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Influence of some fruit traits of mango, *Mangifera indica* L. varieties against maggot development and infestation of mango fruit fly, *Bactrocera dorsalis* (Hendel)

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Abstract
The present study (during year 2014 and 2015) examined the various fruit traits of 10 popular varieties of mango, *Mangifera indica* in relation to resistance against *B. dorsalis* under field conditions. Results indicated significant variations among tested varieties in levels of fruit infestation and maggot density inside the fruit. The varieties Amrapali (6.67%), Gulab Khas (20.00%) and Dashehari (15.00%) were found resistant; Jardalu (21.67%) and Maldah (25.00%) were moderately resistant; Himsagar (36.67%) were susceptible while Chausa (40.00%), Mallika (58.33%), Fazli (58.33%) and Bombay Green (61.67%) were found the highly susceptible to *B. dorsalis* infestation. Principal components were extracted based on fruit traits and first four principal components explained cumulative variation of 89.97 % with eigenvalues >0.5 in *B. dorsalis* infestation. Mango varieties Amrapali, Gulab Khas and Dashehari were classified as resistant to *B. dorsalis* and these could be used in future breeding program as resistant sources.

Keywords: *Bactrocera dorsalis*, fruit traits, mango, resistance

1. Introduction

Mango (*Mangifera indica* L.; Anacardiacae) is one of the most important commercial fruit plant, grown in different parts of India as well as in the tropical and sub-tropical countries of Asia and Africa world [1]. It is popularly known as "the king of fruits" for its juiciness, rich flavors and aromas, taste, high carotenoid content, and high pro-vitamin A value [2]. India is having the richest collection of mango cultivars and ranks first among mango producing countries accounting for more than 50 percent of the world's production [2].

In nature, plants faces many biotic and abiotic stresses which results to change in their genotypic and/or phenotypic traits to come out the effect of stresses [3]. These fight mechanisms against stresses which called as resistances in plants are comes either constitutive or induced. Resistance mechanisms in plants may noticed through antibiosis, where reduced insect survival, prolonged developmental time, decreased size and reduced fitness of new generation adults [4, 5] or antixenosis, where plant traits, either allelochemical or morphological, that impart or changes insect behavior towards the host preference [6, 7] and/or combination of both [8].

However mango is a major fruit crop in India and hold first ranks in world production but its optimum production is constrained by many insect pests, especially fruit flies (Tephritidae: Diptera), that develop in to ripe and unripe fruits [9]. The Oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Tephritidae: Diptera) is a polyphagous pest and infests more than 250 host plants, including many types of commercial fruits [10, 11, 12]. Among many pestiferous tephritid species, *B. dorsalis* attacks on mango and causes serious loss ranging from 5 to 80% [13]. *B. dorsalis* is also a serious concern in terms of its possible introduction to the other important fruit growing regions of the world and listed as one of the most important quarantine pest because of its high invasiveness and adaptability to new environment [14, 15]. As the maggots damage the fruits internally, it is difficult to control this pest with insecticides. Hence, host plant resistance is one of the most effective tools for reducing insect damage and offers the maximum scope for economically viable IPM. This has also been found true for fruit flies in mango [16]. Very few studied with on one or more fruit traits have been done in mango for resistance mechanism against fruit fly attack [16, 17]. Very little attention has been given to development of stress resistant in perennial crops especially in mango against fruit fly attack [18]. It may be due to very little work and not availability of detailed information on the sources of mango fruit traits associated with resistance to fruit fly attack. Keeping above points in mind, the present study was designed to identify various morphological and biochemical fruit traits in popular mango varieties associated with resistance against *B. dorsalis* in terms of fruit infestation and maggot density under field conditions.

