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Endogenous effect of *Syzygium cumini* genotypes on incidence of fruit borers, *Meridarchis scyrodes* and *Dudua aprobola*

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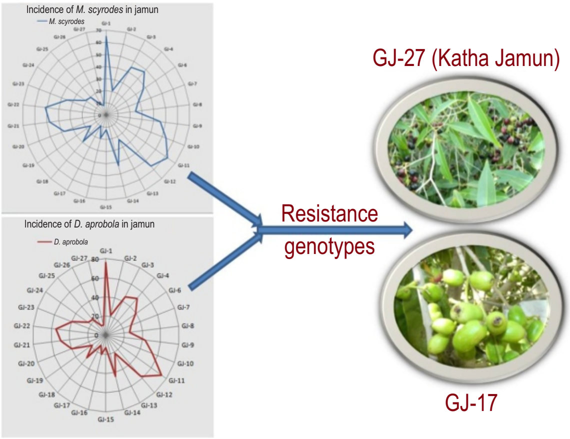
Abstract

Aim: Identification of Jamun (*Syzygium cumini* L. sleeks) resistant genotypes against important fruit borers, *Meridarchis scyrodes* and *Dudua aprobola* for their sustainable management.

Methodology: Twenty-six genotypes of *Syzygium cumini* from the gene bank were tested for resistance against fruit borers. Randomly fruits were collected from three plants of each genotype and mean incidence of fruit borers *Meridarchis scyrodes* and *Dudua aprobola* was recorded along with biophysical structures. The collected fruits were also analyzed for antixenotics and allelochemical biomolecules.

Results: On the basis of resistance scale, 5 genotypes were resistant, 11 were moderately resistant; 7 were susceptible and 2 were highly susceptible to fruit borers (*M. scyrodes and D. aprobola*) infestation. The infestation in different genotypes was negatively correlated with phenols, flavonoides, tannins and alkaloids, while it was positively correlated with fruit length, fruit width, pulp thickness and pulp: stone ratio. The phenolic and tannin content explained 93.30% of genotypic variability against *M. scyrodes* infestation while the genotypic variability explained 81% due to phenolic content followed by tannin content 10.4 % against *D. aprobola* infestation.

Interpretation: The jamun genotypes (GJ-27 & GJ-17) comes out as resistant against fruit bores with minimal infestation that can be used as breeding material for development of high yielding and borer resistant jamun varieties with higher antioxidant activity. We can use the jamun genotypes that resistant to fruit borers with minimal investment to get high yield under good agricultural practices. Therefore, resistance to fruit borers jamun genotypes can be used as part of sustainable management or integrated pest management.



Key words: Endogenous effect, Environment conservation, Fruit bores, HPR, Plant-insect interactions, Jamun

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Introduction

Jamun (*Syzygium cumini* L. skeels) native to South Asia is distributed all over India from Andman Island to northern plains and Kumaon Hill up to 1600 m above mean sea level (Zeven and de Wet, 1982). It is widely distributed in Sri Lanka, Philippines, Malaysia, Thailand and Australia, and popularly known as Jaman, black plum, damson plum, duhat plum and Indian blackberry. Jamun fruit has a bitter sour taste, however, its squash is highly refreshing during summer. They are rich source of antioxidant compounds and has stomachic, carminative, diuretic, cooling and digestive properties. The syrup of jamun fruit also helps in the treatment of diarrhea. Jamun tree is plagued by many major and minor insects that attack the leaves, flowers, fruits, seeds and barks (Butani, 1979). The fruit borer *Meridarchis scyrodes* Meyrick (Lepidoptera: Carposinidae) is a major insect pest of jamun. *M. scyrodes* lay eggs on the fruits at very tender stage and after hatching eggs, the newborn caterpillars enter the fruits and eat near seed pulp and push the feces. Similarly, another insect pest, the leaf roller, *Dudua aprobola* Meyrick (Lepidoptera: Tortricidae) is also reported as a sever pest of jamun in Rajasthan and Gujarat. It has been previously reported that it damage tender leaves and the inflorescence of plant, however, has recently been reported as fruit pest too. Under sever infestation it can cause loss up to 60% (Haldhar and Maheshwari, 2018).

