



Evaluation of Hybrids and Parents of Chilli (*Capsicum annum* L.) for Yield and Resistance to Chilli Leaf Curl Virus

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Chilli (*Capsicum annuum* L.) is the most important vegetable and spice crops that belonging to family Solanaceae. Leaf curl virus disease is a most destructive threat to chilli production which adversely affect yield. Twenty four F₁ hybrids were developed by crossing eleven diverse parents in line x tester mating design and were screened for yield, yield related traits and for resistance to leaf curl virus under natural epiphytotic condition and artificial inoculation using viruliferous white flies at College of horticulture, Bagalkot (University of horticulture science, Bagalkot) during 2021-2023. The analysis of variance indicated the presence of significant variation among the chilli hybrids and parents for the characters observed and reaction to disease. Based on the *per se* performance, the hybrid Byadgi Dabbi x IC284628 recorded the highest individual fruit weight, hybrid Byadgi Kaddi x Punjab Sindhuri observed highest number of fruits per plant and hybrid Byadgi Kaddi x Punjab Lal recorded highest green fruit yield per plant among all the hybrids. The hybrids Byadgi Kaddi x Punjab Surkh, Byadgi Dabbi x Punjab Surkh, Byadgi Dabbi x Punjab Sindhuri and Byadgi Kaddi x Punjab Sindhuri were found to have higher tolerance to chilli leaf curl disease.

Keywords: Hybrids; chilli leaf curl virus; yield; resistance; parents; heterosis.

1. INTRODUCTION

Chilli (*Capsicum annuum* L.) is a most important commercially exploited crop popularly called hot pepper or red pepper belongs to family Solanaceae (nightshade) and origins back to tropical America [1]. The name *Capsicum* is derived from Latin word “*Capsa*” which means “hallow pod.” *Capsicum* genus has wide diversity in plant and fruit characteristics, which make it extremely versatile and suitable for innumerable uses. It is reported as an essential industrial crop, with pungency (capsaicin) being an important pharmaceutical property and also used in the food industry as a colouring agent for colouring a processed food, hence it is major cash crop which is exclusively grown in tropical and sub-tropical countries [2,3,4]. India is leading in chilli production which is followed by China, Thailand, Ethiopia and Indonesia. India is the largest producer, consumer and exporter of chilli, accounting for more than 36.57% of the World’s total dry chilli production [5]. Important states growing chilli are Andhra Pradesh, Telangana, Karnataka, Orissa, Maharashtra, West Bengal, Rajasthan and Tamil Nadu. Karnataka ranks second with an area of 48.25 thousand hectares, production of 615.25 thousand MT and productivity of 12.75 MT/ha [6]. Total production of dry chilli in Karnataka is drastically decreased by 59.7 per cent in last 10 years *i.e.* from 1998-99 (1.29 lakh ha) to 2009-10 (0.52 lakh ha) [7]. This reduction in area of dry chilli production is mainly due to several biotic stresses especially caused by virus. It is reported that chilli is attacked by more than 65 viruses [8].

The yield of chilli crop is adversely affected due to leaf curl disease, caused by chilli leaf curl virus [9] belonging to genus Begomovirus and family Geminiviridae [10]. The white fly (*Bemisia tabaci*) acts as a vector for the transmission of virus into the host plant. The symptoms of the disease include stunting of plant growth, upward curling of leaves, puckering, rosette appearance of the leaves on the top of the plant, reduced internodes and petioles, thickening of veins. The older leaves become leathery and brittle and the affected plant fails to produce flowers and fruits [11,12]. The reduction in yield of chilli due to leaf curl disease may extend up to 100 per cent thus causing a great loss to the farmers [3,13]. Among the various management procedures available to control the leaf curl viral disease in chilli, the most efficient way is by controlling the vectors population using insecticides but it makes cost of chilli cultivation costly, hazardous to human health and environment. On the other hand, growing of chilli varieties/hybrids with resistant to leaf curl disease will serve as a simplest and convenient method to the farmers to control the disease and pave way to reduce the yield loss, cost of cultivation and enables an eco-friendly cultivation. Therefore, the present study was conducted to identify the high yielding hybrids combined with resistance to leaf curl disease among twenty-four F₁ hybrids developed utilizing eleven parents through line x tester mating design.

