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C Aravindh
Horticulture Officer, State Horticulture Farm, Aduthurai, Tamil Nadu, India

P Bhavana
Senior Scientist (Plant Breeding), ICAR, Research Complex for Eastern Region, FSRCHPR, Ranchi, Jharkhand, India

AK Singh
Head, ICAR, Research Complex for Eastern Region, FSRCHPR, Ranchi, Jharkhand, India

AK Jha
Senior Scientist (Plant Pathology), ICAR, Research Complex for Eastern Region, FSRCHPR, Ranchi, Jharkhand, India

Nawed Anjum
Scientist D, Department of Genetics and Genomics, Rajendra Institute of Medical Science, Ranchi, Jharkhand, India

Corresponding Author:
P Bhavana
Senior Scientist (Plant Breeding), ICAR, Research Complex for Eastern Region, FSRCHPR, Ranchi, Jharkhand, India

Genetic variability and association studies for yield traits and bacterial wilt resistance in brinjal (*Solanum melongena* L.)

C Aravindh, P Bhavana, AK Singh, AK Jha and Nawed Anjum

Abstract
Eleven diverse genotypes of brinjal along with twenty four F_1s developed in line x tester fashion were evaluated for genetic variability, correlation and path coefficient for yield, its contributing traits and resistance to bacterial wilt. Significant and higher heritability was observed for percent plant survival against bacterial wilt followed by fruit circumference. High estimates of genotypic coefficient of variation, heritability and genetic advance as percent of mean for fruit yield, fruit weight, fruit length, fruit circumference, number of fruits per plant and percent plant survival against bacterial wilt indicated presence of additive gene action and suitability of these characters for further improvement by selection. Days to 50 % flowering recorded preponderance of non-additive gene action. Fruit yield showed positive significant association with fruit circumference and negative association with days to 50% flowering. Percent plant survival showed significant association with number fruits per plant. Path analysis revealed that fruit circumference followed by fruit length had highest direct effect on fruit yield.

Keywords: Correlation, genetic advance, GCV, heritability, path coefficient, PCV

Introduction

Brinjal (*Solanum melongena* L.) is a significant warm season vegetable crop in the family solanaceae and has chromosomal number 2n=24. It is the most popular vegetable crop cultivated throughout India in an area of 0.74 million hectares with a production of 12.8 million tons (NHB, 2020). West Bengal, Orissa, Gujarat, Bihar, Madhya Pradesh, Chhattisgarh, Andhra Pradesh, and Tamil Nadu are the leading producers. Breeding efforts for brinjal have been concentrated on creating varieties and hybrids with the features *viz*., high yield, earliness, fruit shape, size and colour as per the preference of the consumers, low proportion of seed, soft flesh, lower solanine content, free from lodging and resistant to pests and diseases, which are all important quality indicators in the brinjal development programme.

All brinjal genotypes don't respond well in all agro-climatic zones because of the type of soil and climatic conditions will vary from one zone to another. Consumer preferences also differ from one region to the next, and the regional preferences vary widely in terms of fruit shape, colour, and even the existence of calyx prickles.

The production of all plants is the consequence of a complex combination of genes and environmental influences. It's a quantitative trait that's linked to other characters. Environmental changes have an impact on component characters, including yield. As a result, the only way to increase yield is to pick appropriate component characters. Understanding the relationship between yield and its related features, as well as their direct and indirect contributions to yield, is crucial for improving brinjal production.

The genetic nature and degree of quantitatively inherited features must be elucidated, and the potentiality of parents in hybrid combinations must be evaluated, in order to design a productive breeding strategy in eggplant. The nature of the genetic and prepotency of the possible parents must be considered when choosing parents for hybridization.

Although a vast area is under brinjal cultivation, production is limited by many biotic stresses, and among them, bacterial wilt, incited by *Ralstonia solanacearum*, drastically reduces brinjal production from 11.67 to 96.67% (Bainsla *et al*., 2016) [2]. The knowledge about the genetics of bacterial wilt resistance is scanty, more so in relation to yield and yield components. Genetic study is required to understand the mechanism as well as to create an effective approach for incorporating resistance and improving production.

Hence the present study was undertaken to evaluate best performing inbreds and their Line x Tester crosses for genetic variability and character association studies with regards to yield, its contributing traits and resistance to bacterial wilt.