Plants have several intrinsic protective mechanisms to fight against diseases. The pests and production of allelochemical compounds is one of them and their production increases when plants are attacked by any diseases or pests (Wimp *et al.,* 2007). However, these protective mechanism vary with genetic and phenotypic makeup of plant (Ballhorn *et al.,* 2011), insect nutrient intake and resource diversity (Inbar *et al.,* 2001), insect feeding characters (Gutbrodt *et al.,* 2011) and environmental stresses (Mody *et al.,* 2009). Plant community structures also have an impact on arthropods, including plant species and genetic diversity as well as biological structure (Wenninger and Inouye, 2008; Vehvilainen *et al.,* 2008). The morphometric and biochemical characteristics like trichomes, thorns, spines, hairs, and thicker leaves etc., also affect the insect infestation biology that slow down the life cycle of insects (Hanley *et al.,* 2007; Haldhar *et al.,* 2015 a, b). Allelochemicals such as flavinoids, phenols, tannins, alkaloids etc., produced within the plant may affect the life cycle of insect by affecting the survival, prolonged development time, reduced size and suitability of later generation adults (Gogi *et al.,* 2010). Hence, these types of plant resistance mechanisms have been found to be effective and widely used in pest control in horticultural crops (War *et al.,* 2012; Haldhar *et al.,* 2017).

The cultivation of jamun genotypes that are resistant to fruit borers may be a major part of integrated pest management program. The identification and testing of fruit borers resistant jamun genotypes has not been initiated due to lack of understanding on important intrinsic plant traits which impart resistant against these insects. The effect of these intrinsic or endogenous traits in development of resistance is also known as bottom-up mechanism of resistance. Bottom-up of resistance driven changes to plant-herbivore interactions in systems have been demonstrated in multiple cases (Maseko *et al.*, 2019), the model also supports the theory that top-down pressures (that affect ecosystems on a wider scale than the intended control agent and target plant level) can be significantly altered by bottom-up changes to the system (antixenotics and allelochemicals). The present study was conducted to determine the bottom-up mechanism of biophysical structures and biochemical compounds produced by *jamun* genotypes which impart resistance to fruit borers, *M. scyrodes* and *D. aprobola* infestation under field conditions.

Materials and Methods

Survey and collection of genotypes: During the years 2001 to 2004, a field survey was conducted in the North-Western states of India namely: Rajastha, Haryana, Punjab, Delhi, Gujrat and Maharastra for collection of jamun germplasm. The bud sticks of jamun germplasm were collected on the basis of location of the plants, height, leaf, fruit and occurrence of fruit borers. The collected material was budded on Katha Jamun seedlings at farm repository of CIAH-Central Horticultural Experiment Station, Godhara, Gujarat and planted at field repository recommended horticultural practices. The fruits for the borer infestation study were collected from this orchard during the years 2015-16 and 2016-17.

Screening of jamun genotypes: A total of twenty-six genotypes of *S. cumini* established in the gene bank of experimental farm at CIAH-Central Horticultural Experiment Station, Godhra was used for the preliminary resistance study. Twenty fruits were randomly selected from each plant and fruit borers, *M. scyrodes* and *D. aprobola* incidences were recorded with biophysical structures and allelochemical biomolecules during both these years (2015-16 and 2016-17). On the basis of Kaiser Normalization method, the genotypes were categorized as: immune (no damage), resistant, moderately resistant, susceptible and highly susceptible (Haldhar *et al.*, 2019).

Estimation of biochemical compounds: Randomly five fruits from each replication of all twenty-six genotypes were selected and cut into small pieces and dried for biochemical analysis. The biochemical analysis was carried out with standard procedures like phenols (Malik and Singh 1980), tannins (Schandert, 1970), alkaloids (Haldhar *et al.,* 2017) and flavonoid (Nabavi *et al.,* 2008) using UV-Vis spectrophotometer (Shimadzu, Kyoto, Japan).

