Eco. Env. & Cons. 30 (July Suppl. Issue) : 2024; pp. (S275-S283)
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ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2024.v30i04s.049

Evaluation of hybrids of eggplants (*Solanum melongena* L.) under organic cultivation conditions

Suren Limbu, Laxuman Sharma*, Rajesh Kumar, Manju Rana and Sujata Upadhyay

Department of Horticulture, School of Life Sciences, Sikkim University
6th Mile Tadong, Gangtok 737 102, Sikkim, India

(Received 22 November, 2023; Accepted 19 January, 2024)

ABSTRACT

Organic farming is a sustainable approach in agriculture aimed at maintaining environment-friendly farming by relying on natural/organic inputs. The study aimed to investigate the genetic factors influencing yield in eggplant (*Solanum melongena* L.) hybrids under organic cultivation conditions using the line x tester analysis. Four lines and four testers of eggplant were crossed in a line x tester mating scheme, resulting in 16 F1 hybrids. Heterosis and combining ability for yield and other growth parameters of the hybrids were studied for their yield and other traits. IIHR-563 x Arka Kusumkar (44.63%) and VR-2 x Rajendra Baigan (84.50%) exhibited the maximum heterosis percentage for yield per hectare over the better parent and the check variety (PPL), respectively. In respect to the earliness of the crop, 16 days were shortened in the cross of IIHR-562 x Swarna Mani over its better parent and 5.29 days in IIHR-562 x Mukta Keshi over PPL. IIHR-562, Punjab Baigan 67, Mukta Keshi, and Rajendra Baigan were found to be ideal general combiners for the manifestation of earliness in the crop, and VR-2, Mukta Keshi, and Rajendra Baigan were good combiners for the increase in yield of the crop.The insights of the study can be utilized in optimizing breeding strategies for developing high-yielding eggplant hybrids under organic cultivation conditions.

Key words: *Brinjal, F1 hybrids, Yield, Line x tester, GCA, SCA.*

Introduction

India experienced a significant increase in food production in the era of the green revolution. Nevertheless, the excessive application of chemical fertilizers and pesticides led to diminished soil fertility and the contamination of underground water. Consequently, organic farming has been advocated as an environment-friendly approach to sustainable agriculture (Singh *et al.,* 2019). Notably, Sikkim stands out as the sole state in India that has fully embraced organic farming since 2003. The state cultivates a diverse range of vegetables, including eggplant.

The global annual production of eggplant is 59 million tonnes (FAO 2022), with India contributing 12.77 million tonnes from 0.68 million hectares, representing 5.93% of the total vegetable area and 6.10 % of total vegetable production (Department of Agriculture & Farmers Welfare, GoI 2021-22). It ranks fourth in economic importance among solanaceous vegetables, following potato, tomato, and pepper (Oladosu *et al.,* 2021; Taher *et al.,* 2017).

India's primary origin for eggplant displays a wide range of genetic and phenotypic variations. These variations, combined with the crop's natural cross-pollination tendencies, offer the potential for crop improvement through heterosis (Gramazio *et al.,* 2023; Boyaci *et al.,* 2015; Reddy and Patel, 2014; Bhushan *et al.,* 2012). Besides its wide popularity among consumers with different preferences regarding fruit shape, fruit colour, fruit size, and other characteristics of the crop, the availability of high-yielding eggplant varieties and hybrids have boosted global and Indian production. However, continued crop improvement through hybridization remains crucial for enhancing both yield and quality (Alam and Salimullah 2021; Kumar *et al.,* 2020; Akpan *et al.,* 2016; Prasad 2007).

Environmental stresses caused by a changing climate have led to limited production in major eggplant-producing countries (Alam and Salimullah, 2021). Therefore, farmers require improved varieties to ensure sustainable production and adapt to the challenges posed by climate change (Taher *et al.,* 2017). Heterosis, the increase in character value in F1 hybrids compared to the average value of both parents, is a primary goal in plant breeding and has been widely employed in various crop species. One of the most effective methods for identifying the best combiners, whether to harness heterosis or accumulate productive genes, is combining ability analysis (Rameshkumar *et al.,* 2023; Alam and Salimullah, 2021; Legesse, Pixley and Botha *et al.,* 2009). The deployment of heterosis across multiple attributes including yield, earliness, and broader adaptability for enhancing brinjal's genetic potential has emerged as a crucial tool (Shankaraiah and Rao, 1990) and the manifestation of heterosis in eggplant is expected to increase because of its various economic traits and the ease of hybridization (Siddhu *et al.,* 2005). Understanding the gene action and trait inheritance for crop improvement is essential. The Line x Tester (LxT) mating design is one of several mating designs used to obtain information that reveals the performance of the parents in a series of cross combinations (Kaushik, 2019). In this scheme, lines serve as female parents, and testers serve as male parents. In consideration of the aforementioned factors, the L x T was designed to investigate heterosis and the combining ability of various eggplant genotypes, with the aim of producing superior F1 hybrids exhibiting enhanced yields and other economically valuable traits in the plant under fully organic conditions.

