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Inheritance of resistance to phomopsis blight and fruit rot in brinjal

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Abstract: The F_5 generations of IPM-31 cultivar of brinjal (*Solanum Melongena* L.) crosses were evaluated for their genotypic and phenotypic performances for disease resistance to Phomopsis blight and fruit rot and concerned yield characters. F_5 plants (derived from crossing with IPM-31and commercial cultivars Dohazari G and Laffa S) were grown out of seeds collected from selfed F_4's. The 3 parents and F_5 generation were inoculated with *Phomopsis vexans* under confined field condition. It was observed that the inoculated F_5 plants remained free of infection from *P. vexans* and exhibited differential disease reaction. Percent disease index (PDI) of leaf ranged from 0.00 to 17.23% and fruit ranged from 0.00 to 26.58%. Among the parents, Dohazari G and Laffa S were found susceptible (S) and IPM-31 showed resistant (R) reaction against *P. vexans.* All F_5 crosses showed resistant reaction. The genotypes were also studied to estimate the variability, heritability, genetic advance, correlation coefficient among its yield contributing characters and heterosis over better parent. Significant differences were observed among the genotypes for all characters under study. High genotypic and phenotypic coefficient of variation were found in number of fruits per plant, number of secondary branches plant^{-1} and number of primary branches plant^{-1}. In contrast, fruit length, fruit breadth, individual fruit weight and plant height had shown low genotypic and phenotypic coefficient of variation. Very high heritability estimates together with very low genetic advance were recorded for fruit breadth. The present study interprets highest genetic advance (51.21) for individual fruit weight and lowest (2.11) for fruit breadth. Both positive and negative heterosis was observed on different characters. The cross Laffa S x IPM-31 had the highest (26.33%) negative and significant heterosis over better parent for number of fruits per plant.
Key words: genotypic, phenotypic, resistance, variability, heritability, genetic advance.

Introduction

Eggplant cultivars commonly known as brinjal are grown in Bangladesh showed a wide range of variations in yield performance and disease reaction. Fruit rot caused by *Phomopsis vexans* (Sac & Syd) is one of the major constraints in successful cultivation of eggplant in Bangladesh (Das, 1998). Almost all eggplant cultivars of Bangladesh are reported susceptible to this disease. The disease is reported to cause 15-20% (30-50% in severe case) yield loss (Das, 1998; Khan, 1999) estimated equivalent to Tk 1850 million or 30.84 US $ per annum.

Fungicides of bio-sources and use of host-resistance would be the alternative to chemical spray. Bio-fungicides are yet to be in commercial use in Bangladesh. Also source of resistance to phomopsis fruit rot is not handy. However, continued searching for the source of resistance since 2001 revealed the existence of variation in reaction of eggplant cultivars of Bangladesh against *P. vexans* (Islam, 2006). IPM-31 cultivar developed by IPM lab was consistently found resistant to *P. vexans* (Meah, 2003). IPM-31 was crossed to two commercial cultivars of eggplant –Dohazari G and Laffa S. All F_1, F_2, F_3 and F_4 plants of both the crosses showed resistance (Islam, 2006; Hasan, 1990). Seeds from F_4 plants were planted to get F_5 plants. These plants were evaluated for genotypic and phenotypic characters to see the segregating nature for resistance.

The assessment of genetic variation is a major concern of plant breeders and population geneticists. Availability of sufficient variation is required for the production of new varieties that are aimed towards the improvement of crop productivity and able to withstand damage from biotic and abiotic factors.

Therefore, the present research work was undertaken to determine the inheritance of resistance to Phomopsis blight and fruit rot in the F_5 generation of IPM-31 cultivar of brinjal.

Materials and Methods

Genetic materials: Seeds of the parental and F_5 populations of the intervarietal crosses of eggplant, viz. (1) Dohazari G x IPM-31 (2) Laffa S x IPM-31 were obtained from IPM Lab, Department of Plant Pathology, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Inoculation of eggplant by *Phomopsis vexans*: Five plants per plot for each cultivar/entry, were inoculated at the flowering stage and again 5 plants at the fruiting stage. Seventy millilitre spore suspension (5 x 10^6 spore/ml) prepared with all the 44 isolate mixtures folloing the key of Islam(2005), was sprayed on each plant. Another 5 plants were kept uninoculated (control).The spraying was done at afternoon. Inoculated plants were kept moist and covered with transparent polythene sheet for 24 hours for ensuring better infection.