Fruit morphomatric observations: The biophysical parameters of jamun fruits like pulp thickness, fruit width and fruit length were recorded from 10 fruits from each replications of all 26 genotypes using a Digital Vernier micrometer (MITU-TOYO, 300 mm, 0.01 mm reading capacity).

Statistical analyses: Square root and angular converted values were used to achieve generality within the data prior to analysis. The data were statistically analyzed using the SPSS 16 software (O'Connor, 2000). The parameter methods were compared using Tukey's significant differences (HSD) tests for paired comparisons. The regression and correlation between fruit borers infestation with allelochemical and antixenotic properties were also established using correlation analysis techniques and a multidisciplinary analysis of intelligent retrieval measures.

Results and Discussion

Twenty six genotypes of jamun were tested for resistance against fruit borers, *M. scyrodes* and *D. aprobola* during 2015-16 and 2016-17. The genotype GJ-27 (Katha Jamun) was found to be highly resistant; GJ-26, GJ-19, GJ-17 and GJ-15 were found resistant; GJ-2, GJ-6, GJ-7, GJ-8, GJ-13, GJ-16, GJ-18, GJ-20, GJ-23, GJ-24 and GJ-25 were moderately resistant; GJ-3, GJ-4, GJ-9, GJ-10, GJ-12, GJ-14, GJ-21 and GJ-22 were susceptible while GJ-1 and GJ-11 were highly susceptible genotypes (Table 1). Fruit borer, *M. scyrodes* infestation in 2015-16 ranged from 8.23 to 64.70% and it ranged from 8.10 to 64.97% during 2016-17. The incidence of fruit borer, *D. aprobola* ranged from 10.80 to 76.30% in 2015-16 and from 10.63 to 76.10% in 2016-17 (Fig. 1). Pooled data of fruit infestation from *M. scyrodes* (8.17-64.83%) and *D. aprobola* (10.72-76.20%) in both years were significantly lower in resistance genotypes and higher in susceptible genotypes. The percentage of fruit borer, *M. scyrodes* infestation was highest in GJ-1 (64.83 %) and significantly lowest in GJ-27 (8.17 %) followed by GJ-17 (9.97 %). Percent fruit infestation from *D. aprobola* was maximum in GJ-1 (76.20 %) and minimum in GJ-27 (10.72 %) followed by GJ-26 (11.05 %) (Table 1). Han *et al.* (2016) studied the plant diversity that effects on the interaction of herbivore in different habitats. However, variability in the internal characteristics of plants is responsible for the variability of a

Table 1: Fruit borers, *M. scyrodes* and *D. aprobola* infestation in different genotypes of Jamun