Materials and Methods

Four lines, namely VR-2 (L1), IIHR-562 (L2), IIHR-563 (L3), Punjab Baigan 67 (L4), and four male testers, namely Arka Kusumkar (T1), Mukta Keshi (T2), Rajendra Baigan (T3), and Swarna Mani (T4), were crossed in a Line x Tester (L x T) mating design, resulting in 16 hybrids combinations. These hybrids, as well as the parent used in the crosses and PPL as a check variety, were evaluated for Plant Height (PH), Number primary branches per plant (NBP), Days taken to 50% flowering (DTF), Days taken to first harvesting (DTH), Number fruits per plant (NFP), Fruit weight (FW), Fruit length (FL), Fruit circumference (FC), Fruit Yield per plant (FYP) and Fruit yield hectare (FYH). The experimental field was arranged in a Randomized Block Design (RBD) with three replications of each genotype. The study was conducted at the experiment field of Sikkim University (27º12′52" N and 88º38′45" E) at an elevation of 1050 meters above sea level. Heterosis was analyzed following Panse and Sukhatme (1967) and the magnitude of heterosis [percentage of F1 hybrids over better parent and commercial variety (PPL) was estimated using Turner (1953) and Fonseca and Patterson (1968). OPSTAT an online software program was used to estimate the general combining ability (GCA) and specific ability analysis (SCA)

Heterobeltiosis (BP)= F1-P/F1 X100 Where, BP= better performance of the ether of the parents in the cross, F1= mean performance of F1.

Standard heterosis (SH) = F1-CV/SC/F1 X100 Where, CV/SC = mean performance of check variety/standard check, F1= mean performance of F1

Results

Effects of genotypes on yield and other characters in eggplant

Table 1 revealed that the F1 hybrid between IIHR 562 and Mukta Keshi achieved the maximum plant height, which was comparable to that of 23 IIHR-562 X Mukta Keshi, Punjab Baigan 67 x Rajendra Baigan, Punjab Baigan, VR-2 x Rajendra Baigan, and Punjab Baigan 67 x Swarna Mani. The check variety PPL exhibited the lowest plant height. Mukta Keshi had the highest number of primary branches per plant which was at par with IIHR-563 x Mukta Keshi, IIHR-563, Punjab Baigan 67 x Rajendra Baigan, Punjab Baigan x Mukta Keshi, Punjab Baigan, IIHR 563, Rajendra Baigan, VR-2 x Arka Kusumkar, IIHR-563 x Rajendra Baigan, IIHR-562 x Mukta Keshi, VR-2 x Mukta Keshi, Punjab Baigan 67 x Arka Kusumakr, PPL. In contrast, the minimum number of branches was recorded in IIHR 562. The shorter the time taken for flowering and harvesting, the earlier the crop matures. Therefore, crosses of IIHR-562 x Mukta Keshi, Punajb baigan 67 x Arka Kusumakr, and IIHR562 x Rajendra Baigan demonstrated earliness in flowering and harvesting. The maximum number of days taken for 50% flowering was observed with the cross IIHR-563 x Swarna Mani, followed by Swarna Mani, VR2, and IIHR 563. Similarly, the maximum number of days for the first harvest was recorded with Swarna Mani, Arka Kusumkar, IIHR-563 x Arka Kusumkar, IIHR 563, and IHR-563 x Swarna Mani. The highest number of fruits per plant was observed in PPL, which was at par with IIHR-563 x Mukta Keshi, IIHR-563 x Arka Kusumkar, while the minimum was recorded in Swarna Mani and IIHR-563 x Swarna Mani.

Swarna Mani and Mukta Keshi had the maximum individual fruit weight, while PPL, VR2, and Punjab Baigan had the minimum fruit weight.F1 hybrid of IIHR-563 x Mukta Keshi produced the longest fruit length and was significantly superior to all other genotypes, while Swarna Mani, IIHR-563 x Swarna Mani, and IIHR 562 had shorter fruits. Mukta Keshi and Swarna Mani had the maximum fruit circumference and were significantly similar to each other, while PPL and Punjab Baigan 67 x Swarna Mani had the smallest fruit circumference. Crosses of VR-2 x Arka Kusumakr and VR-2 x Rajendra Baigan yielded the maximum fruit yield per plant and yield per hectare, while IIHR 562 and IIHR-562 x Arka Kusumkar had the minimum yield per plant, and IIHR 562 and IIHR 563 had the minimum yield per hectare (Table 2).

Estimation of heterosis over the better parent and check variety (PPL) for yield and other different characters in eggplant

Referring to Table 3, among the 16 F1 hybrids, seven exhibited heterosis for plant height compared to

Table 1. Effects of genotypes onplant height, number of primary branches per plant, days taken to 50% flowering, days taken for first harvesting and number of fruits per plant in eggplant