Harvesting and processing: The mature fruits were harvested at the edible stage at an interval of seven days. A sharp knife was used to harvest the fruits to avoid damage of twigs. Depending upon the genotypes, harvesting of fruits was continued for a period of about one and half a month since the fruits attained plucking stage at different times. The harvesting was continued from mid January, 2009 to 1st week of March, 2009.

Observation and data collection: Data were collected at an interval of 7 days up to 21 days after inoculation on Percent Leaf infection, Percent LAD (Leaf Area Diseased), Percent flower infection, Percent fruit infection, Percent FAD (Fruit Area Diseased) and Lesion size (mm) on fruits. Percent LAD (Leaf Area Diseased) and FAD (Fruit Area Diseased) were estimated by eye observations. A single leaf/fruit surface area was considered as 100%. Deducting the healthy area, the diseased area was estimated. Average of %LAD/FAD was then calculated dividing the total by the number of leaves/fruits investigated and finally graded into different groups as outlined in Table 1.

The lesion size was estimated in square centimeter using a measuring scale. The test entries were graded in various categories of resistance and susceptibility utilizing the standard area diagram of Islam (2006) with slight modification as follows:

Lesion size (sq. cm.) on fruit	Reaction
0.0 - 0.05	R (Resistant)
0.06 - 0.5	T (Tolerant)
0.6 - 1.0	MT (Moderately Tolerant)
1.01 - 2.0	MS (Moderately Susceptible)
2.01 – 3.0	S (Susceptible)
>3.0	HS (Highly Susceptible)

Table 1. Measurement of disease severity reactions of Phomopsis blight and fruit rot of eggplant.

% LAD/FAD	Scale	Reaction
0 - 1	1	R
1.1 - 10	2	MR/T
10.1 - 25	3	MS
25.1 - 50	4	S
> 50	5	HS

R = Resistant, MR = Moderately Resistant, T = Tolerant, S = Susceptible, HS = Highly Susceptible, Percent disease index (PDI)/severity was calculated as per formula of Singh (1984), the formula of

$$PDI = \frac{\text{Sum of total ratings}}{\text{Total number of observations x highest grade in the scale}} \times 100$$

Yield contributing characters: The yield contributing characters from the parents and F_5 populations were studied and data were recorded from all the plants of each population on individual plant basis. The characters were plant height, number of primary branches per plant, number of secondary branches per plant, fruit length, fruit breadth, number of fruits per plant and Individual fruit weight.

Data analysis: All the characters above were analyzed according to the method described by Steel and Torrie (1960) Duncan's Multiple Range Test (DMRT) was performed to test the differences between the genotypes.

Genotypic and phenotypic variances as well as Heritability in broad sense (h^2_b) were estimated according to formula given by Johnson *et al.* (1955); while genotypic and phenotypic coefficients of variation were estimated according to the following formula given by Burton (1952). The expected genetic advance (GA) for different characters under investigation was estimated according to the formula used by Johnson *et al.* (1955) and Allard (1960). Genotypic and phenotypic covariances were calculated using the formula given by Singh and Chaudhary (1985).Genotypic and phenotypic correlation coefficients between different characters in all possible combinations were calculated with the formula given by Miller *et al.* (1958).Comparing the mean of F_5 hybrids over mid parental value, the amount of heterosis was estimated by using following formula.

Percentage of heterosis over better parent (BP)

$$= \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where, $\overline{F_1}$ = Mean value of the character of F_1 individuals

$\overline{BP}$ = Mean value of better parent

Results and Discussion

Evaluation of parents and F_5 plants against *Phomopsis vexans*

Flowering stage: F_5 eggplants and respective parents when inoculated showed different percentage leaf infection and severity (leaf area diseased), which have been presented in table 2. Among the five F_5 crosses and three respective parents, the highest 33.21% leaf infection was found in cultivar Dohazari G followed by 21.69% leaf infection in cultivar Laffa S. Parent IPM-31 did not show any infection on leaf but the F_5 offsprings (Laffa S x IPM-31) and (Dohazari G x IPM-31) showed leaf infection ranged from 2.40 to 2.72%. The highest PDI (leaf) was recorded in cultivar Dohazari G followed by that in cultivar Laffa S.