Genotypes	Fruit infestation (%)						Resistance category
	M. scyrodes			*D. aprobola*			
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	
GJ-1	64.70 (53.55)*	64.97 (53.71)	64.83 (53.63)	76.30 (61.16)	76.10 (61.01)	76.20 (61.08)	HS
GJ-2	20.77 (27.06)	20.63 (26.97)	20.70 (27.01)	21.07 (27.30)	20.93 (27.20)	21.00 (27.25)	MR
GJ-3	44.83 (42.01)	44.53 (41.84)	44.68 (41.92)	45.13 (42.19)	44.93 (42.07)	45.03 (42.13)	S
GJ-4	48.17 (43.93)	47.20 (43.38)	47.68 (43.65)	51.47 (45.82)	51.20 (45.67)	51.33 (45.75)	S
GJ-6	37.30 (37.62)	37.13 (37.52)	37.22 (37.57)	39.27 (38.77)	39.03 (38.63)	39.15 (38.70)	MR
GJ-7	28.13 (32.01)	27.93 (31.88)	28.03 (31.95)	29.63 (32.93)	29.43 (32.80)	29.53 (32.87)	MR
GJ-8	24.60 (29.68)	24.30 (29.48)	24.45 (29.58)	26.23 (30.70)	25.87 (30.46)	26.05 (30.58)	MR
GJ-9	45.20 (42.23)	44.97 (42.09)	45.08 (42.16)	43.43 (41.19)	43.23 (41.07)	43.33 (41.13)	S
GJ-10	53.27 (46.86)	53.07 (46.74)	53.17 (46.80)	54.27 (47.44)	53.90 (47.23)	54.08 (47.33)	S
GJ-11	62.07 (51.96)	61.90 (51.86)	61.98 (51.91)	73.73 (59.32)	73.50 (59.17)	73.62 (59.25)	HS
GJ-12	56.13 (48.51)	55.93 (48.40)	56.03 (48.45)	57.73 (49.46)	57.53 (49.34)	57.63 (49.40)	S
GJ-13	22.87 (28.51)	22.67 (28.37)	22.77 (28.44)	21.37 (27.50)	21.13 (27.34)	21.25 (27.42)	MR
GJ-14	43.03 (40.98)	42.83 (40.86)	42.93 (40.92)	44.27 (41.69)	44.10 (41.59)	44.18 (41.64)	S
GJ-15	12.17 (20.37)	12.00 (20.23)	12.08 (20.30)	13.17 (21.26)	13.00 (21.12)	13.08 (21.19)	R
GJ-16	19.83 (26.41)	19.73 (26.34)	19.78 (26.37)	20.60 (26.93)	20.40 (26.79)	20.50 (26.86)	MR
GJ-17	10.03 (18.40)	9.90 (18.27)	9.97 (18.34)	12.30 (20.47)	12.10 (20.29)	12.20 (20.38)	R
GJ-18	29.07 (32.58)	28.87 (32.46)	28.97 (32.52)	32.00 (34.43)	31.70 (34.25)	31.85 (34.34)	MR
GJ-19	15.87 (23.44)	15.63 (23.26)	15.75 (23.35)	18.37 (25.32)	18.20 (25.20)	18.28 (25.26)	R
GJ-20	37.70 (37.86)	37.53 (37.76)	37.62 (37.81)	39.97 (39.19)	39.80 (39.10)	39.88 (39.15)	MR
GJ-21	47.77 (43.70)	47.53 (43.57)	47.65 (43.63)	50.07 (45.02)	49.90 (44.92)	49.98 (44.97)	S
GJ-22	51.27 (45.71)	51.07 (45.59)	51.17 (45.65)	55.20 (47.97)	54.93 (47.82)	55.07 (47.90)	S
GJ-23	35.23 (36.36)	35.03 (36.24)	35.13 (36.30)	39.47 (38.89)	39.30 (38.79)	39.38 (38.84)	MR
GJ-24	21.13 (27.26)	20.90 (27.10)	21.02 (27.18)	23.63 (29.07)	23.33 (28.87)	23.48 (28.97)	MR
GJ-25	19.53 (26.17)	19.27 (25.98)	19.40 (26.08)	22.37 (28.20)	22.17 (28.06)	22.27 (28.13)	MR
GJ-26	10.07 (18.44)	9.87 (18.25)	9.97 (18.34)	11.13 (19.47)	10.97 (19.32)	11.05 (19.40)	R
GJ-27	8.23 (16.65)	8.10 (16.51)	8.17 (16.58)	10.80 (19.15)	10.63 (18.99)	10.72 (19.07)	HR
Mean+- SD	**33.42+17.04**	**33.21+17.02**	**33.32+17.03**	**35.88+18.67**	**35.67+18.65**	**35.78+18.66**	
SEM	**1.17**	**1.18**	**1.17**	**1.60**	**1.59**	**1.59**	
LSD (P = 0.05)	**3.32**	**3.36**	**3.34**	**4.54**	**4.52**	**4.53**	

*Values in parentheses are angular-transformed values. R- resistant; MR- moderately resistant; S- susceptible and HS- highly susceptible

Table 2: Biochemical fruit traits of different genotypes of Jamun, *Syzygium cumini*