2. Materials and Methods

2.1 Screening of the selected mango varieties

For confirming the extent of *B. dorsalis* infestation in mango varieties, three plants of each ten popular varieties of mango *viz.*, Bombay Green, Gulab Khas, Jardalu, Himsagar, Dashehari, Mallika, Amrapali, Chausa, Fazli and Maldah were selected for screening during year 2014 and 2015. All selected varieties were already established in randomized block design in National Germplasm Repository of Sub-tropical Fruit Crops, at ICAR Research Complex for Eastern Region Research Centre, Ranchi, Jharkhand, India (23° 45′ N latitude, 85° 30′ E longitude, elevation 620 m AMSL). All the recommended agronomic practices were performed equally in each experimental plant. Ten fruits were randomly selected from each plant at the time of harvesting and were brought to the laboratory for microscopic examination for fruit infestation. For counting the number of maggots per fruit, ten fruit fly infested fruits from each variety were randomly selected and kept in cages for full ripening. The full ripened fruits were then dissected and numbers of maggots were counted in each infested fruit. The varieties were categorized by following the rating system as immune (no damage), highly resistant (1–10%), resistant (11–20%), moderately resistant (21–30%), susceptible (31–40%), and highly susceptible (>40.0%).

2.2 Morphological fruit traits of selected mango varieties

Five readily harvested fresh fruits of each variety were randomly selected to record data on the morphological traits (Peel thickness, pulp content, fruit length and fruit diameter). Fruit diameter and fruit length were measured at maximum point with a Digital Vernier Caliper (RSK™, 150 mm, 0.01 mm reading capacity). Peel thickness was measured at five different positions of each fruit using Digital Vernier Caliper. Pulp content of fruits at fully matured stage was performed as per the procedure suggested by Maynard [19].

2.3 Biochemical fruit traits of selected mango varieties

Three fresh fruits of each genotype at maturity stage were randomly selected from three trees in the orchard. Extraction procedure of harvested fruits was done on the same day. The peel and pulp separation and sample preparation procedure were followed according to Verghese *et al.* [17]. For quantification of biochemicals contents, the procedures were followed for ascorbic acid as AOAC [20] methodology; total sugar as Hedge and Hofreiter [21]; total phenols through folin-ciocalteau method as Singleton & Rossi [22] and flavonoid as Chun *et al.* [23]. The concentrations of total phenol and flavonoid were determined using a standard calibration curve of gallic acid and catechin, respectively and expressed as respective chemical equivalent/g of sample.

2.4 Statistical analysis

All the data were subjected to analysis of variance (ANOVA) using IBM SPSS Statistics version 21 software. Means were compared using Tukey's honestly significant difference (HSD) tests for paired comparisons at probability level of 5%. Required transformations (angular and square root transformed value wherever applicable) were used to attain normality in the data before analysis [24]. Correlations between morphological and biochemical fruit traits and fruit fly parameters (percent fruit infestation and maggot density per fruit) were determined using correlation analysis at the 95% significance level. PAST 3 (Palaeontological Statistics) [25] computer software was used for principal component analysis. To determine the PCs which accounted for the greatest amount of variation for each trait, the eigenvectors of the PCs were compared for each trait.

3. Results

3.1 Screening of mango varieties

The data on 10 selected mango varieties against fruit fly resistance during 2014 and 2015 are presented in Table 1. The results revealed that the variety Bombay Green showed significantly highest percent fruit infestation (61.67%) categorized as highly susceptible, which was followed by Mallika (58.53%), Fazli (58.53%) and Chausa (40.00%). The mango varieties Amrapali, Gulab Khas and Dashehari were categorized as resistant against fruit fly infestation and development of maggots inside the fruits. Maldah and Himsagar were categorized as moderately resistant to susceptible based on infestation level (Table 1). The maggot densities ranged from 2.85 to 22.65 maggots per fruit and significantly lower in resistant varieties than the susceptible varieties. The maggot density was highest in variety Mallika (22.65 maggots/fruit) followed by Fazli (19.85 maggots/ fruit). The minimum maggot density was found in Amrapali (2.85 maggots/fruit) followed by Dashehari (3.85 maggots/fruit). The maggot density per fruit increased with an increase in percentage fruit infestation, and there was a significant positive correlation ($r = 0.88$; $P \leq 0.01$) between percentage fruit infestation and larval density per fruit (Table 2).

3.2 Fruit traits of mango varieties

Significant diverged range between morphological traits of mango varieties i.e. peel thickness, pulp content, fruit length and fruit diameter were measured from 0.28 to 0.55 mm, 43.88 to 82.86%, 88.40 to 136.25 mm and 59.80 to 93.67 mm, respectively (Table 3). The fruit length and fruit diameter had significant positive correlations whereas; peel thickness of fruits had significant negative correlations with the percentage fruit infestation. Maggot density in fruits had only positive correlation with percent pulp content of mango fruits.