Crosses	PH (cm)	NBP	DTF	DTH	NFP
L1 (VR-2)	135.25±3.47^{def}	4.70±0.45^{abcdef}	57.89±2.08^{abc}	73.87±1.28^{bcd}	9.40±0.82^{efgh}
L2 (IIHR-562)	124.95±1.99^{h}	3.93±0.20^{f}	50.95±0.18f^{gh}	66.37±3.11^{fghijk}	6.57±0.62^{k}
L3 (IIHR-563)	133.20±1.40^{fg}	4.89±0.23^{abcde}	57.49±1.65^{abc}	77.12±1.41^{ab}	5.92±0.17^{k}
L4 (Punjab Baigan 67)	139.90±4.03^{ab}	5.02±0.86^{abc}	50.21±1.06^{ghi}	66.50±3.05^{fghijk}	11.73±0.67^{c}
T1(Arka Kusumkar)	130.54±0.86^{g}	4.40±0.79^{bcdef}	54.95±1.88^{cde}	80.0±1.041^{a}	8.98±0.24^{fghi}
T2 (Mukta Keshi)	137.05±2.10^{bcde}	5.41±0.85^{a}	48.95±1.95^{ghij}	69.82±1.00^{defg}	5.96±0.18^{k}
T3 (Rajendra Baigan)	99.82±0.92^{j}	4.93±0.23^{abcd}	56.18±1.67^{bcd}	73.87±3.37^{bcd}	9.67±0.31^{efg}
T4 (Swarna Mani)	135.52±1.78^{cdef}	4.16±0.03^{cdef}	59.57±0.98^{ab}	80.01±2.78^{a}	3.57±0.41^{l}
VR-2 X Arka Kusumkar	135.63±1.45^{cdef}	4.96±0.12^{abc}	55.29±1.59^{cde}	72.01±2.29^{cde}	10.07±0.54^{ef}
VR-2 X Rajendra Baigan	138.85±1.27^{abc}	4.79±0.59^{abcdef}	45.96±0.27^{jk}	70.45±3.38^{def}	10.43±0.69^{de}
VR-2 X Mukta Keshi	134.04±1.24^{ef}	4.71±0.43^{abcdef}	46.29±2.84^{jk}	68.89±1.95^{efgh}	8.70±0.65^{ghi}
VR-2 X Swarna Mani	134.57±0.58^{def}	4.07±0.06^{def}	55.29±3.17^{cde}	73.75±1.63^{bcd}	6.94±0.67^{jk}
IIHR-562 X Arka Kusumkar	124.44±0.63^{h}	4.49±0.53^{bcdef}	51.67±1.40^{efg}	68.31±0.47^{efghi}	7.90±0.60^{ij}
IIHR-562 X Rajendra Baigan	135.58±1.35^{cdef}	4.23±0.89^{cdef}	48.79±1.10^{ghij}	63.97±2.06^{ijk}	6.00±0.00^{k}
IIHR-562 X Mukta Keshi	140.55±1.90^{a}	4.94±0.52^{abcd}	45.60±3.17^{jk}	62.38±1.94^{k}	7.85±0.23^{ij}
IIHR-562 X Swarna Mani	115.11±1.57^{i}	4.03±0.11^{ef}	47.66±0.37^{hijk}	67.21±2.08^{fghij}	6.92±0.34^{jk}
IIHR-563 X Arka Kusumkar	135.08±0.11^{def}	4.88±0.73^{abcde}	52.39±2.78^{defg}	78.45±2.53^{a}	12.53±0.42^{abc}
IIHR-563 X Rajendra Baigan	137.82±0.61^{abcd}	4.85±0.20^{abcde}	54.57±3.62^{cdef}	69.44±3.27^{defg}	8.37±0.87^{hi}
IIHR-563 X Mukta Keshi	136.05±1.45^{cdef}	5.15±0.28^{ab}	50.85±0.72^{fgh}	64.85±0.72^{hijk}	13.42±0.75^{ab}
IIHR-563 X Swarna Mani	125.75±1.77^{h}	4.29±0.35^{bcdef}	60.78±1.40^{a}	76.34±0.53^{abc}	4.64±0.74^{l}
Punjab Baigan 67 X Arka Kusumkar	136.67±0.47^{bcde}	4.78±0.45^{abcdef}	46.54±1.57^{ijk}	63.64±2.33^{ijk}	11.95±0.39^{c}
Punjab Baigan 67 Rajendra Baigan	140.00±1.48^{ab}	5.02±0.10^{abc}	46.13±1.37^{jk}	66.63±2.56^{fghijk}	11.49±0.77^{cd}
Punjab Baigan 67 X Mukta Keshi	124.74±2.48^{h}	4.80±0.45^{abcdef}	43.87±1.89^{k}	65.63±2.26^{ghijk}	12.22±068^{bc}
Punjab Baigan 67 X Swarna Mani	139.50±2.06^{ab}	4.27±0.42^{cdef}	52.52±2.71^{defg}	68.56±1.32^{efgh}	9.62±1.18^{efg}
PPL	95.64±0.98^{k}	4.93±0.21^{abcd}	50.83±1.17^{fgh}	65.86±2.67^{ghijk}	13.64±0.32^{a}
Mean	130.65±1.20	4.66±0.31	51.65±1.37	70.16±1.59	8.98±0.43
LSD @ 0.05%	3.38	0.87	3.91	4.47	1.21

Table 1. PH= Plant Height; NBP= Number of primary branches per plant; DTF= Days taken for 50% flowering; DTH= Days taken for first harvesting; NFP= Number of fruits per plant. Mean with different letters indicate significant differences by the least significant difference (LSD).