Genotypes	Flavonoid content (mg 100 g^{-1})*	Tannins content (mg 100 g^{-1})	Total Phenol content (mg 100 g^{-1})	Total alkaloid content (%)
GJ-1	7.18	22.47 (4.83)**	21.20 (4.71)	0.021
GJ-2	14.08	41.73 (6.53)	33.43 (5.86)	0.044
GJ-3	9.84	33.51 (5.87)	24.52 (5.05)	0.036
GJ-4	8.64	30.08 (5.57)	21.92 (4.78)	0.026
GJ-6	14.30	42.89 (6.62)	27.58 (5.34)	0.035
GJ-7	12.53	38.94 (6.31)	30.42 (5.60)	0.041
GJ-8	13.10	37.35 (6.19)	30.71 (5.63)	0.042
GJ-9	9.16	34.69 (5.95)	23.03 (4.90)	0.034
GJ-10	6.94	26.46 (5.23)	18.75 (4.44)	0.034
GJ-11	6.24	24.30 (5.03)	19.74 (4.55)	0.025
GJ-12	7.50	28.49 (5.42)	27.21 (5.31)	0.026
GJ-13	10.89	42.13 (6.57)	31.92 (5.72)	0.049
GJ-14	10.71	37.76 (6.21)	24.90 (5.09)	0.033
GJ-15	16.64	45.72 (6.84)	36.72 (6.14)	0.053
GJ-16	13.34	44.76 (6.76)	29.96 (5.55)	0.049
GJ-17	14.31	48.01 (7.00)	35.59 (6.05)	0.058
GJ-18	12.04	40.35 (6.43)	30.36 (5.59)	0.033
GJ-19	14.51	44.63 (6.75)	38.06 (6.24)	0.047
GJ-20	11.90	38.57 (6.29)	27.43 (5.33)	0.040
GJ-21	8.34	32.19 (5.76)	26.46 (5.23)	0.033
GJ-22	7.53	31.46 (5.70)	21.07 (4.70)	0.029
GJ-23	12.65	40.99 (6.48)	28.62 (5.44)	0.036
GJ-24	11.71	41.46 (6.51)	28.13 (5.37)	0.045
GJ-25	14.42	45.40 (6.80)	33.35 (5.84)	0.043
GJ-26	15.61	50.82 (7.20)	33.77 (5.89)	0.066
GJ-27	17.04	53.33 (7.37)	37.03 (6.16)	0.055
Mean+- SD	**11.58+3.16**	**38.40+8.01**	**28.53+5.56**	**0.04+0.01**
SEM	**0.75**	**0.17**	**0.19**	**0.002**
LSD (P = 0.05)	**2.14**	**0.49**	**0.54**	**0.006**

* Analysis taken on dry weight basis of complete fruit of jamun. **Values in parenthesis are square root-transformed

resource for converting bottom-up effects.

In addition, the results may also depend on the strategy of feeding on herbivores under different food habitats. However, the above effects are highly variable and depend on both biotic and abiotic factors, such as genotypes/ plant species (Haldhar *et al.,* 2018a,b), insect feed capacity (Han *et al.,* 2016), feeding specialization (Visschers *et al.,* 2019), resource diversity (Inbar *et al.,* 2001) and environmental pressure capacity (Mody *et al.,* 2009). Wuletaw *et al.* (2021) reported that the availability of enough genetic diversity in the wheat genetic resources (land races, wild relatives, cultivars, etc.) for resistance to Hessian fly, Russian wheat aphid, greenbug and sun pest. Many R genes - including 37 genes for Hessian fly, 11 genes for Russian wheat aphid and 15 genes for greenbug have been identified from these genetic resources. Some of these genes have been deployed singly or in combination in the breeding programs to develop high yielding varieties with resistance to insects.

Flavonoid, tannins, total phenols and alkaloid content ranged from 7.18 to 17.04 mg per 100g, 22.47 to 53.33 mg per100g, 18.75 to 38.06 mg per 100g and 0.021 to 0.066 % (on dry weight basis), respectively that were highest in resistance genotypes and lowest in susceptible genotypes. The flavonoid content (17.04 mg per 100g) and tannin content (53.33 mg per 100g) were found highest in GJ-27 and lowest content in GJ-1 (flavonoid content 7.18 mg per 100g and tannin content 22.47 mg per 100g). The total phenols content (38.06 mg per 100g) was highest in GJ-19 and lowest in GJ-10 (18.75 mg per 100g). The total alkaloid content was highest in GJ-26 (0.066 %) genotype and lowest in GJ-1 (0.021 %) with significantly lower values in resistant genotypes (Table 2). Percent fruit infestation of fruit borers, *M. scyrodes* and *D. aprobola* had significant negative correlation with flavonoid (-0.93 and -0.91), tannins (-0.95 and -0.94), phenols (-0.92 and -0.90) and total alkaloid (-0.93 and -0.92) (Table 4). No information is available about the association of biochemical factors with fruit borers in jamun but other crops having the information. The chemical concentration of glucosinolates in wild cabbage (*Brassica oleracea*) is high and which is secondary metabolites that act as chemical protection against insects and its concentration increases from summer to winter season (Gols *et al.,* 2018).