Level of biochemical content in mango fruits had differential rate of response on maggot development of *B. dorsalis* and their infestation on different mango varieties in present study (Table 3). Phenols (65.00 to 208.25 mg of GA Eq. /100g in peel and 23.15 to 71.25 mg of GA Eq. /100g in pulp) Flavonoid (180.25 to 501.68 mg Catechin Eq. /100g in peel and 61.50 to 167.58 mg Catechin Eq. /100g in pulp) and ascorbic acid (45.00 to 140.13 mg/100g) contents values significantly higher in resistant and lower in susceptible varieties. The general trend of different varieties suggests that higher the phenolic and flavonoids contents lower the infestation level and maggot development. Only total sugar of fruit content had positive (non significant) correlation in present study whereas, other biochemical traits *viz.*, ascorbic acid, phenols and flavinoid contents had significant negative correlation with the percentage fruit infestation and the larval density per fruit.

Table 1: Varietal reactions of mango against maggot density and percent fruit infestation of *B. dorsalis*.

Varieties	No. of maggots/fruit			Percent fruit infestation			Resistance category*
	2014	2015	Pooled	2014	2015	Pooled	
Bombay Green	17.30±2.69^{c}	17.60±2.58^{c}	17.45±2.57^{c}	53.33±2.79^{c}	70.00±3.65^{c}	61.67±3.35^{c}	HS
Gulab Khas	4.10±0.90^{a}	3.70±0.94^{a}	3.90±0.90^{a}	16.67±1.05^{ab}	23.33±2.79^{ab}	20.00±2.00^{ab}	R
Jardalu	9.10±1.16^{b}	9.60±1.33^{b}	9.35±1.22^{b}	23.33±2.79^{ab}	20.00±3.16^{ab}	21.67±2.69^{ab}	MR
Himsagar	16.20±2.16^{c}	16.60±2.19^{c}	16.40±2.12^{c}	33.33±4.59^{bc}	40.00±3.65^{b}	36.67±3.77^{bc}	S
Dashehari	3.80±0.66^{a}	3.90±0.81^{a}	3.85±0.72^{a}	13.33±1.05^{ab}	16.67±2.79^{ab}	15.00±1.91^{ab}	R
Mallika	23.10±3.20^{d}	22.20±3.13^{d}	22.65±3.09^{d}	53.33±4.59^{c}	63.33±2.79^{bc}	58.33±3.54^{c}	HS
Amrapali	2.90±0.59^{a}	2.80±0.71^{a}	2.85±0.63^{a}	3.33±1.05^{a}	10.00±1.83^{a}	6.67±1.49^{a}	HR
Chausa	5.80±0.61^{ab}	6.20±0.79^{ab}	6.01±0.69^{ab}	33.33±1.05^{bc}	46.67±2.11^{bc}	40.00±2.00^{bc}	HS
Fazli	19.70±2.39^{cd}	20.00±2.49^{cd}	19.85±2.38^{cd}	50.00±3.16^{c}	66.67±3.80^{bc}	58.33±3.54^{c}	HS
Maldah	6.90±0.82^{ab}	7.20±1.24^{ab}	7.05±1.02^{ab}	23.33±1.05^{ab}	26.67±2.79^{ab}	25.00±1.91^{ab}	MR
LSD (*P= 0.05*)	0.0001	0.0001	0.0001	0.004	0.001	0.002	
F calculated	17.48	16.33	16.85	4.19	5.31	4.75	
Error degree of freedom	90	90	90	20	20	20	

Value following different letter down the column are significantly different using Tukey's HSD test
*R- resistant, MR- moderately resistant, S -susceptible and HS- highly susceptible.

Table 2: Correlation coefficient (*r*) between percent fruit infestation and larval density per fruit with different fruit traits of mango, *M. indica* varieties.