Table 2. Disease reaction of eggplant crosses and parents against *Phomopsis vexans* in *in situ* induced condition

F_5/Parents	Leaf infection (%)	PDI (Leaf) (%)	Flower infection (%)	Reaction
F_5 (Dohazari G × IPM-31)				
Green Globose	2.72 c	2.72 b	2.25c	Resistant
Green Long	2.64 c	2.64 b	2.14c	Resistant
F_5 (Laffa S × IPM-31)				
Green Globose	2.56 c	2.56 b	2.56c	Resistant
Green White Long	2.40 c	2.40 b	2.78c	Resistant
Purple Globose	2.64 c	2.64 b	2.94c	Resistant
IPM-31	0.00 d	0.00 c	0.00d	Resistant
Laffa S	21.69 b	15.09 a	24.58b	Susceptible
Dohazari G	33.21 a	17.23 a	32.25a	Susceptible
CV (%)	9.23	14.37	5.55	
LSD	2.605	3.948	1.562	

Means followed by different letters are statistically significant at 0.01 alpha levels.

In case of flower infection, the maximum 32.25% flower infection was recorded in variety Dohazari G followed by 24.58% in variety Laffa S. Flower infection in the F_5 offsprings (Laffa S x IPM-31) and (Dohazari G x IPM-31) was ranged from 2.14 to 2.94%. No flower infection was found in cultivar IPM-31. On the basis of flower infection, the cultivar IPM-31 and F_5 offsprings of eggplants were graded as resistant whereas cultivar Dohazari G and cultivar Laffa S were graded as susceptible (Table 2).

Fruiting stage: Upon inoculation, fruits of F_5 crosses and respective parents showed different lesion sizes and percentage fruit infection (Table 3). Among the five F_5 crosses and three respective parents, the highest lesion size 3.21 cm^2 was found in parent cv Dohazari G followed by parent cv. Laffa S (2.59 cm^2). The F_5 progenies (Laffa S x IPM-31 and Dohazari G x IPM-31) showed lesion size 0.037 - 0.045 cm^2 but the parent cv. IPM-31 had no lesion at all. Considered the lesion size, both F_5 populations were graded resistant. Dohazari G and Laffa S plants were graded susceptible while IPM 31 plants as resistant as usual.

The highest percentage of fruit infection was recorded in parent cv. Dohazari G (Table 3) followed by parent cv. Laffa S. There was no fruit infection in parent cv. IPM-31 but the F_5 progenies of eggplants (Laffa S × IPM-31) and (Dohazari G × IPM-31) showed fruit infection of 2.78% and 3.86% respectively.

Table 3. Lesion and percentage of infection produced on fruits of F_5 eggplants and respective parents inoculated with *Phomopsis vexans*

F_5/Parents	Lesion size (cm^2)	Fruit infection (%)	PDI (Fruit) (%)	Reaction
F_5 (Laffa S x IPM-31)	0.037c	2.78c	1.76b	Resistant
F_5 (Dohazari G x IPM-31)	0.045c	3.86c	0.795b	Resistant
IPM-31(Katabegun WS)	0.00d	0.00d	0.00c	Resistant
Dohazari G	3.21a	47.23a	22.25a	Susceptible
Laffa S	2.59b	42.09b	26.58a	Susceptible
% Coefficient of Variation	6.23	11.37	6.85	
LSD	0.605	1.948	4.368	

Means followed by different letters are statistically significant at 0.01 alpha levels.

The cultivar IPM-31 did not produce any lesion against *Phomopsis vexans* and was graded as resistant. The cultivars Laffa S and Dohazari G produced 2.59 cm^2 and 3.21 cm^2 lesions respectively and were denoted as susceptible. This result agrees with Meah (2003) who reported that Laffa S and Dohazari G were susceptible on the basis of their lesion sizes. The findings are in agreement with Meah and Islam (2005) and Kalda (1972) who also reported similar results.

When F_5 plants were grouped based on colour and shape, all were graded resistant, a few plants (1.78-3.96%) in all the groups showed infection though. Fruit shape influenced the infection chances-long fruits in both F_5 populations had less infection than round (Globose) fruits. Fruit colour had no effect on the intensity of infection (Table 4 & Fig. 1).