2. MATERIALS AND METHODS

The present investigation about the evaluation of chilli hybrids and parents for yield, yield related

traits and resistance to chilli leaf curl virus at College of horticulture Bagalkot (University of Horticulture Science, Bagalkot) during 2020-2021. The experimental material consists of 24 hybrids and 11 parents during 2020-21. Bagalkot comes under the zone-3 of region-2 among the Agro-climatic zones of Karnataka. It is situated in Northern Dry Zone of Karnataka with an altitude of 533 meters above the mean sea level and at a latitude and longitude of 16° 46' North and 74° 59' East, respectively. This zone has benefits of both South-West and North- East monsoons. The average rainfall of this area is 563 mm distributed over a period of six to eight months with peak during August month. The soil of the experimental site comprised of black soil, before sowing, a composite soil sample was drawn from experimental area to a depth of 0-30 cm and analysed for chemical properties. The experimental plot was ploughed and brought into a fine tilth and applied the farm yard manures (FYM) and recommended dose of fertilizers (NPK). Seedlings were transplanted in a rows spaced at 60 cm and 45 cm from plant to plant. All the other recommended cultivation practices were followed as per the package of practice of UHS, Bagalkot.

Based on the genotypic reaction for leaf curl virus resistance, the resistant lines were used as donor parents to transfer the virus resistance to the popular Byadgi varieties. Total eight resistant genotypes and three susceptible parents were used for crossing in line x tester fashion as suggested by Kempthorne [14] to produce

twenty-four F₁ hybrids. The experiment was laid out in Randomised Block Design with two replications and a standard check. Seedlings of chilli hybrids and parents were raised in protrays and 35 days old seedlings were transplanted at a distance of 60 x 45 cm in the month of February during the summer season. The experimental site and season were found to be favourable for white fly build up in the past years [15]. All the cultural practices were followed as per package of practice of UHS, Bagalkot.

Observations recorded: Five plants in each entry in each replication were randomly selected, tagged and the following observations were recorded from the tagged plants. The data on growth, yield and yield related parameters viz., plant height, number of primary branches per plant, number of secondary branches per plant, number of fruits per plant, fruit length, fruit width, individual green fruit weight and green fruit yield per plant.

Plant height: The height of the plants was measured from the ground level to the tip of the main shoot at the time of first harvest. The mean of five plants was computed and expressed in centimetres.

Number of primary branches per plant: Number of primary branches arising from the main stem was recorded at 60 days after transplant from five tagged plants, the mean of five plants was computed and recorded as number of primary branches per plant.

Table 1. Details of chilli lines, testers and commercial check used in the study

Sl. No.	Entry	Genotypes
Lines		
1.	L1	Byadgi Dabbi
2.	L2	Byadgi Kaddi
3.	L3	Sankeshwar
Testers		
1.	T1	EC391087
2.	T2	IC342426
3.	T3	IC342464
4.	T4	IC284628
5.	T5	Punjab Lal
6.	T6	Punjab Tej
7.	T7	Punjab Sindhuri
8.	T8	Punjab Surkh
Commercial check		
1.	CC	Sarphan hybrid 102

Table 2. Indexing of leaf curl virus in chilli

Symptom severity grade	Symptoms	Reaction (%)	Category
0	No symptom	0	Immune
1	0-5% Curling and clearing of upper leaves	1 – 10	Highly Resistant
2	6-25% Curling, clearing of leaves and swelling of veins	11 – 25	Resistant
3	26-50% Curling, puckering and yellowing of leaves and swelling of veins	26 – 40	Moderately Resistant
4	51-75% leaf curling and stunted plant growth and blistering of internodes	41 – 60	Susceptible
5	>75% curling and deformed small leaves, stunted plant growth with small flowers and no or small fruit set	>60	Highly Susceptible

Number of secondary branches per plant: All the branches borne on the primary branches were counted and recorded at 60 days after transplant from five tagged plants, the mean of five plants was computed and recorded as number of secondary branches.

Number of fruits per plant: Number of fruits harvested from each of the tagged plants in an experimental plot from all pickings during crop season was totaled and average number per plant was worked out.

Fruit length: Length of five randomly selected mature fruits measured individually from the base of calyx to the tip of fruit and average of five fruits was worked out.

Fruit width: The fruits selected for measuring fruit length were used to measure the diameter of fruit at widest point of the fruit with vernier caliper at red ripe stage. Average of five fruits diameter was recorded.