their respective better parents, while this was not the case for standard heterosis, as all the F1s showed superiority over the check variety (PPL). In the case of the number of primary branches per plant, only four of the crosses showed heterosis for the number of branches per plant compared to both the better parents and the check variety. Earliness with respect to 50% flowering and the first harvesting of the crop was observed due to negative heterosis compared to the parents and the standard check in the crosses of IIHR-562 x Rajendra Baigan, IIHR-562 x Mukta Keshi, IIHR-563 x Mukta Keshi, Punjab Baigan 67 x Arka Kusumkar, and Punjab Baigan 67 x Swarna Mani. The maximum heterosis for the number of fruit per plant over the better parent was recorded in IIHR-563 x Rajendra Baigan, followed by IIHR-563 x Arka Kusumkar, IIHR-563 x Mukta Keshi, VR-2 x Rajendra Baigan, VR-2 x Arka Kusumkar, IIHR-562 x Swarna Mani, Punjab Baigan 67 x Mukta Keshi, and Punjab Baigan 67 x Arka Kusumkar. Only the cross between IIHR-563 x Mukta Keshi exhibited positive heterosis over the check variety for the trait. In terms of heterosis for fruit shape, only VR-2 x Swarna Mani, IIHR-562 x Arka Kusumkar, IIHR-562 x Rajendra Baigan, IIHR-562 x Swarna Mani, IIHR-563 x Mukta Keshi, and Punjab Baigan 67 x Mukta Keshi exhibited heterosis over the better parent for fruit length, while all the crosses showed negative heterosis against the standard check. For the circumference of the fruit, all the crosses reported negative heterosis against the better parent, and the reverse was observed in the case of heterosis over PPL. The maximum heterosis percentages for fruit yield per hectare, 44.6% over the better parent and 84.50% over PPL, were achieved by IIHR-563 x Arka Kusumkar and VR-2 x Rajendra Baigan, respectively.

General combining ability effects of parents for yield and other different characters in eggplant

Genotype analysis in Table 3 revealed that VR-2,

Table 2. Effects of fruit weight, fruit length, fruit circumference, fruit yield per plant and fruit yield per hectare.

Crosses	FW (g)	FL (cm)	FC (cm)	FYP (Kg)	FYH(Q)
L1 (VR-2)	6.07 ± 0.48^{jk}	23.98 ± 1.06^{b}	133.79 ± 3.08^{c}	1.21 ± 0.05^{bcd}	268.31 ± 10.78^{bcd}
L2 (IIHR-562)	5.48 ± 0.44^{kl}	15.57 ± 1.11^{g}	63.29 ± 2.91^{ij}	0.43 ± 0.05^{l}	95.76 ± 10.71^{l}
L3 (IIHR-563)	6.83 ± 0.26^{ij}	18.00 ± 0.00^{de}	71.57 ± 1.92^{ghi}	0.42 ± 0.01^{l}	93.18 ± 1.24^{l}
L4 (Punjab Baigan 67)	8.70 ± 0.42^{cd}	11.10 ± 1.30^{jkl}	68.94 ± 1.15^{hij}	0.82 ± 0.03^{h}	182.85 ± 6.16^{h}