Materials and Methods

The present experiment was conducted to study genetic variability and character association in eleven inbreds and twenty four L x T crosses during Rainy season, 2021 at ICAR RCER FSRCHPR (Research Complex for Eastern Region Farming System Research Centre for Hill and Plateau Region) Plandu, Ranchi. The research farm is situated at VII agro-climatic zone (Central and North Eastern Part of Jharkhand) and is located in between 23° 17' North latitudes and 85˚19' East longitudes with the elevation of 625 meters MSL (Mean Sea Level). The site receives an average rainfall at the amount of 1400mm per annum, mostly during the Southeast monsoon period (June-August) as well as the average temperature ranged from 7.5 °C in December to 37.7 °C in May. The relative humidity ranged from 55% in winter to 88% in rainy season. The soil type of the research field was observed with laterite soil with texture being sandy loam at surface and pH of the soil is 4.5- 5.5.

During the kharif season of July 2021, all thirty-five entries (8 lines, 3 testers and 24 F_1 hybrids) of seeds were sown in portray under nursery condition. The seedlings of 30 days old were transplanted in the research field under open condition. The selected 10 healthy seedlings from each entry were planted under RBD (Randomised block design) with 3 replications at the spacing of 1 x 0.5 m distance. The standard cultivation practices were followed for the cultivation of brinjal crops as recommended package of practices by SAU's and ICAR Institutes. Throughout the cultivation period, adequate cultural and plant protection measures were implemented.

Data collection

In each of the 3 replications, the observations were noted on five randomly selected plants, and the mean values were used for the analysis of this research work. Data on days to 50% flowering, fruit length, fruit circumference, average fruit weight, number of fruits per plant, percent plant survival against wilt, fruit yield per plant and fruit yield per ha were recorded. Wilt resistance data was recorded as percentage of plants survived at 90 days after transplanting under natural field conditions. Susceptible checks showed 100% mortality indicating sufficient inoculums under natural field conditions. Evaluating material was transplanted in wilt sick plots during rainy season and artificially inoculated with bacterial suspension (Biovar III, Race 1) in the third leaf axil from the top. Observations on death count due to bacterial wilt were recorded 90 days after transplanting. Scoring was done on the basis of percentage of wilted plants *viz.*, 1-20% resistant and >20% as susceptible.

Statistical analysis

The genotypic and phenotypic coefficients of variation were calculated as suggested by Burton (1952) [3], while heritability and genetic advances were estimated as per the procedure of Allard (1960) [1]. Correlation and path analysis were carried out using statistical package OPSTAT.

Results and Discussion

Analysis of Variance

Analysis of Variance revealed significant differences for all the traits in the randomized block design's analysis of variance with regard to all the genotypes, parents and hybrids with the exception to parents vs hybrids were significant only for fruit length, fruit weight, number of fruits per plant, fruit yield per plant and total yield which suggested that the genotypes were highly variable (Table 1).

Table 1: Analysis of variance for different yield and yield traits and percent plant survival against wilt in brinjal

		Mean sum of square							
Source of variation	**D.F**	**DTFF**	**FL**	**FC**	**FW**	**NFPP**	**FY/P**	**TY**	**PPS**
Replication	2	0.8	1.52	1.54	430.543	19.077	0.246	106.46	21.181
Genotypes	34	54.57**	24.145**	48.25**	6358.369**	111.117**	0.303**	189.296**	2996.215**
Parents	10	72.018**	56.895**	89.84**	15895.206**	66.383**	0.338**	205.515**	2351.352**
Hybrids	23	49.231**	10.413**	31.798**	1905.457**	130.307**	0.262**	155.713**	3148.956**
Parents vs Hybrids	1	2.889	12.461*	10.77	13406.973**	117.069**	0.886**	799.518**	5931.794
Error	68	5.28	2.345	3.56	825.817	7.725	0.066	38.489	26.357

*Significant at 5% level

**Significant at 1% level

Mean performance

The analysis of the per se performance of the eleven parents and twenty four F1 hybrids for each of the studied traits showed a wide range of mean values, indicating that the parents used in this research had been genetically diverse and had potential breeding significance, which supported the analysis of variance's predictions (Table 2).