Fruit weight: Fruit weight was calculated by adding the weight of five randomly selected green fruits from each of five tagged plants at third harvest and divided it by total number of fruits and expressed in gram.

Fruit yield per plant: The weight of fruits from all the pickings was recorded from five tagged plants and the average weight of fruits per plant was calculated and expressed in grams.

Per cent of disease infection and disease severity under natural field conditions and artificial screening under mass inoculation were recorded based on the scales for classifying leaf curl disease reactions as developed by Kumar et al. [16]. The phenotypic reactions of host plants

were recorded in terms of symptomatic expression following a disease scoring scale (0-5) given by Banerjee and Kallo, [17] and Kumar et al. [16]. From the recorded observation percent disease incidence (PDI) was calculated. The data on scoring value of chilli leaf curl disease were subjected to suitable statistical analysis, and the hybrids were categorized into six categories based on methods adopted by Reddy et al. [18]

Percent disease incidence (PDI): The incidence of leaf curl virus was calculated by using the following formula developed by Kumar et al. [16] and statistically analysed.

$$\text{Percent disease incidence (\%)} = \frac{\text{Number of diseased plants}}{\text{Total number of plants observed}} \times 100$$

3. RESULTS AND DISCUSSION

Based on the genotypic reaction for leaf curl virus resistance, the resistant lines identified during previous experiments were used as donor parents to transfer the virus resistance to the popular Byadgi varieties. These hybrids were tested for leaf curl virus resistance in the natural field condition in the hot spot area and artificial screening under mass inoculation, which are the best measures to know the resistance or tolerance against virus. The analysis of variance for various characters observed in chilli parents and hybrids under the study are presented in the Table 3. The analysis of variance indicated the presence of significant variation among the hybrids for characters under study. The mean performance of the parents and hybrids for yield and yield related characters are presented in Table 4.

Table 3. Analysis of variance (mean sum of squares) for yield, yield related traits and disease resistance in chilli

Sl. No.	Characters	Replication	Genotypes	Parents	Parents (Line)	Parents (Tester)	Parents (L vs T)	Parents vs Crosses	Crosses	Error
	d.f.	1	34	10	2	7	1	1	23	34
1	Plant height	41.56	947.56***	225.03**	66.65*	301.58***	5.92	45.76	1300.91***	24.34
2	No. of primary branches	0.06	1.16***	0.70***	0.24***	0.93***	0.05	4.97***	1.13***	0.11
3	No. of secondary branches	0.05	9.79***	5.19***	2.05*	6.75***	0.55	19.41***	11.37***	0.43
5	No. of fruits per plant	110.35	2533.12***	3945.23***	570.42***	3932.19***	10786.08**	23.15***	2028.29***	192.64
6	Fruit weight	0.02	22.39***	38.81***	17.98**	31.16***	134.03**	12.63***	15.67***	2.57
7	Fruit length	0.18	30.30***	50.01***	48.21***	22.86***	243.75***	6.75***	22.75***	0.62
8	Fruit width	0.00	0.45***	0.46***	0.77***	0.43***	0.03*	0.77***	0.42***	0.01
9	Green fruit yield	19001.41	276081.18***	165275.41***	25143.71***	203584.56***	177374.77***	43863.19***	334354.03***	7799.50
11	Disease incidence	15.56	1727.78***	3112.10***	2.00	131.42***	30197.06***	1021.59***	1156.61***	22.88

* indicates significance of values at $p = 0.05$, ** indicates significance of values at $p = 0.01$
 *** indicates significance of values at $p = 0.001$

Table 4. Estimation of *per se* performance of parents and hybrids for yield, yield related parameters and disease resistance in chilli

Sl.No.	Genotypes	Plant height (cm)	No. of primary branches	No. of secondary branches	No. of fruits per plant	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Green fruit yield (g/plant)
Parents									
1	Byadgi Dabbi	67.69	3.63	7.80	42.67	19.54	13.03	1.92	829.09
2	Byadgi Kaddi	75.60	4.19	9.19	55.62	18.23	19.01	1.49	1018.34
3	Shankeshwar	78.93	4.25	9.77	76.16	13.82	22.77	0.69	1027.91
4	EC391087	61.53	5.06	11.59	63.13	6.98	4.23	2.22	440.76
5	IC342426	50.99	4.96	11.10	65.34	16.79	13.66	1.44	1099.63
6	IC342464	89.07	3.50	7.00	85.29	12.54	11.89	1.12	1071.91
7	IC284628	73.53	4.10	8.85	77.13	17.54	15.16	1.62	1271.82
8	Punjab Lal	72.46	4.16	10.02	96.13	12.53	9.73	0.93	1204.42
9	Punjab Tej	81.02	3.21	6.90	161.87	8.66	10.50	0.99	1390.52
10	Punjab Sindhuri	71.07	4.49	10.66	174.49	7.95	8.72	0.77	1388.00