T1(Arka Kusumkar)	8.85 ± 0.29^{c}	14.94 ± 1.57^{g}	63.51 ± 0.51^{ij}	0.57 ± 0.01^{jk}	125.84 ± 2.01^{jk}
T2 (Mukta Keshi)	7.48 ± 0.36^{fghi}	27.10 ± 0.56^{a}	175.93 ± 4.11^{b}	1.03 ± 0.02^{ef}	229.70 ± 3.38^{ef}
T3 (Rajendra Baigan)	10.80 ± 0.80^{b}	12.45 ± 0.71^{ijk}	96.45 ± 2.93^{d}	0.94 ± 0.04^{fg}	208.84 ± 9.61^{fg}
T4 (Swarna Mani)	5.10 ± 0.25^{l}	26.36 ± 1.54^{a}	194.67 ± 7.85^{a}	0.66 ± 0.08^{ij}	147.02 ± 17.46^{ij}
VR-2 X Arka Kusumkar	6.90 ± 0.08^{hi}	14.50 ± 1.87^{gh}	131.32 ± 0.65^{c}	1.29 ± 0.03^{ab}	286.93 ± 6.54^{ab}
VR-2 X Rajendra Baigan	6.83 ± 0.24^{ij}	17.74 ± 0.37^{ef}	136.33 ± 8.45^{c}	1.39 ± 0.18^{a}	309.51 ± 38.97^{a}
VR-2 X Mukta Keshi	6.03 ± 0.63^{jk}	16.09 ± 0.56^{fg}	130.06 ± 0.38^{c}	1.17 ± 0.05^{cd}	259.38 ± 10.51^{cd}
VR-2 X Swarna Mani	7.90 ± 0.30^{def}	24.42 ± 0.42^{b}	169.19 ± 7.39^{b}	1.12 ± 0.06^{de}	248.99 ± 13.00^{de}
IIHR-562 X Arka Kusumkar	8.89 ± 0.31^{c}	12.52 ± 0.74^{ijk}	65.82 ± 4.13^{hij}	0.53 ± 0.07^{kl}	117.62 ± 14.66^{kl}
IIHR-562 X Rajendra Baigan	7.73 ± 0.27^{efg}	22.03 ± 1.45^{c}	173.04 ± 2.06^{b}	1.04 ± 0.01^{ef}	230.68 ± 2.69^{ef}
IIHR-562 X Mukta Keshi	8.81 ± 0.62^{c}	11.55 ± 0.77^{jk}	77.45 ± 2.67^{fgh}	0.61 ± 0.01^{jk}	134.83 ± 2.10^{jk}
IIHR-562 X Swarna Mani	6.00 ± 0.16^{k}	15.33 ± 0.69^{g}	82.88 ± 1.82^{efg}	0.56 ± 0.02^{jk}	124.50 ± 4.19^{jk}
IIHR-563 X Arka Kusumkar	7.46 ± 0.38^{fghi}	12.79 ± 0.92^{hij}	64.92 ± 2.53^{ij}	0.82 ± 0.02^{h}	182.00 ± 3.89^{h}
IIHR-563 X Rajendra Baigan	6.99 ± 0.10^{ghi}	23.63 ± 0.74^{bc}	68.06 ± 1.76^{hij}	0.60 ± 0.01^{jk}	132.41 ± 2.81^{jk}
IIHR-563 X Mukta Keshi	15.32 ± 0.82^{a}	10.68 ± 1.26^{kl}	93.48 ± 5.04^{de}	1.25 ± 0.09^{bc}	277.74 ± 19.48^{bc}
IIHR-563 X Swarna Mani	5.37 ± 0.18^{kl}	19.8 ± 0.30^{d}	173.45 ± 4.53^{b}	0.75 ± 0.06^{hi}	165.77 ± 14.01^{hi}
Punjab Baigan 67 X Arka Kusumkar	8.47 ± 0.45^{cde}	12.33 ± 0.47^{ijk}	69.52 ± 5.04^{hi}	0.84 ± 0.06^{gh}	187.29 ± 14.07^{gh}
Punjab Baigan 67 Rajendra Baigan	8.91 ± 0.17^{c}	14.24 ± 0.92^{ghi}	87.53 ± 2.96^{def}	1.03 ± 0.03^{ef}	229.21 ± 5.75^{ef}
Punjab Baigan 67 X Mukta Keshi	8.27 ± 0.20^{cdef}	12.31 ± 0.52^{jk}	66.26 ± 2.00^{hij}	0.83 ± 0.05^{gh}	183.89 ± 10.52^{gh}
Punjab Baigan 67 X Swarna Mani	7.68 ± 0.58^{efgh}	9.29 ± 0.41^{lm}	64.56 ± 1.87^{hij}	0.64 ± 0.06^{ijk}	142.98 ± 13.13^{ij}
PPL	10.55 ± 0.50^{b}	8.46 ± 0.67^{m}	55.85 ± 1.32^{j}	0.75 ± 0.02^{hi}	167.76 ± 4.25^{hi}
Mean	8.90 ± 0.30	16.29 ± 0.29	103.16 ± 4.67	0.85 ± 0.04	189.32 ± 9.01
LSD @ 0.05%	0.82	1.91	13.15	0.17	25.35