Table 4. Disease reaction on different colour of fruits of F_5 eggplants inoculated with *Phomopsis vexans*

Progenies (Fruit Characters)	No. of fruits inoculated	No. of fruits infected	Fruit Infection (%)	PDI (Fruit) (%)	Lesion size (cm^2)	Reaction
F_5 (Laffa S x IPM-31)						
Green globose	178	7	2.76ab	1.56b	0.028c	Resistant
Green white long	188	4	1.78b	1.78ab	0.036b	Resistant
Purple globose	180	8	2.81ab	1.94a	0.046a	Resistant
F_5 (Dohazari G x IPM-31)						
Green globose	214	13	3.96a	0.85c	0.042b	Resistant
Green long	170	7	1.84b	0.74c	0.048a	Resistant

Means followed by different letters are statistically significant at 0.01 alpha levels.

Performance of the genotypes and their variabilities: The mean of yield attributes are shown in Table 5. All the yield attributes had highly significant (P>0.01) differences amongst the genotypes. This means differences exist between the tested genotypes even within the singular environment where they were grown.

Plant height ranged from 57.008 cm to 69.222 cm and the F_5 generation (Laffa S × IPM-31) was the tallest of all and significant. In contrast, the parent cv Dohazari G had the shortest height and was statistically identical with the genotypes Laffa S, IPM-31 and statistically different from F_5 generation (Dohazari G × IPM-31) (Table 5).

Number of primary branches $plant^{-1}$ ranged from 7.950 to 18.84. IPM-31 produced highest number of primary branches and secondary branches. It was statistically different from all other genotypes. The parent cv.

Dohazari G produced lowest number of primary branches and it was also statistically dissimilar with that of F_5 generation (Dohazari G × IPM-31, Dohazari G × IPM-31) and cv. Laffa S. The lowest number of secondary branches was observed in cv. Dohazari G and it was statistically identical with all other rests except cv. IPM-31 where the range for secondary branches plant^{-1} prevailed from 14.537 to 23.063.

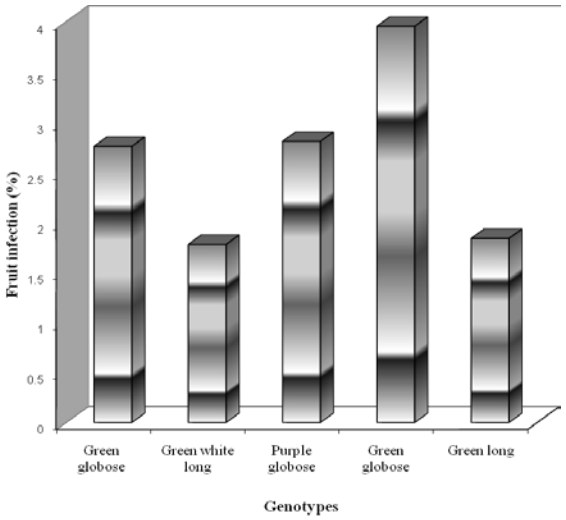

Fig 1. Fruit infection of 5 cross materials of F_5 offspring of eggplants

Number of fruits plant^{-1}, the principal yield attribute, ranged from 11.925 to 24.425. The parent cv Dohazari G produced the highest number and it was statistically identical with cv Laffa S. The second highest number of fruits Green Globose was recorded in F_5 generation (Laffa S x IPM-31) and it was statistically identical with IPM-31 and Dohazari G x IPM-31. All other progenies and IPM-31 had statistically similar number of fruits. The parent cv Dohazari G had shown the highest fruit length and it was statistically different with other genotypes. In contrast, the lowest fruit length was observed in the F_5 progeny Green Globose (Laffa S x IPM-31) which was significantly different from other F_5 progenies (Dohazari G x IPM-31).

Fruit breadth was recorded as 6.248 to 9.463 cm. The highest fruit breadth was observed in F_5 progeny (Laffa S x IPM-31) Green Globose which statistically different with rest. The lowest fruit diameter appeared in F_5 progeny (Laffa S x IPM-31) Green White Long and showed significant difference from the rests.