Sl.No.	Genotypes	Plant height (cm)	No. of primary branches	No. of secondary branches	No. of fruits per plant	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Green fruit yield (g/plant)	
11	Punjab Surkh	83.61	3.57	8.09	139.56	10.23	12.48	1.20	1413.44	
12	Standard Check	63.55	3.64	8.86	75.81	11.08	11.73	1.11	839.48	
Hybrids										
1.	BD x EC391087	51.05	4.80	12.38	52.78	7.25	5.11	2.02	382.71	
2.	BD x IC342426	42.96	5.72	13.23	73.54	14.23	14.92	1.42	1041.10	
3.	BD x IC342464	115.38	3.60	7.01	50.07	13.85	12.65	0.84	691.58	
4.	BD x IC284628	43.85	5.76	13.43	81.90	14.78	15.49	1.72	1210.40	
5.	BD x PL	68.01	4.47	10.61	118.37	13.70	10.54	0.72	1604.92	
6.	BD x PT	60.44	4.62	11.32	112.23	13.01	10.99	0.77	1432.99	
7.	BD x PS	76.47	4.30	8.80	109.83	12.20	8.70	0.66	1313.27	
8.	BD x PSU	89.75	4.15	7.73	117.55	13.32	12.81	1.10	1544.58	
9.	BK x EC391087	53.57	4.76	12.10	62.03	6.53	6.15	1.91	403.54	
10.	BK x IC342426	41.43	5.60	12.87	85.03	14.10	16.06	1.24	1184.19	
11.	BK x IC342464	120.28	3.86	7.26	69.11	13.80	12.92	0.78	923.85	
12.	BK x IC284628	48.61	4.89	12.62	86.77	14.52	16.88	1.61	1242.76	
13.	BK x PL	73.96	4.30	9.04	124.66	13.62	11.11	0.68	1686.92	
14.	BK x PT	57.55	4.65	11.58	114.36	12.79	11.62	0.76	1460.49	
15.	BK x PS	80.98	4.29	8.49	166.31	8.11	9.05	0.60	1347.66	
16.	BK x PSU	93.49	4.76	7.62	119.88	13.17	13.03	0.94	1578.13	
17.	SWR x EC391087	56.34	6.62	11.74	65.06	5.24	7.71	1.83	340.74	
18.	SWR x IC342426	46.45	4.05	14.17	71.14	14.02	17.05	1.17	996.94	
19.	SWR x IC342464	125.83	6.02	7.59	41.30	13.71	13.05	0.78	564.81	
20.	SWR x IC284628	45.67	4.31	13.45	84.82	14.28	18.35	1.53	1200.50	
21.	SWR x PL	71.34	4.40	9.30	113.33	13.39	12.56	0.67	1503.63	
22.	SWR x PT	64.55	4.26	9.73	108.19	12.76	12.58	0.75	1380.14	
23.	SWR x PS	86.13	3.96	8.13	150.85	8.53	9.59	0.58	1286.43	
24.	SWR x PSU	101.56	4.76	7.34	114.05	13.10	13.07	0.90	1493.67	
	S.Em ±	3.12	0.24	0.46	9.72	1.15	0.55	0.06	61.66	
	C.D. at 5%	8.95	0.68	1.33	27.92	3.30	1.59	0.16	177.03	
	C.D. at 1%	12.01	0.91	1.78	37.46	4.43	2.13	0.22	237.53	

Where: CD – Critical difference, S.Em ± - Standard error of mean

BD – Byadgi Dabbi, BK – Byadgi Kaddi, SWR – Sankeshwar, PL – Punjab Lal, PT – Punjab Tej, PS – Punjab Sindhuri, PSU – Punjab Surkh

Table 5. Screening of chilli hybrids and their parents for resistance to leaf curl virus under natural epiphytotic condition