Table 2. FW= Fruit weight; FL= Fruit length; FC= Fruit circumference; FYP= Fruit yield per plant, FYH= Fruit yield per hectare. Mean with different letters indicate significant differences by the least significant difference (LSD).

IIHR-563, Punjab Baigan 67, Mukta Keshi, and Rajendra Baigan showed positive general combining ability for plant height, while IIHR-562, Arka Kusumkar, and Swarna Mani exhibited negative combining ability for this trait. Most genotypes, except VR-2, IIHR-562, and Swarna Mani, contributed positively to the number of primary branches per plant. Negative GCA is desirable for early flowering and first harvesting (Kushwaha *et al.*, 2020). Among the parents, IIHR-562 and Punjab Baigan 67 lines, as well as Mukta Keshi and Rajendra Baigan testers were found to be suitable parents for the earliness in F1s. IIHR-563, Punjab Baigan 67, Arka Kusumkar, and Swarna Mani positively influenced the number

Table 3. Estimation of heterosis over the better parent and check variety (PPL) for yield and other different characters in eggplant

Crosses	PH (cm)		NBP		DTF		DTH		NFP	
	BP (%)	SH (%)	BP (%)	SH (%)	BP (%)	SH (%)	BP (%)	SH (%)	BP (%)	SH (%)
V2-2 X Arka Kusumkar	0.28	41.81	5.46	0.54	-4.49	8.78	-10.00	9.34	7.13	-34.60
VR-2 X Rajendra Baigan	1.32	45.18	-11.34	-2.77	-20.61	-9.58	-4.64	6.96	10.92	-35.23
VR-2 X Mukta Keshi	-0.90	40.15	-4.53	-4.46	-20.04	-8.93	-6.75	4.60	-9.97	-42.81
VR-2 X Swarna Mani	-0.70	40.71	-13.40	-17.44	-7.18	8.78	-7.82	11.98	-26.17	-25.12
IIHR-562 X Arka Kusumkar	-4.67	30.12	2.05	-8.92	-5.97	1.65	-14.62	3.73	-11.99	-15.77
IIHR-562 X Rajendra Baigan	-1.07	41.76	-21.83	-14.27	-4.24	-4.01	-8.38	-2.87	-8.68	-26.70
IIHR-562 X Mukta Keshi	12.49	46.96	0.14	0.20	-18.83	-10.28	-15.56	-5.29	-18.76	-16.52
IIHR-562 X Swarna Mani	-15.06	20.35	-3.20	-18.26	-20.00	-6.24	-16.00	2.04	5.33	-43.10
IIHR-563 X Arka Kusumkar	1.41	41.23	-0.14	-0.95	-8.86	3.08	-1.96	19.11	39.55	-29.32
IIHR-563 X Rajendra Baigan	0.56	44.10	-10.36	-1.69	-5.07	7.36	-9.96	5.44	40.44	-33.78
IIHR-563 X Mukta Keshi	2.14	42.25	4.46	4.53	-11.55	0.03	-15.92	-1.54	38.86	45.21
IIHR-563 X Swarna Mani	-7.21	31.48	-12.34	-13.05	2.02	19.57	-4.58	15.92	-21.61	-49.13
Punjab Baigan 67 X Arka Kusumkar	-2.31	42.90	-4.78	-3.11	-15.30	-8.43	-20.46	-3.37	1.93	-19.75
Punjab Baigan 67 Rajendra Baigan	0.07	46.39	-7.09	1.89	-8.13	-9.25	-4.56	1.17	-2.05	-15.55
Punjab Baigan 67 X Mukta Keshi	-10.83	30.43	-4.32	-2.64	-21.92	-13.70	-11.15	-0.35	4.24	-21.64
Punjab Baigan 67 X Swarna Mani	-0.28	45.86	-14.95	-13.46	-11.85	3.32	-14.31	4.10	-17.97	-27.20

Cont. of Table 3.

Crosses	FW (g)		FL (cm)		FC (cm)		FYP (Kg)		FYH(Q)	
	BP (%)	SH (%)	BP (%)	SH (%)	BP (%)	SH (%)	BP (%)	SH (%)	BP (%)	SH (%)
V2-2 X Arka Kusumkar	-1.84	135.14	-22.06	-34.60	-39.54	71.39	6.61	72.16	6.94	71.04
VR-2 X Rajendra Baigan	-22.51	144.11	-8.65	-35.23	-34.55	109.65	15.15	85.71	15.35	84.50
VR-2 X Mukta Keshi	-2.79	132.87	-44.15	-42.81	-32.93	90.15	-3.58	55.63	-3.33	54.61
VR-2 X Swarna Mani	-13.09	202.94	30.08	-25.12	-7.35	188.69	-7.44	49.40	-7.20	48.42
IIHR-562 X Arka Kusumkar	3.64	17.85	0.38	-15.77	-19.57	47.99	-7.06	-29.43	-6.54	-29.89
IIHR-562 X Rajendra Baigan	-1.64	209.84	3.39	-26.70	-18.72	160.36	0.32	38.41	0.43	37.51
IIHR-562 X Mukta Keshi	-19.70	38.67	-18.48	-16.52	-25.82	36.49	-35.82	-19.10	-35.44	-19.63
IIHR-562 X Swarna Mani	-57.43	48.40	9.55	-43.10	-41.84	81.21	-15.58	-25.30	-15.32	-25.79
IIHR-563 X Arka Kusumkar	-9.30	16.23	-15.78	-29.32	-28.94	51.18	44.12	9.20	44.63	8.49
IIHR-563 X Rajendra Baigan	-61.32	21.86	-6.60	-33.78	-12.79	179.35	-42.58	-20.55	-42.35	-21.07
IIHR-563 X Mukta Keshi	-3.07	67.38	41.81	45.21	-40.65	26.28	32.98	66.64	32.99	65.56
IIHR-563 X Swarna Mani	-10.90	210.56	-21.46	-49.13	-24.68	134.67	12.56	-0.54	12.75	-1.19
Punjab Baigan 67 X Arka Kusumkar	0.85	24.48	-4.37	-19.75	-17.45	45.78	2.43	12.37	2.43	11.64
Punjab Baigan 67 Rajendra Baigan	-50.25	56.73	2.41	-15.55	-47.47	68.28	-0.32	37.53	-0.21	36.63
Punjab Baigan 67 X Mukta Keshi	-31.30	18.65	-23.48	-21.64	-1.13	45.47	-12.06	10.33	-11.95	9.61
Punjab Baigan 67 X Swarna Mani	-66.83	15.60	-11.72	-27.20	-64.77	9.77	-21.86	-14.21	-21.81	-14.77

Table 3. PH= Plant height; NBP= Number of branches primary branches per plant; DTF= Days taken to 50% flowering; DTH= Days taken for first Harvesting; NFP= Number of fruits per plant; FW= Fruit weight; FL= Fruit length; FC= Fruit circumference; FYP= Fruit yield per plant, FYH= Fruit yield per hectare. BP= Better parent; SH: Standard heterosis.

of fruits per plant in hybrids. Only VR-2, Mukta Keshi, and Swarna Mani exhibited positive GCA for fruit weight, while IIHR-563, Punjab Baigan 67, and Rajendra Baigan had positive GCA for fruit length. VR-2, IIHR-562, Mukta Keshi, and Swarna Mani have positive GCA for fruit circumference. VR-2, Mukta Keshi, and Rajendra Baigan were recognized as good combiners for crop yields (Table 3).