Table 3: Morphological (antixenotic) fruit traits of different genotypes of Jamun, *Syzygium cumini*

Genotypes	**Fruit length (cm)**	**Fruit width (cm)**	**Pulp thickness (cm)**	**Pulp: stone ratio**
GJ-1	2.42	2.05	0.45	4.58
GJ-2	2.20	1.90	0.47	0.76
GJ-3	2.03	2.14	0.34	2.88
GJ-4	2.60	1.93	0.37	2.29
GJ-6	2.48	1.94	0.27	1.31
GJ-7	2.18	1.99	0.32	2.69
GJ-8	2.10	2.93	0.43	2.41
GJ-9	2.43	2.50	0.42	2.13
GJ-10	2.12	1.95	0.41	2.26
GJ-11	2.16	2.39	0.53	4.27
GJ-12	2.21	2.31	0.48	3.59
GJ-13	2.06	1.98	0.51	3.13
GJ-14	1.76	2.12	0.37	3.69
GJ-15	1.80	1.71	0.17	2.17
GJ-16	1.91	1.23	0.14	2.52
GJ-17	1.96	1.98	0.27	1.08
GJ-18	2.24	2.52	0.51	3.75
GJ-19	1.99	2.08	0.36	1.24
GJ-20	2.41	2.43	0.48	3.41
GJ-21	2.41	1.94	0.31	3.26
GJ-22	2.33	1.85	0.32	3.29
GJ-23	2.26	2.34	0.39	3.45
GJ-24	2.34	2.21	0.39	4.27
GJ-25	2.28	1.70	0.34	2.31
GJ-26	1.69	2.01	0.25	1.95
GJ-27	1.54	1.30	0.14	0.60
Mean+- SD	**2.15+0.26**	**2.06+0.36**	**0.36+0.11**	**2.67+1.09**
SEM	**0.09**	**0.06**	**0.04**	**0.09**
LSD (P = 0.05)	**0.27**	**0.17**	**0.11**	**0.26**

Table 4: Correlation coefficient (r) between percent infestation of *M. scyrodes* and *D. aprobola* with different allelochemicals and antixenotic fruit traits of jamun genotypes

Allelochemicals and antixenotic fruit traits	***Meridarchis scyrodes* Meyrick**	***Dudua aprobola* (Meyrick)**
Flavonoid content (mg $100g^{-1}$)	-0.926**	-0.907**
Tannins content (mg $100g^{-1}$)	-0.950**	-0.945**
Phenols content (mg $100g^{-1}$)	-0.919**	-0.900**
Total alkaloid content (%)	-0.926**	-0.923**
Fruit length (cm)	0.576**	0.563**
Fruit width (cm)	0.333NS	0.321NS
Pulp thickness (cm)	0.513**	0.508**
Pulp:stone ratio	0.608**	0.633**

**Significant at P = 0.01 (two-tailed); * Significant at P = 0.05 (two-tailed)

Phenolic compounds also play an important role in reducing the cyclic of active oxygen species such as superoxide anion and hydroxide radicals, H_2O_2 and singlet oxygen, which turn into a reaction cascade leading to the activation of immune enzymes (Maffei *et al.,* 2007). Tannins, flavonoids and isoflavonoids may protect the plant from pests by affecting the behavior, growth and development of insect herbivores (Nath *et al.,* 2017). It has been reported that phenols, tannins, and flavonoids increase plant immunity against fruit fly and provide important negative correlations with fruit infestations (War *et al.,*