Table 2: Mean performance of the lines and testers for yield traits and bacterial wilt resistance of brinjal

Genotype	Days to 50% flowering	Fruit length (cm)	Fruit cir.(cm)	Avg fruit weight (g)	No. of fruits per plant	Fruit yield per plant (kg)	Total yield (t/ha)	% Plant Survival against Bacterial Wilt
LINES								
S. Avilamb	41.67	21.57	8.67	61.00	14.71	1.07	25.91	16.33
HAB-792	46.67	10.80	9.20	32.67	23.12	0.73	17.24	90.00
HABR-6	46.33	8.53	20.00	137.00	11.46	1.06	23.44	45.33
HAB-913	40.33	8.30	15.00	67.33	15.43	1.11	26.97	59.67
HABR-21	47.33	12.33	18.00	140.00	7.57	1.25	31.18	42.33
S.Pratibha	44.00	14.97	12.23	84.33	15.00	0.99	24.04	60.00
S. Shyamli	32.00	8.50	25.23	202.00	12.92	1.95	42.57	71.67
HAB-917	49.33	9.30	14.53	285.00	4.80	0.87	10.41	24.33
Lines Mean	43.46	11.79	15.36	126.17	13.13	1.13	25.22	51.21
TESTERS								
HAB-901	40.67	8.17	16.90	81.00	15.90	1.12	26.63	94.00
IC-545901	46.33	15.67	11.80	78.00	13.26	0.77	19.31	92.00
IC-261786	47.00	15.83	6.67	119.67	14.05	0.84	19.79	91.33
Testers mean	44.67	13.22	11.79	92.89	14.41	0.91	21.91	92.44
Parent Mean	43.79	12.18	14.38	117.09	13.47	1.07	24.32	62.45
HYBRIDS								
Hybrid Mean	43.43	11.44	13.70	92.75	15.75	1.26	30.26	46.26
Grand Mean	43.54	11.67	13.91	100.40	15.04	1.20	28.39	51.35
S.E.(m)	1.33	0.88	1.09	16.59	1.61	0.15	3.58	2.96
C.D. @ 5%	3.74	2.49	3.07	46.82	4.53	0.42	10.11	8.36
C.D. @ 1%	4.97	3.31	4.08	62.18	6.02	0.55	13.42	11.11

Parameters of Genetic variability

The parameters of genetic variability *viz*., phenotypic and genotypic coefficient of variation, broad sense heritability and genetic advance as percentage of mean have been depicted in Table 3.

Table 3: Estimates of GCV, PCV and Genetic advance of 35 genotypes of brinjal

Variances	Days to 50% flowering	Fruit length (cm)	Fruit cir. (cm)	Avg. fruit weight (g)	No. of fruits per plant	Fruit yield per plant (kg)	Total yield (t/ha)	% Plant Survival against Bacterial Wilt
Heritability	83.22	84.55	92.42	79.18	69.27	54.52	63.02	98.08
Genetic Advance	8.91	8.01	10.69	127.94	7.53	0.43	12.38	56.93
Genetic Advance as percent of mean	20.35	65.76	74.33	109.26	55.86	35.54	50.91	91.15
GCV	10.83	34.72	37.53	59.61	32.58	23.37	31.13	44.68
PCV	11.87	37.76	39.04	66.99	39.15	31.65	39.22	45.12

Heritability, Phenotypic and genotypic coefficients of variation

The success of any plant breeding programme is heavily reliant on understanding the genetic variation contained in a given crop species for the attribute under development. The genotypic coefficient of variation evaluates the extent of variability present in a crop and also allows for comparison of the degree of variability existing in various traits. The interaction between genotype and environment results in the character denoted as phenotypic expression. To examine the inheritance pattern of the specific trait under study, the entire variation must be partitioned into heritable and non-heritable components.

Heritability refers to the degree to which a trait is passed on from parent to offspring. High heritability values imply that the trait under investigation is least affected by their environment in its expression, and such traits could be enhanced by using easy selection procedures. Furthermore, knowledge on genetic variety, heritability, and genetic advance aids in estimating the genetic gain that could be acquired in subsequent generations if selection is used to improve the trait under study. A comparison of heritability values and predicted genetic advance expressed as a percentage of means provides insight into the nature of gene action influencing a certain trait.

The heritability (h^2) values ranged from 54.52 to 98.08. The significant and higher heritability was observed for percent plant survival against bacterial wilt (98.08) followed by fruit circumference (92.42), fruit length (84.55), days to fifty percent flowering (83.22), average fruit weight (79.18), number of fruits per plant (69.27) and total yield per hectare (63.02) whereas, significant and moderate heritability was recorded for fruit yield per plant (54.52).

Higher genotypic coefficient of variation, higher phenotypic coefficient of variation, high heritability and high genetic advance as percent mean for total yield, fruit weight, fruit length, fruit circumference, number of fruits per plant and percent plant survival against bacterial wilt indicates significance of additive gene action governing this trait. So, further selection will improve this trait. Similar results were obtained for some of these characters by Sharma and Swaroop (2000) [8] and Sunitha and Bandhopadhya (2005) [10].