The highest individual fruit weight was found in F_5 offspring (Laffa S x IPM-31) Green Globose which differed significantly with F_5 progeny (Laffa S x IPM-31) Purple Globose and parent IPM 31. There was no significant difference among F_5 progeny (Dohazari G x IPM-31), parent cv Laffa S and cv Dohazari G for fruit weight. The lowest individual fruit weight was observed in IPM 31.

Variability, heritability and genetic advance for yield contributing characters of eggplant: Different genetic parameters as the yield contributing characters in eggplant i.e. genotypic and phenotypic variance, genotypic and phenotypic coefficient of variation, heritability and genetic advance are presented in Table 6.

Highest genotypic variance (δ^2g) and phenotypic variance (δ^2p) was found in individual fruit weight plant^{-1}.This was followed by Number of fruits plant^{-1}, number of secondary branches plant^{-1} and plant height. Low magnitude of δ^2g and δ^2p were observed in fruit breadth, number of primary branches plant^{-1} and fruit length.

The highest genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was found in number of fruits plant^{-1}.That was higher than number of secondary branch, number of primary branches plant^{-1} and fruit length. In contrast lowest GCV and PCV were originated for plant height.

Table 5. Mean performance of 3 parents and 5 cross materials of F_5 offspring of eggplants for yield contributing components.

Genotypes	Plant height (cm)	Number of primary branches/ plant	Number of secondary branches/ plant	Number of fruits/ plant	Fruit length (cm)	Fruit breadth (cm)	Individual fruit weight (gm)
(Dohazari G x IPM-31)							
Green Globose	58.990 b	14.800 b	16.275 b	12.550 b	15.528 bc	7.785 cd	293.895 a
Green Long	59.202 b	14.000 b	16.600 b	12.975 b	16.214 b	7.800 cd	280.913 ab
(Laffa S x IPM-31)							
Green Globose	69.222 a	15.950 b	17.125 b	13.000 b	11.102 d	9.463 a	297.925 a
Green White Long	59.440 b	15.250 b	15.625 b	11.925 b	16.352 bc	6.248 e	277.530 ab
Purple Globose	67.082 a	14.375 b	15.325 b	12.175 b	11.795 d	8.640 abc	252.577 b
IPM-31	68.392 a	18.840 a	23.063 a	12.170 b	12.490 d	8.985 ab	213.500 c
Laffa S	67.792 a	12.875 bc	18.820 b	23.675 a	15.025 c	8.148 bc	288.205 a
Dohazari G	57.008 a	7.950 c	14.537 b	24.425 a	23.305 a	7.010 de	289.100 a
CV (%)	4.81	15.94	10.75	10.25	7.72	5.38	5.48
LSD (%)	6.239	2.155	2.459	1.870	2.383	o.849	30.2

Lettering is done at alpha level=0.01

All characters showed high heritabilities, ranging from 66.62% for plant height to 99.10% for number of fruit/plant. Highest genetic advance in percentage (84.68) was found in number of primary branches plant^{-1} and lowest genetic advance in percentage (11.44) was found for plant height in the present study.

Relationships between different yield contributing characters: In eggplant, different yield contributing characters and their relationships were studied through analysis of correlation coefficients between them.

Table 6. Estimation of genetic parameters for yield contributing characters in 5 genotypes of eggplant

Characters	Grand Mean	Mean Range	Genotypic variance (σ^2 g)	Phenotypic variance (σ^2p)	Genotypic Coefficient of Variation (GCV%)	Phenotypic Coefficient of Variation (PCV %)	Heritability (%)	Genetic advance	Genetic Advance (%)
Plant height (cm)	64.75	58.99-69.89	19.38	29.09	6.80	8.33	66.62	7.41	11.44
Number of primary branches/plant	6.76	4.00-12.88	8.74	9.90	43.77	46.58	88.29	5.72	84.68
Number of secondary branches/plant	11.42	5.33-23.06	53.89	55.40	64.27	65.17	97.28	14.91	64.28
Number of fruits/plant	9.11	1.93-24.43	96.04	96.91	107.55	108.03	99.10	20.10	72.36
Fruit length (cm)	15.42	11.10-23.31	15.21	16.62	25.30	26.45	91.48	7.68	49.82
Fruit breadth (cm)	7.90	6.25-9.46	1.21	1.39	13.93	14.93	87.04	2.11	26.72
Individual fruit weight (gm)	275.46	213.50-299.10	794.91	1022.39	10.24	11.61	77.75	51.21	18.59