	Percent infestation	Maggot Density	PT	PC	FL	FD	AA	TS	PPL	PPU	FPL
Maggot Density	0.88**	-	-	-	-	-	-	-	-	-	-
PT	-0.68*	-0.53	-	-	-	-	-	-	-	-	-
PC	0.56	0.63*	-0.26	-	-	-	-	-	-	-	-
FL	0.69*	0.56	-0.38	0.64*	-	-	-	-	-	-	-
FD	0.64*	0.53	-0.60	0.68*	0.82**	-	-	-	-	-	-
AA	-0.67*	-0.54	0.58	-0.50	-0.42	-0.49	-	-	-	-	-
TS	0.48	0.49	-0.43	-0.21	-0.18	-0.20	-0.33	-	-	-	-
PPL	-0.95**	-0.79**	0.71*	-0.59	-0.61	-0.67*	0.84**	-0.43	-	-	-
PPU	-0.92**	-0.74*	0.60	-0.42	-0.65*	-0.71*	0.64*	-0.31	0.94**	-	-
FPL	-0.71*	-0.49	0.50	-0.49	-0.60	-0.74*	0.60	-0.17	0.74*	0.76*	-
FPU	-0.73*	-0.56	0.48	-0.45	-0.61	-0.67*	0.59	-0.25	0.73*	0.73*	0.98**

** Correlation is significant at the 0.01 level (2-tailed) * Significant at the 0.05 level (two-tailed)

Table 3: Morphological and biochemical fruit traits of different varieties of mango, *M. indica*.

Varieties	Morphological fruit traits				Biochemical fruit traits					
	Peel thickness (mm)	Pulp content (%)	Fruit length (mm)	Fruit diameter(cm)	Ascorbic Acid (mg)	Total sugar (g/100)	phenol (mg of GA Eq./100g)		Flavonoids (mg of catechin Eq./100g)	
							Peel	Pulp	Peel	Pulp
Bombay Green	0.35±0.004^{bc}	66.32±0.34^{c}	96.40±2.13^{b}	70.40±1.38^{bc}	47.50±1.17^{a}	11.96±0.90^{NS}	65.00±1.59^{a}	23.15±2.86^{a}	236.00±2.31^{b}	76.66±2.21^{b}
Gulab Khas	0.44±0.008^{e}	54.32±0.99^{b}	99.25±3.21^{b}	61.50±2.46^{a}	120.00±1.15^{d}	11.90±0.97^{NS}	165.27±2.70^{f}	53.25±2.65^{d}	501.68±4.48^{i}	167.58±4.33^{f}
Jardalu	0.46±0.003^{f}	67.20±0.28^{c}	107.40±2.50^{c}	72.20±1.75^{c}	45.00±0.76^{a}	10.83±1.01^{NS}	140.38±2.22^{e}	48.58±1.83^{d}	345.62±2.90^{f}	113.65±3.14^{cd}
Himsagar	0.34±0.001^{b}	71.71±0.53^{de}	99.40±1.50^{b}	88.20±2.35^{e}	80.50±1.42^{c}	10.56±0.47^{NS}	120.65±2.05^{d}	40.15±1.24^{c}	326.50±2.00^{e}	111.25±2.60^{cd}
Dashehari	0.43±0.007^{e}	43.88±0.77^{a}	88.40±2.78^{a}	59.80±1.98^{a}	120.10±1.12^{d}	10.87±0.36^{NS}	186.57±3.05^{g}	62.19±1.17^{e}	365.50±2.36^{g}	105.62±2.78^{c}
Mallika	0.43±0.006^{e}	82.86±1.13^{f}	128.93±4.15^{d}	79.73±4.50^{d}	67.53±1.01^{b}	11.70±0.72^{NS}	92.65±3.50^{b}	36.25±1.56^{c}	310.25±2.74^{d}	84.25±1.80^{b}
Amrapali	0.55±0.003^{g}	70.52±2.10^{d}	89.50±2.15^{a}	62.80±2.30^{a}	140.13±2.30^{e}	10.31±0.60^{NS}	208.25±5.81^{h}	71.25±1.74^{f}	410.65±3.87^{h}	140.15±4.21^{e}
Chausa	0.41±0.002^{d}	74.08±0.30^{e}	135.30±3.01^{e}	93.67±2.25^{f}	80.16±1.30^{c}	10.00±0.28^{NS}	102.65±4.30^{bc}	31.25±1.57^{bc}	180.25±2.71^{a}	61.50±1.98^{a}
Fazli	0.28±0.004^{a}	76.89±0.21^{e}	136.25±3.80^{e}	93.25±3.05^{f}	67.80±1.29^{b}	11.80±0.43^{NS}	83.15±3.66^{b}	29.65±0.79^{b}	260.50±3.62^{c}	83.65±1.72^{b}
Maldah	0.36±0.003^{c}	72.44±0.43^{de}	97.20±1.70^{b}	68.80±3.95^{b}	64.50±1.15^{b}	11.50±0.40^{NS}	115.65±3.00^{d}	65.28±1.13^{e}	363.50±2.48^{g}	118.95±3.68^{d}
LSD (*P= 0.05*)	0.0001	0.0001	0.0001	0.0001	0.0001	0.39	0.0001	0.0001	0.0001	0.0001
F calculated	388.59	127.90	228.60	113.90	600.12	1.12	187.63	86.60	896.62	112.95
Error degree of freedom	40	40	40	40	20	20	20	20	20	20