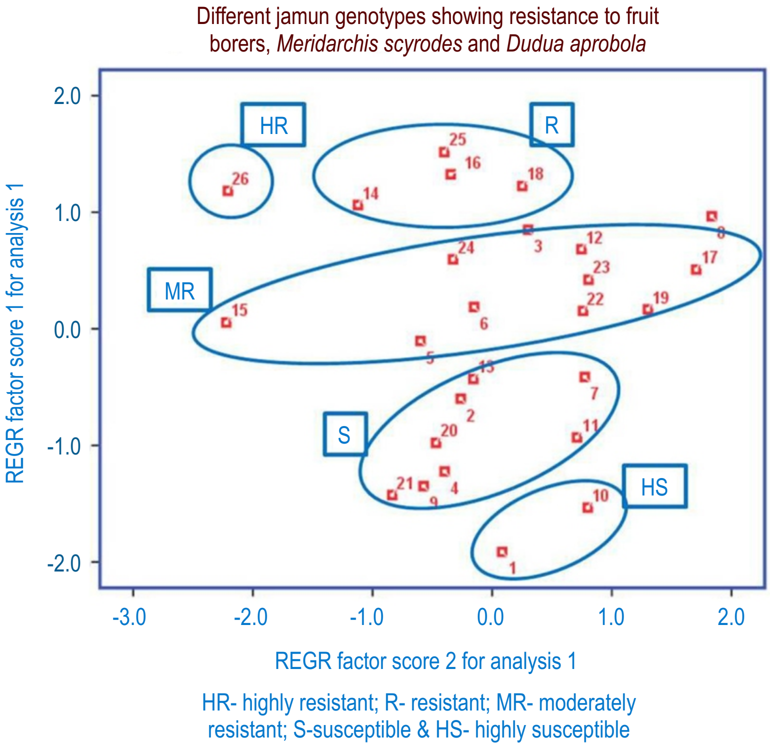

Fig. 1: Different jamun genotypes showing resistance to fruit borers, *Meridarchis scyrodes* and *Dudua aprobola*.

2012). Cotton contains tannin and gossypol chemical which have harmful effect on aphid, *A. gossypii* and when concentrations of these chemicals increases then increases the mortality of cotton aphid (Ma *et al.,* 2019). Multivariate analysis of phenol and tannin content explained the highest variability of *M. scyrodes* infestation. Variation in fruit infestation of *D. aprobola* was major role of phenol content (81.00%) followed by tannin content (10.40%). Haldhar *et al.* (2017) found that flavinoid and tannin content played a major role in resistance to fruit fly infestation and larval population in cucurbit plants. Zeist *et al.* (2018) reported that *Solanum lycopersicum* genotypes containing high levels of allelochemicals are promising in the context of advancements aiming at creating lines adequate for insect and arachnid resistance.

The fruit length, fruit width, pulp thickness and pulp: stone ratio ranged between 1.54 to 2.60 cm, 1.30 to 2.93 cm, 0.14 to 0.53 cm and 0.60 to 4.27 ratio, respectively that parameters are lowest in resistance genotypes and highest in susceptible genotypes. The fruit length (1.54 cm), fruit width (1.30 cm), pulp thickness (0.14 cm) and pulp: stone ratio (0.60) was found minimum in GJ-27 genotype but maximum fruit length (2.60 cm) was noted in GJ-4, fruit width (2.93 cm) in GJ-8, pulp thickness (0.53 cm) in GJ-11 and pulp: stone ratio (4.27) in GJ-11 and GJ-24 genotypes, respectively (Table 3). The fruit length (0.58 and 0.56), fruit width (0.33 and 0.32), pulp thickness (0.51 and 0.51) and pulp: stone ratios (0.61 and 0.63) have positive correlation with the percent fruit infestation of fruit borers, *M. scyrodes* and *D. aprobola* (Table 4). Structural features such as spines and thorns, trichomes, firmness or strong leaves, from granite minerals into plant tissue and twisted branches (stem shaped shoots producing axillary angles) play an important role in protecting plants from herbivores (He *et al.,* 2011). In these findings, the antixenotic characteristics of plants play an important role in providing resistance to plants and and found significant differences in each genotypes (Simmons *et al.,* 2010). Haldhar *et al.* (2019) found that the resistant germplasm of lasora having more leaf size, leaf roughness and leaf hairyness but less in susceptible germplasm of lasora. A positive correlation was observed between leaf length and leaf width and negative correlations with percent bug infestation and bug density per leaf. However, Gogi *et al.* (2010) reported that morphological factors like rind hardiness, fruit width and number of long ribs have shown 100% variability in fruit infestation. This variation in morphological fruit characteristics may be due to differences in the germplasm/ genotypes tested, and the class of fruit identified to measure these traits is a major factor in pest control in plants (Gogi *et al.,* 2010). Haldhar *et al.* (2017) reported emerg significant difference in fruit infestation due to ovary pubescence length followed by rind thickness in kachri againstence of a fruit fly. A step-by-step multivariate analysis showed that phenol and tannin content accounted for 93.30% of fruit borer, *M. scyrodes* infestation. Significant differences in fruit infestation were explained by the phenol content (84.50%)