Individual fruit weight was positively and significantly correlated with plant height (0.818**), number of primary branches plant^{-1} (0.702**) and number of secondary branches plant^{-1} (0.729**) and insignificant with fruit length (0.397) and fruit breadth (0.124). It was negatively and significantly correlated with number of fruits per plant (-0.796**). Plant height was positively and significantly correlated with number of primary branches plant^{-1}(0.704**), number of secondary branches plant^{-1}(0.693**), fruit length (0.427*) and individual fruit weight (0.818**). Plant height was insignificant with fruit breadth (-.297) but negatively significant with number of fruits per plant (-.680**). The relationship of number of primary branches plant^{-1} with number of secondary branches plant^{-1} (0.764**) and individual fruit weight (0.702**) was positively significant at both levels. There were negative significant correlation among number of fruits per plant, fruit breadth (-0.534*) and individual fruit weight (-0.796**).

The relationship of fruit length and fruit breadth with all other characters was positive except number of fruits per plant though it was insignificant. Fruit breadth had negative correlation with all characters except number of secondary branches and was insignificant at both phenotypic and genotypic level.

Heterosis of the cross for yield contributing characters in eggplant: For individual crosses i.e. five F_5 crosses, percent heterosis was estimated for different characters over better parent (BP) and are presented in Table 7. The percent heterosis for plant height ranged from 7.60 to 22.59 over their corresponding higher parental values. Both F_5 crosses (Laffa S × IPM-31) and (Dohazari G × IPM-31) showed significant heterosis over better parent at 0.1% and 1% level respectively.

Positive heterosis was obtained in F_5 cross Dohazari G × IPM-31 for plant height, fruit breadth and individual fruit weight over better parental values. Number of secondary branches showed negative heterosis in F_5 cross Dohazari G × IPM-31 and negative heterosis in F_5 cross Laffa S × IPM-31. Individual fruit weight showed positive heterosis in both crosses over better parent but statistically insignificant. Negative significant heterosis was found in both crosses for number of fruits plant^{-1} over both parental values. Heterosis were obtained in both crosses for fruit length ranged from -0.34% (negative in F_5 cross Dohazari G × IPM-31) to 10.69% (positive in F_5 cross Laffa S × IPM-31) over better parental values.

The percent heterosis for fruit breadth ranged from -13.34 % (in cross Laffa S × IPM-31) to 5.82 % (in F_5 cross Dohazari G × IPM-31) over their corresponding higher parental values over mid parental values. Both crosses showed significant heterosis but negative over better and positive over mid parental values.

Table 7. Percent heterosis for different characters in F_5 generation in eggplant

Cross	Plant height (cm)	Number of primary branches /plant	Number of secondary branches/plant	Number of fruits /plant	Fruit length (cm)	Fruit breadth (cm)	Individual fruit weight (gm)
(Laffa S x IPM-31)	22.59***	15.83***	12.09***	-26.33***	10.69***	-13.34***	7.01
(Dohazari G x IPM-31)	7.60**	-13.68***	-20.99***	-23.29***	-0.34	5.82***	1.72

Here, ** $p < 0.05$; *** $p < 0.001$, Note: For each cross indicates percent heterosis over better parent

Vadivel and Bapu (1990) found high heritability, coupled with high genetic gain from fruit girth and length indicating the predominance of additive gene effects. Therefore, selection for these characters would get a good response even in the early generation. In the present study, high heritability and genetic advance for fruit breadth, fruit length, number of secondary branches plant^{-1}, number of fruits plant^{-1} and individual fruit weight indicated the possibility of improvement of these traits contributing to yield. These results can interpret with results of Baswana *et el.* (2002), Nainar *et al.* (1991).They showed high heritability for number of fruits plant^{-1} with high genetic

advance as percentage of mean. On the other hand, Singh and Singh (2004) reported high heritability for these traits which partially agree with the present study. This indicated that the presence of major role of additive gene action in the inheritance of these characters.

Donor parent IPM-31 and the plants of its F_5 generation showed resistant reaction to *Phomopsis vexans*. The F_5 plants also showed positive response to genetic characters in terms of agronomic and yield contributing properties. It may be concluded that the resistance trait in IPM-31 transferred to F_1 through cross with susceptible eggplant cultivars is continued to be inherited.

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