Sl. No	Chilli hybrids	Natural screening		Artificial screening	
		Per cent disease index (%)	Disease reaction	Per cent disease index (%)	Disease reaction
1	BD x EC391087	54.00	S	57.00	S
2	BD x IC342426	66.00	HS	69.00	HS
3	BD x IC342464	74.00	HS	70.00	HS
4	BD x IC284628	78.00	HS	68.00	HS
5	BD x PL	57.50	S	51.00	S
6	BD x PT	29.00	MR	32.00	MR
7	BD x PS	25.00	R	22.00	R
8	BD x PSU	21.50	R	24.00	R
9	BK x EC391087	49.00	S	53.00	S
10	BK x IC342426	36.00	MR	42.00	MR
11	BK x IC342464	59.00	S	62.00	HS
12	BK x IC284628	68.00	HS	73.00	HS
13	BK x PL	52.00	S	57.00	S
14	BK x PT	29.00	MR	35.00	MR
15	BK x PS	25.00	R	22.00	R
16	BK x PSU	14.00	R	17.00	R
17	SWR x EC391087	79.00	HS	82.00	HS
18	SWR x IC342426	76.00	HS	66.00	HS
19	SWR x IC342464	74.00	HS	67.00	HS
20	SWR x IC284628	88.00	HS	73.00	HS
21	SWR x PL	57.50	S	55.00	S
22	SWR x PT	36.50	MR	40.00	MR
23	SWR x PS	40.00	MR	52.00	S
24	SWR x PSU	31.50	MR	35.00	MR
Chilli Parents					
25	Byadgi Dabbi	99.50	HS	98.00	HS
26	Byadgi Kaddi	99.00	HS	99.00	HS
27	Shankeshwar	97.50	HS	98.00	HS
28	EC391087	9.00	HR	10.00	HR
29	IC342426	15.00	R	19.00	R
30	IC342464	22.50	R	27.00	MR
31	IC284628	29.00	MR	34.00	MR

Sl. No	Chilli hybrids	Natural screening		Artificial screening	
		Per cent disease index (%)	Disease reaction	Per cent disease index (%)	Disease reaction
32	Punjab Lal	4.50	HR	8.00	HR
33	Punjab Tej	18.50	R	22.00	R
34	Punjab Sindhuri	16.00	R	23.00	R
35	Punjab Surkh	8.00	HR	10.00	HR
36	Standard Check	80.00	HS	71.00	HS

Table 6. Categorization of chilli hybrids and their parents for resistance to leaf curl virus based on virus symptoms under natural condition and artificial inoculation

Disease reaction	Natural screening		Artificial screening	
	No. of genotypes	Hybrid and parents	No. of genotypes	Hybrid and parents
Immune	0	-	0	-
Highly resistant	3	EC 391087, Punjab Lal, Punjab Surkh	3	EC 391087, Punjab Lal, Punjab Surkh
Resistant	8	Byadgi Dabbi x Punjab Sindhuri, Byadgi Dabbi x Punjab Surkh, Byadgi Kaddi x Punjab Sindhuri, Byadgi Kaddi x Punjab Surkh, IC342426, IC342464, Punjab Tej, Punjab Sindhuri	7	Byadgi Dabbi x Punjab Sindhuri, Byadgi Dabbi x Punjab Surkh, Byadgi Kaddi x Punjab Sindhuri, Byadgi Kaddi x Punjab Surkh, IC342426, Punjab Tej, Punjab Sindhuri
Moderately resistant	7	Byadgi Dabbi x Punjab Tej, Byadgi Kaddi x IC342426, Byadgi Kaddi x Punjab Tej, Shankeshwar x Punjab Tej, Shankeshwar x Punjab Sindhuri, Shankeshwar x Punjab Surkh, IC284628	7	Byadgi Dabbi x Punjab Tej, Byadgi Kaddi x IC342426, Byadgi Kaddi x Punjab Tej, Shankeshwar x Punjab Tej, Shankeshwar x Punjab Surkh, IC284628, IC342464
Susceptible	6	Byadgi Dabbi x Punjab Lal, Byadgi Dabbi x EC391087, Byadgi Kaddi x EC391087, Byadgi Kaddi x Punjab Lal, Byadgi Kaddi x IC342464, Shankeshwar x Punjab Lal	6	Byadgi Dabbi x Punjab Lal, Byadgi Dabbi x EC391087, Byadgi Kaddi x EC391087, Byadgi Kaddi x Punjab Lal, Shankeshwar x Punjab Lal, Shankeshwar x Punjab Sindhuri,
Highly susceptible	12	Byadgi Dabbi x IC342426, Byadgi Dabbi x IC342464, Byadgi Dabbi x IC284628, Byadgi Kaddi x IC284628, Shankeshwar x EC391087, Shankeshwar x IC342426, Shankeshwar x IC342464, Shankeshwar x IC284628, Byadgi Dabbi, Byadgi Kaddi, Shankeshwar, Standard Check	13	Byadgi Dabbi x IC342426, Byadgi Dabbi x IC342464, Byadgi Dabbi x IC284628, Byadgi Kaddi x IC284628, Shankeshwar x EC391087, Shankeshwar x IC342426, Shankeshwar x IC342464, Shankeshwar x IC284628, Byadgi Dabbi, Byadgi Kaddi, Shankeshwar, Standard Check, Byadgi Kaddi x IC342464,