followed by tannin (8.80%) and pulp intensity (2.20%).

Significant differences in fruit borer attacks, *D. aprobola* was due to phenol content (81.00%) followed by tannin content (10.40%) and total alkaloid content (2.30%), while the remaining fruit characteristics accounted for <1.0% variation within the fruit infestation of *D. aprobola*. Based on the above allelochemical and antixenotic characters, it was not possible to combine the entries as the variables were not consistent with the other group. Therefore, the main component analysis was performed to detect parsimony and reduce the magnitude by extracting a small number of components calculated by multiple variables within the original multivariate data. The main principal component analysis (PCA) was based on eight parameters namely, flavonoid, tannins, phenols, total alkaloid content, fruit length, fruit width, pulp thickness and pulp: stone ratio. The two main components (PCs) were exposed to the eigen ≥1.0 value, after rotating varimax with the Kaiser normalization process that changed three fold. The developed communities of all the variables tested were ≥ 0.5 indicating that the variables were well represented by the released PCs collectively describing 82.61% variance. PC1 accounted for 59.92% variance while PC2 accounted for 23.42% variance. PC1 had loads of flavonoid content (0.91), tannins content (0.92), phenols (0.93) content, alkaloid content (0.89), fruit length (-0.55) and pulp: stone content (-0.58). Fruit width (0.93) and pulp stiffness (0.86) are loaded into PC2. Haldhar *et al.* (2015b) found that 90% variation in fruit fly incidence due to ovary pubescence length, rind intensity, flavonoid content, ascorbic acid, free amino acid, tannins content and phenol content that are major variables for resistance to in watermelon. Haldhar *et al.* (2017) showed that two main components were released explaining the total variation of 88.2 percent fruit fly infestation. Principal component one having 71.6 percent variation while principal component second explained 16.6% of the total variation in melon fruit fly infestation of kachri crop.

Thus, from the above account, a minimum borers infestation was found in resistant genotypes of jamun plant may be due to allelochemicals (biochemicals) and antixenotic (biophysical). Jamun genotypes GJ-27 (highly resistant) and GJ-17 were classified as resistant to fruit borers, *M. scyrodes* and *D. aprobola* in semi-arid climate conditions. Certain allelochemical traits (e.g. tannins, flavonoid, alkaloids and phenols content) and antixenotic traits (e.g. pulp thickness and pulp: stone ratio) were associated with jamun resistance against *M. scyrodes* and *D. aprobola* and therefore, it can be used as markers in plant breeding programme to select resistant genotypes that may be used in the long-term breeding program.

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Add-on Information

Authors' contribution: S.M. Haldhar: Conceived, conceptualized, investigation and writing of original draft; **A.K. Singh:** Helped in data collection; **D. Singh:** Draft editing; **M.K. Berwal:** Statistical analysis; **J.S. Gora:** Statistical analysis and editing; **R. Kumar:** Reviewed manuscript; **D.K. Saroilia:** Critically analyzed the manuscript.

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