Low genotypic coefficient of variation, medium phenotypic coefficient of variation, higher heritability and high genetic advance as percent mean for days to fifty percent flowering indicating the significance of non-additive gene action

governing this trait. Percent plant survival showed high genotypic coefficient of variation and phenotypic coefficient of variation, higher heritability and genetic advance as percent mean indicating the significant of additive gene action governing this trait.
Other traits observed medium to higher GCV and PCV, medium to higher heritability and high genetic advance as percent mean showing the additive gene action controlling all these traits. So, here simple selection is effective for further crop improvement.

Correlation
The genotypic and phenotypic correlation coefficient for fruit yield per hectare and its association existing among the seven traits are presented in Table 4 (upper line genotypic and lower line phenotypic correlation coefficients respectively).
Strong positive correlation among the yield and yield traits was reported except fruit length. This means that improvement in any yield trait would result in improvement of yield. Correlation study showed that days to fifty percent flowering was significant and negatively correlated with fruit circumference and total yield per hectare; Fruit circumference was significant and positively correlated with fruit weight and total yield per hectare; Number of fruits per plant was significant and positively correlated with percent plant survival against bacterial wilt at both genotypic and phenotypic level. Positive association of fruit yield with fruit length was reported by Patel and Sarnaik (2004) [6] and with number branches/plant and plant height by Prasath *et al*. (2001) [7].

Table 4: Genotypic and phenotypic correlation co-efficient for yield related traits of brinjal

Traits	DTFF	FL	FC	FW	NFPP	PPS	FYPH
DTFF	1						
FL	0.216NS 0.164 NS	1					
FC	-0.582** -0.465**	-0.724** -0.608**	1				
FW	0.009NS 0.076 NS	-0.436* -0.248NS	0.479** 0.494**	1			
NFPP	-0.253NS -0.219 NS	0.136NS 0.040NS	-0.435* -0.285NS	-0.907** -0.676**	1		
PPS	-0.141NS -0.111 NS	-0.213NS -0.190NS	-0.113NS -0.106NS	-0.426* -0.358*	0.632** 0.503**	1	
FYPH	-0.897** -0.744**	-0.179NS -0.098NS	0.716** 0.585**	-0.047NS 0.003NS	-0.054NS 0.156NS	0.047NS 0.031NS	1

Path coefficient analysis
Highest direct effect was recorded by fruit circumference at both genotypic and phenotypic level followed by fruit length. In case of indirect effect, fruit weight had highest indirect effect via fruit circumference at both genotypic and phenotypic level. Highest direct effect on fruit yield by plant height was observed by Mohanty (1999) [5] and fruit breadth by Singh *et al*. (2003) [9]. Direct and indirect effect of yield traits over fruit yield per hectare at genotypic level is given in the Table 6. Mishra *et al*. (2007) [4], Singh *et al*. (2003) [9] and Sharma and Swaroop (2000) [8] observed similar indirect effects on fruit yield.

Table 6: Direct and indirect effect of yield component on fruit yield at a genotypic level

Traits	DTFF	FL	FC	FW	NFPP	PPS	rG
DTFF	-0.127	0.201	-0.850	0.001	-0.094	-0.027	-0.897**
FL	-0.027	0.931	-1.058	-0.034	0.051	-0.041	-0.179NS
FC	0.074	-0.674	1.462	0.037	-0.162	-0.022	0.716**
FW	-0.001	-0.406	0.701	0.078	-0.338	-0.081	-0.047NS
NFPP	0.032	0.127	-0.635	-0.071	0.372	0.121	-0.054NS
PPS	0.018	-0.199	-0.166	-0.033	0.235	0.191	0.047NS

Residual effect = 0.02133

Conclusion
The present study was undertaken to evaluate best performing inbreds and their Line x Tester crosses for genetic variability and character association studies with regards to yield, its contributing traits and resistance to bacterial wilt. High genotypic coefficient of variation, heritability and genetic advance as percent of mean was observed for fruit yield, fruit weight, fruit length, fruit circumference, number of fruits per plant and percent plant survival against bacterial wilt indicated presence of additive gene action and suitability of these characters for further improvement by selection. Fruit yield showed positive significant association with fruit circumference and negative association with days to 50% flowering. Percent plant survival showed significant association with number fruits per plant. Path analysis at genotypic and phenotypic levels revealed that fruit circumference had highest positive direct effect on total yield as well as the correlation coefficient of fruit circumference was highly significant and positive.

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