Value following different letter down the column are significantly different using Tukey's HSD test

3.3 Principal component analysis

Ten parameters *viz.*, peel thickness, fruit length, fruit diameter, pulp content, ascorbic acid, total sugar, phenol and flavinoid content both peel and pulp were considered to perform the principal component analysis (PCA) for normalization and grouping of resistant traits. Eigenvalue, the principal components variance contribution rate and the cumulative variance contribution rate is presented in Table 4. The first four principal components (PCs) with eigenvalues >0.5 explained 89.97 % of variation among 10 mango varieties. Other PCs had eigenvalues <0.5 and have not been interpreted. The first PC, which is the most important component, explained 62.91 % of total variation. Eigen vector of the first principal component (PC1) had high loading values for fruit flies infestation (-0.34), larval count of fruits (-0.30), peel phenol (0.35) and pulp phenol (0.33). The variation in total sugar was accounted by PC2 and represented 21.50 % of total variation. PC3 mainly represented the Pulp % (0.66), peel flavonoids (0.36) and pulp flavonoids (0.36). PC4 explained mainly peel thickness (-0.44), fruit length (0.36), fruit diameter (0.37) and ascorbic acid content (0.57). The biplot was plotted between PC1 and PC2 to compare the mango varieties on the basis of multiple traits therefore can be candidates to be used as parents in mango breeding (Figure 1). More interesting genotypes were Bombay Green, Fazli, Chausa, Amrapali and Gulab Khas that were disposed in gaps and are the most promising ones. On the biplot (Figure 1), group of varieties (Amrapali, Gulab Khas and Dashehari) in the extreme right side represented the resistant group against *B. dorsalis*. However, varieties (Bombay Green, Mallika, Chausa and Fazli) in the extreme left side (Figure 1) denoted the susceptible group against *B. dorsalis* infestation.

Table 4: Component loadings of parameters for resistance against *B. dorsalis* in mango fruits.

Parameters	PC 1	PC 2	PC 3	PC 4
Fruit flies infestation	-0.34	0.17	0.00	0.04
Maggot count of fruits	-0.30	0.23	0.24	-0.08
Peel thickness	0.26	-0.24	0.24	-0.44
Fruit length (mm)	-0.27	-0.23	0.33	0.36
Fruit Diameter (mm)	-0.30	-0.31	0.16	0.37
Pulp %	-0.24	-0.18	0.66	-0.33
Ascorbic Acid (mg)	0.28	-0.15	0.10	0.57
Total sugar (g/100)	-0.10	0.69	0.12	0.08
PEEL phenol	0.35	-0.15	0.07	0.12
PULP phenol	0.33	-0.04	0.16	-0.16
PEEL flavonoids	0.30	0.30	0.36	0.15
PULP flavonoids	0.30	0.25	0.36	0.16
Eigenvalue	7.55	1.79	0.88	0.58
% variance	62.91	14.89	7.31	4.86
Cumulative %	62.91	77.80	85.11	89.97

4. Discussion

Finding a suitable host for oviposition and development is very crucial step to all phytophagous insects and olfaction plays an important role in enabling the host plants recognition [26, 27]. Further selection to plant as a host by insects is expressed by feeding, oviposition either uses of the plant for completes their offspring development [28]. Against the herbivore's selections, plants also have direct and indirect defenses mechanisms in which plants possesses the characteristics that affect the herbivore's biology such as mechanical protection on the surface of the plants (e.g., hairs, trichomes, thorns, spines and thicker leaves) or production of toxic chemicals such as terpenoids, alkaloids, anthocyanins, phenols, and quinones) that either kill or retard the development of the herbivores [29]. These variations even possesses in plants varieties/ genotypes due to the environmental stress or genetic makeup, which alter the nutritional values for herbivores [7].