Specific combining ability effects of crosses for yield and other different characters in eggplant

The magnitude of specific combining ability (SCA) for all 16 crosses involving different traits is detailed in Table 4. Crosses such as VR-2 and Arka Kusumkar, IIHR-562 and Mukta Keshi, IIHR-563 and Mukta Keshi, Punjab Baigan 67 x Rajendra Baigan, and Punjab Baigan x Swarna Mani displayed positive combining ability for plant height and the number of primary branches per plant. Conversely, F1 hybrids resulting from IIHR-563 x Swarna Mani, IIHR-563 x Mukta Keshi, and Punjab Baigan 67 x Arka Kusumkar exhibited negative combining ability for the time taken for the crop's harvesting period. Positive SCA for the number of fruits per plant was observed in crosses like VR-2 X Swarna Mani, IIHR-562 x Swarna Mani, IIHR-563 x Arka Kusumkar, Punjab Baigan 67 x Rajendra Baigan, and Punjab Baigan x Swarna Mani. Conversely, the remaining crosses showed negative combining ability for this trait. Among the crosses,

Table 4. General combining ability effects of parents for yield and other different characters in eggplant

Parents	PH	NBP	DTF	DTH	NFP	FW	FL	FC	FYP	FYH
L1 (VR-2)	2.375	-0.008	0.447	2.494	-0.281	38.359	-1.055	2.606	0.34	75.346
L2 (IIHR-562)	-4.48	-0.22	-1.83	-3.32	-2.15	-3.57	-0.11	-0.23	-0.22	-48.95
L3 (IIHR-563)	0.27	0.15	4.38	3.49	0.43	-3.39	0.81	1.16	-0.05	-11.38
L4 (Punjab Baigan 67)	1.83	0.08	-3.00	-2.67	2.01	-31.40	0.36	-3.54	-0.07	-15.02
T1(Arka Kusumkar)	-0.45	0.14	1.21	1.82	1.30	-20.47	-0.04	-2.55	-0.03	-7.40
T2 (Mukta Keshi)	4.67	0.08	-1.40	-1.16	-0.25	12.88	-0.36	3.83	0.11	24.59
T3 (Rajendra Baigan)	0.45	0.26	-3.61	-3.35	1.24	-11.56	1.64	-2.93	0.06	13.10
T4 (Swarna Mani)	-4.67	-0.48	3.80	2.68	-2.29	19.15	-1.23	1.64	-0.14	-30.30

Table 5. PH= Plant height; NBP= Number of branches primary branches per plant; DTF= Days taken to 50% flowering; DTH= Days taken for first Harvesting; NFP= Number of fruits per plant; FW= Fruit weight; FL= Fruit length; FC= Fruit circumference; FYP= Fruit yield per plant, FYH= Fruit yield per hectare.

Table 5. Specific combining abilityeffects of crosses for yield and other different characters in eggplant

Crosses	PH	NBP	DTF	DTH	NFP	FW	FL	FC	FYP	FYH
VR-2 X Arka Kusumkar	0.30	0.19	3.37	-1.08	-0.26	10.07	0.03	-1.14	0.08	18.13
VR-2 X Rajendra Baigan	-1.59	0.08	-3.35	0.33	1.64	-18.27	0.27	-4.28	0.04	8.71
VR-2 X Mukta Keshi	-2.18	-0.18	-0.81	0.96	-1.57	-0.12	-2.52	0.83	-0.14	-29.92
VR-2 X Swarna Mani	3.47	-0.09	0.79	-0.21	0.19	8.31	2.22	4.59	0.01	3.09
IIHR-562 X Arka Kusumkar	-4.03	-0.07	2.03	1.03	-0.56	-13.51	1.07	-0.29	-0.12	-26.89
IIHR-562 X Rajendra Baigan	2.00	-0.28	1.76	-0.34	-0.92	60.37	0.23	2.84	0.25	54.18
IIHR-562 X Mukta Keshi	11.18	0.26	0.78	0.26	-0.55	-10.80	-0.69	-0.88	-0.14	-30.18
IIHR-562 X Swarna Mani	-9.15	0.09	-4.57	-0.94	2.04	-36.07	-0.62	-1.67	0.01	2.89
IIHR 563 X Arka Kusumkar	1.85	-0.05	-3.47	4.36	1.49	-14.59	-1.28	-1.41	0.00	-0.08
IIHR 563 X Rajendra Baigan	-0.52	-0.03	1.32	-1.67	-1.13	-44.79	-1.44	3.07	-0.37	-81.66
IIHR 563 X Mukta Keshi	1.93	0.10	-0.19	-4.08	2.45	5.06	4.90	-3.13	0.34	75.16
IIHR 563 X Swarna Mani	-3.26	-0.03	2.33	1.39	-2.81	54.32	-2.18	1.47	0.03	6.59
Punjab Baigan 67 X Arka Kusumkar	1.88	-0.08	-1.93	-4.30	-0.66	18.03	0.18	2.84	0.04	8.84
Punjab Baigan 67 X Rajendra Baigan	0.11	0.23	0.27	1.68	0.41	2.69	0.94	-1.63	0.08	18.78
Punjab Baigan 67 X Mukta Keshi	-10.93	-0.18	0.21	2.86	-0.33	5.85	-1.70	3.19	-0.07	-15.06
Punjab Baigan 67 X Swarna Mani	8.94	0.03	1.45	-0.24	0.59	-26.56	0.58	-4.40	-0.06	-12.57

