression models	F- test	R^2 in per cent	Per cent role of each traits
Fruit damage (%)			
$Y=493.70-0.46\ X_1+0.65\ X_2-0.11\ X_3-1.94\ X_4-81.48\ X_5-2.30\ X_6$	$F_{6,21}=55.44$; $p<0.001$	94.06	0.47
$Y=529.72-0.53\ X_1+0.43\ X_2-0.10\ X_3-1.71\ X_4-89.33\ X_5$	$F_{5,22}=64.28$; $p<0.001$	93.59	60.38
$Y=104.66-1.16\ X_1+0.28\ X_2-0.19\ X_3-5.91\ X_4$	$F_{4,23}=2.86$; $p<0.001$	33.21	11.23
$Y=104.36-1.33\ X_1-0.84\ X_2-0.23\ X_3$	$F_{3,24}=2.25$; $p<0.001$	21.98	3.9
$Y=98.52-1.33\ X_1-1.04\ X_2$	$F_{2,25}=2.76$; $p<0.001$	18.08	6.28
$Y=61.84-1.10\ X_1$	$F_{1,26}=3.40$	11.8	11.8
Maggot density per fruit			
$Y=68.37-0.02\ X_1+0.11\ X_2-0.02\ X_3-0.34\ X_4-11.84\ X_5+0.37\ X_6$	$F_{6,21}=8.96$; $p<0.001$	71.91	0.66
$Y=62.54-0.01\ X_1+0.14\ X_2-0.02\ X_3-0.38\ X_4-10.57\ X_5$	$F_{5,22}=10.9$; $p<0.001$	71.25	45.32
$Y=12.26-0.09\ X_1+0.12\ X_2-0.03\ X_3-0.87\ X_4$	$F_{4,23}=2.01$; $p<0.001$	25.93	13.16
$Y=12.22-0.11\ X_1-0.04\ X_2-0.04\ X_3$	$F_{3,24}=1.72$; $p<0.001$	12.77	12.71
$Y=11.21-0.11\ X_1-0.08\ X_2$	$F_{2,25}=0.87$; $p<0.001$	0.06	0.02
$Y=8.50-0.09\ X_1$	$F_{1,26}=1.278$	0.04	0.04

X_1 = Fruit length (cm), X_2= Fruit diameter (mm), X_3 = Number of longitudinal ridges, X_4 = Height of longitudinal ridges (mm), X_5 = Fruit toughness (kg/cm^2), X_6 = Fruit rind thickness (mm) and R^2=coefficient of determination.

Further, backward step-wise multiple regression analysis was studied to know the influence of biophysical fruit traits on fruit infestation and density of maggot per fruit (Table 5). An analysis reported that an average of biophysical fruit traits such as fruit diameter, fruit length, number of longitudinal ridges, fruit toughness, height of longitudinal ridges and fruit rind thickness indicated 94.06% of the total variation in fruit infestation. The maximum difference in fruit infestation was explained by fruit toughness was 60.38% followed by fruit length was 11.80% and height of longitudinal ridges was 11.23%. Whereas, the remaining biophysical fruit traits noticed less than 4.0% variation in the fruit infestation (Table 5). Fruit diameter, fruit length, number of longitudinal ridges, fruit toughness, height of longitudinal ridges and fruit rind thickness indicated 71.91% of the total variation in the maggot density per fruit. The percent fruit infestation had significant positive correlation with fruit length, fruit diameter and flesh thickness and negative correlation with length of ovary pubescence, rind hardness at immature stage, rind hardness at mature stage and pericarp thickness in snapmel on Haldhar *et al.,* (2018).

The maximum difference in the maggot density was reported by fruit toughness was 45.32% followed by height of longitudinal ridges was 13.16% and number of longitudinal ridges was 12.71%. Other parameters noticed less than one per cent difference in maggot density per fruit (Table 5). Maximum variation in fruit infestation and larval density in watermelon were explained by length of ovary pubescence (82.5 and 83.6%, respectively) followed by fruit length (4.3 and 3.0%, respectively) and rind thickness (3.2 and 2.0%, respectively) (Haldhar *et al.,* 2015b). However, Gogi *et al.* (2010) indicated that the biophysical parameters explained 100% of the total deviation in fruit infestation in bitter gourd and Duradundi *et al.* (2017) that the biophysical traits explained showed 100 per cent total variation in fruit infestation in ridge gourd. The fruit weight, fruit length, spine length and spine density were positively correlated with bitter guard fruit damage. The fruit hardness had a significant negative correlation (-0.9046 and -0.9205) to fruit damage at the phenotypic and genotypic levels (Mawtham *et al.,* 2020; Nath *et al.,* 2017a).

CONCLUSION

It can be concluded from the present investigation that, Palee-1 and Leena was registered as resistant genotypes. The IC-541218-1 and Akra Harita were reported highly susceptible genotypes. The biophysical traits such as fruit toughness and rind thickness was noticed significantly highest in the resistant genotypes (Palee-1 and Leena) compared to the highly susceptible genotypes (IC-541218-1 and Akra Harita). These biophysical traits which impart resistance against fruit fly infestation. These marker traits can be well utilized in the development of bitter gourd varieties of conferring melon fruit fly resistance in the near future.

Acknowledgements. The authors wish to express sincere thanks to faculty of College of Horticulture, Kolar (University of Horticultural Sciences, Bagalkot, Karnataka) for encouragement and laboratory and field facilities during research work.

Conflict of interest. Nil.

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How to cite this article: Chandan K.C., Doddabasappa, B., Gangadhar Narabenchi, Amarananjundeswara, H., Mushrif, S.K., Manjunatha, R. and Bhanu, K.R.M. (2021). Biophysical Traits as Resistance Sources in Bitter Gourd Genotypes Against Melon Fruit Fly (*Bactrocera cucurbitae* Coquillett). *Biological Forum – An International Journal*, *13*(3): 000-000.