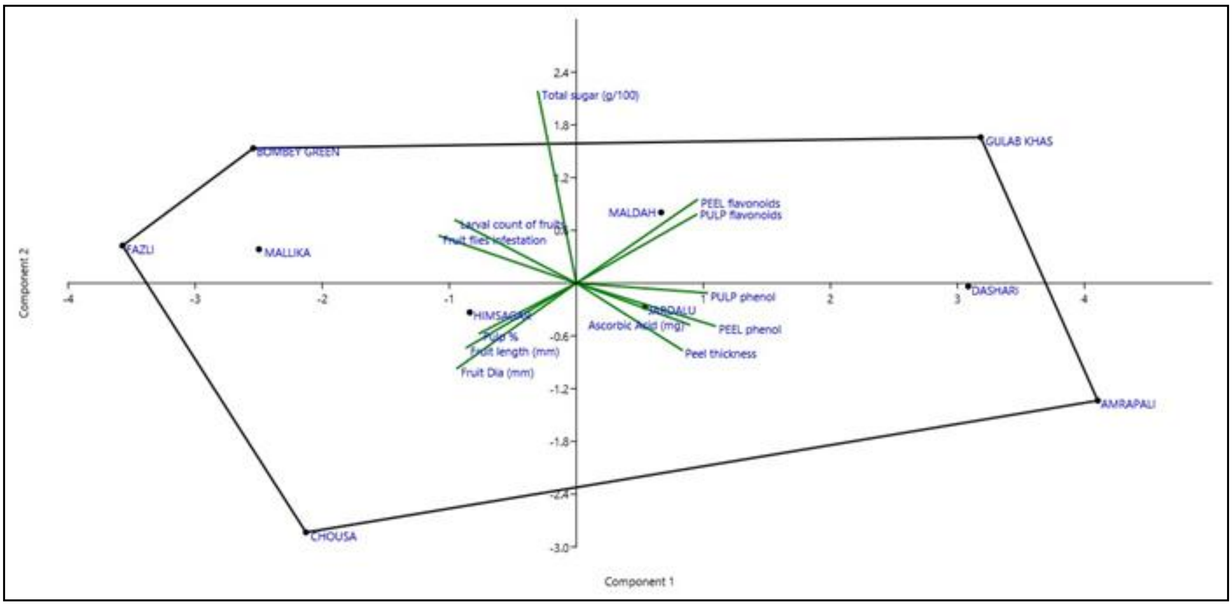

Fig 1: Plot of principal component1 and principal component 2 showing clusters of mango varieties resistance *B. dorsalis.*

The mango varieties Amrapali, Gulab Khas and Dashehari were categorized as resistant against *B. dorsalis* infestation and development of maggots while Bombay Green, Mallika, Fazli and Chausa were categorized as susceptible in the present study. The percentage fruit infestation and maggot density per fruit were found to be significantly lower in resistant and higher in susceptible varieties of mango. There is a lot of studies have done which showed that varieties/genotypes of the same species could significantly differ in their response to insect pest attacks [30, 31, 32, 33, 34, 28, 17] and it is influenced by morphological and biochemical traits of plants. Similar to present findings Verghese *et al.* [17] and

Jayanthi and Verghese [16] were also reported lower fruit infestation and maggot densities in resistant varieties of mango than on their susceptible varieties.