Table 6. PH= Plant height; NBP= Number of branches primary branches per plant; DTF= Days taken to 50% flowering; DTH= Days taken for first Harvesting; NFP= Number of fruits per plant; FW= Fruit weight; FL= Fruit length; FC= Fruit circumference; FYP= Fruit yield per plant, FYH= Fruit yield per hectare.

positive combining ability for fruit weight was found in Punjab Baigan 67 with all testers except Swarna Mani, as well as in the crosses of IIHR-562 x Rajendra Baigan, VR-2 x Swarna Mani, and VR-2 x Arka Kusumkar. Additionally, VR-2 x Swarna Mani, IIHR-562 x Rajendra Baigan, and Punjab Baigan x Arka Kusumkar displayed positive combining ability for fruit shape. Out of the 16 crosses, nine exhibited positive combining ability for yield, including VR-2 x Arka Kusumkar, VR-2 x Rajendra Baigan, VR-2 x Swarna Mani, IIHR-562 x Rajendra Baigan, IIHR-562 X Swarna Mani, IIHR-563 x Mukta Keshi, IIHR-563 x Swarna Mani, Punjab Baigan 67 x Arka Kusumkar, and Punjab Baigan 67 x Rajendra Baigan (Table 5).

Discussion

Selecting parents based on phenotypic traits is key to improving vegetable crops. However, the Line x Tester mating design has proven to be a promising tool for selecting important traits in solanaceous crops, including eggplant (Chattopadhyay *et al.,* 2012; Yadav *et al.,* 2013; Sood and Kumar, 2010). When compared to other solanaceous crops, the improvement of eggplants through breeding is restricted, despite their significant economic and nutritional importance (Mistry *et al.,* 2018). A significant amount of heterosis has been recorded through line x tester mating analysis for yield and various characteristics in eggplant by Rahul, Mittal and Kumar, 2022; Kaushik, 2019; Sujin and Karuppaiah, 2018; Ramani *et al.,* 2017; Sivakumar *et al.,* 2017; Shamloul, Kalid and Elsaye, 2017; Viradiya 2016; Sharma *et al.,* 2016; Ramani, Vaddoria and Patel, 2015; Kumar *et al.,* 2013; Singh, Sidhu and Kumar, 2012; Prasath *et al*., 2000. A shorter flowering period indicates early harvest, and in this context, negative heterosis is a beneficial trait (Reddy, 2014; Karuppaiah, Sekar and Senthilkumar, 2007). In hybrid combinations, general combiners significantly impact the inheritance of favorable genes (Kushwaha *et al.,* 2020) and the effect of this has influenced the specific crosses resulting in the earliness of the crop and higher in earliness of some of the F1 hybrids compared to their parents like IIHR-562 x Mukta Keshi, Punjab Baigan 67 x Arka Kusumkar, and IIHR-562 x Rajendra Baigan and yield in VR-2 x Rajendra Baigan, VR- x Arka Kusumkar, and IIHR-563 x Arka Kusumkar.

Conclusion

The F1 hybrid between IIHR 562 and Mukta Keshi, along with several other combinations, exhibited impressive plant height. This information is pivotal for selecting varieties that can lead to taller and potentially more productive plants. Mukta Keshi, among others, demonstrated a high number of primary branches, which is a desirable trait for increased yield. This insight aids in the selection of parent varieties for improving branch abundance in eggplant. The study identified hybrid combinations, such as IIHR-562 x Mukta Keshi, Punjab Baigan 67 x Arka Kusumkar, and IIHR-562 x Rajendra Baigan, that displayed early flowering and harvesting. Early maturity is crucial for efficient crop management. Detailed information about fruit traits, including length, circumference, and weight, was provided. Certain combinations exhibited superior fruit characteristics, such as longer fruit length and larger fruit circumference, which can enhance marketability. Hybrid combinations like VR-2 x Arka Kusumkar and VR-2 x Rajendra Baigan yielded the highest fruit yield per plant and per hectare. This underlines the significance of choosing the right combinations for improved crop productivity. Heterosis was observed in several traits, offering the potential to enhance plant height and the number of primary branches. All F1 hybrids outperformed the check variety (PPL), indicating their superiority. Some parent genotypes showed positive GCA for specific traits, providing valuable insights into suitable parent selections for transmitting desirable traits to hybrid offspring. SCA varied among hybrid combinations, with some displaying positive SCA for specific traits like plant height and the number of primary branches. This information is crucial for developing superior hybrids. Overall, the research emphasizes the importance of considering specific traits and combining abilities when designing breeding programs for eggplants. These findings can aid breeders in selecting suitable parent varieties, creating optimal hybrid combinations, and ultimately improving crop performance. The data presented in this report offers a valuable resource for advancing eggplant breeding and crop enhancement efforts under organic conditions, ultimately supporting sustainable and environmentally friendly eggplant cultivation practices.

Conflict of Interest- None

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