The morphological traits of fruits were diverse among the tested mango varieties. The fruit length and fruit diameter had significant positive correlations whereas peel thickness of fruits had significant negative correlations with the percentage fruit infestation in present study. Maggot density in fruits had only positive correlation with percent pulp content of mango fruits. In these findings, bio-physical fruit-traits were also found significantly different among genotypes/varieties [35, 32, 28]. Similar results were documented by Gogi *et al*. [35] that fruit length, fruit diameter and number of longitudinal ribs per fruit, which were significantly lowest in resistant and highest in susceptible genotypes, had a significant positive correlation with the percent fruit infestation and maggot density per fruit. However, rind hardness, height of small ridges, height of longitudinal ribs and pericarp thickness, which were significantly highest in resistant and lowest in susceptible genotypes, had a significant negative correlation with the percent fruit infestation and maggot density per fruit. These variations in measurements of morphological fruit-traits may be attributed to differences in the tested genotypes and/or stage of the fruits selected for measuring these traits, as reported in earlier studies [35, 28].

The biochemical traits of fruits were significantly different among the studied mango varieties. The total sugar was lowest in resistant and highest in susceptible varieties, whereas ascorbic acid, phenols and flavonoids (peel and pulp) contents were highest in resistant and lowest in susceptible varieties. Similar findings also reported in peel of mango varieties by Verghese *et al*. [17] with lower phenolics between 6.06 and 13.56 mg/g in peels of susceptible varieties (Banganapalli, Alphonso and Totapuri), whereas in resistant varieties (Langra, EC-95862) it was higher between 42.37 and 53.12 mg/g. The trend was the same for phenolics in pulp. In the susceptible varieties, the phenolic content was <0.60 mg/g and in resistant varieties, it was 2.33–2.36 mg/g. The biochemical characters such as total sugar and crude protein were positively correlated with fruit borer infestation, whereas, total phenols had negative correlation [36, 37, 28]. Similar to our findings, it has been demonstrated that phenols and flavonoids enhanced plant defenses against insects [7, 37, 17, 28]. The phenols and flavonoids enhanced the resistance may be due to antibiosis (which is prevention of development of the organism in the host) [38, 39] which is higher concentration of phenolics in Amrapali, Gulab Khas and Dashehari, as phenolics are known to impart resistance. Phenolic compounds have the ability to form insoluble complexes with proteins, act as enzymes inhibitors or are oxidized to toxic quinones. Morphological and biochemical characters individually were not possible to group the varieties as variables which were not in agreement to each other. So, principal component analysis was performed to achieve parsimony and reduce the dimensionality. In the principal component analysis smallest number of components can be extracting that accounts for the majority of the variation in the original multivariate data. The first four principal components (PCs) explained 89.97 % of cumulative variation among 10 mango varieties. The biplot between PC1 and PC2 which explained 77.80 % of cumulative variation, showed two discrete classes of varieties. The group of varieties grouped into highly resistant (Amrapali) and resistant (Gulab Khas, Dashehari) whereas, varieties (Bombay Green, Mallika, Chausa and Fazli) grouped in to highly susceptible (HS) varieties. Similarly, Principal Component analysis of ridge gourd varieties also showed four discrete classes (resistant, moderately resistant, susceptible and highly susceptible) based on biplot method against fruit flies infestation [28]. In present study, Amrapali was found to be highly resistant against *B. dorsalis* infestation. This along with Gulab Khas and Dashehari, can be used as parent in hybridization to develop varieties which having inherent source of resistant material against fruit flies infestation. Even though, Amrapali has been used as a parent (mostly as a female parent) in many of the crosses for developing mango variety due its thick peel, precocious, dwarfness, regularity of bearing and fruit quality [40, 41] but fortuitously it also have resistant source against fruit flies infestation. The resulted one of the hybrid (Pusa Arunima) between Amrapali and Sentation also had thick peel like Amrapali against medium thick in Sensation [41]. So Amrapali is good combiner for thick peel in to other varieties so, provide safeguard against fruit flies infestation.

5. Conclusion

Resistant source *viz.*, Amrapali, Gulab Khas and Dashehari is an important lead in fruit fly resistance breeding and uses of resistant varieties is an important tool for environment friendly pest control. So, resistant traits of varieties as a direct or indirect barrier against fruit fly infestation should be taken forward to breed varieties with higher content and acceptable commercial traits. Certain traits (morphological and biochemical) were significantly linked to resistance of mango against *B. dorsalis* and therefore, can be used as marker traits in further breeding programmes to select resistant varieties. This strategy would prevent the need to use insecticides which will render fruits pesticides residue-free as fruit flies attack mango during preharvest phase.

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