3.1 Plant Height

Heterosis for plant height traits is directly related to yield as the growth and yield parameter are strongly associated for increased production. The *per se* range for plant height of 41.43 cm (Byadgi Kaddi x IC342426) to 125.83 cm (Shankeshwar x IC342464) was recorded by F₁ hybrids as compared to parents 50.99 cm (IC342426)–89.07 cm (IC342464) and check (63.55 cm). Wide range of heterosis was exhibited by F₁ hybrids for plant height. Similar results were also reported by Rekha et al. [19], Abrham et al. [20], Rao et al. [21] and Rohini and Lakshmanan [22].

3.2 Number of Primary Branches

Primary branches are the essential growth parameter which acts as source for supporting yield and its component traits. The parents showed the variation from 3.21 (Punjab Tej) – 5.06 (EC391087) for number of primary branches whereas, the hybrid crosses had the range from 3.60 (Byadgi Dabbi x IC342464) – 6.62 (Shankeshwar x EC391087). For number of primary branches, positive heterosis was noticed in majority of the crosses. These results are in agreement with Rekha et al. [19], Rao et al. [21] and Rohini and Lakshmanan [22], Thilak et al. [23], Vijeth et al. [24] and Aiswarya et al. [25].

3.3 Number of Secondary Branches

The number of secondary branches is important as the fruits are borne on the axils of secondary branches which directly favours to number of fruits per plant. The parents showed the variation for number of secondary branches which ranged from 6.90 (Punjab Tej) - 11.59 (EC391087) whereas, among the F₁ hybrid crosses it ranged from 7.01 (Byadgi Dabbi x IC342464) – 14.17 (Shankeshwar x IC342426). These findings are in conformity with those of Gawali et al. [26], Rekha et al. [19] and Rao et al. [21].

3.4 Number of Fruits Per Plant

Number of fruits per plant is the most important primitive component which directly influence the fruits yield. Heterosis for yield is mainly attributed to heterosis for number of fruits per plant. The parents varied from 42.67 (Byadgi Dabbi) to 174.49 (Punjab Sindhuri) for number of green fruits per plant. Among F₁ hybrids number of fruits per plant ranged from 41.30 (Shankeshwar x IC342464) to 166.31 (Byadgi Kaddi x Punjab Sindhuri). These results are in conformity with work of Patel et al. (2015), Spaldon et al. [27],

Gawali et al. [26], Reka et al. [19], Rao et al. [21] and Mopidevi et al. [28], Thilak et al. [23], Ganefianti and Fahrurrozi [29], Chakrabarty et al. [30], Vijeth et al. [24] and Aiswarya et al. [25].

3.5 Fruit Weight

Mean values for fruit weight among chilli genotypes varied significantly from 6.98 g (EC391087) to 19.54 g (Byadgi Dabbi) for parents while, the F₁ crosses varied from 5.24 g (Shankeshwar x EC391087) to 14.78 g (Byadgi Dabbi x IC284628). With respect to average fruit weight, the magnitude of heterosis over commercial check 11.08 g. These results are in agreement with those of Abrham et al. [20], Rao et al. [21], Rohini and Lakshmanan [22], Mopidevi et al. [28], Ganefianti and Fahrurrozi [29] and Nikornpun et al. [31].

3.6 Fruit Length

Fruit length is one of the important yield parameters, which directly contributes to the fruit weight, thereby affecting the total yield. A critical analysis of the data for this trait shows the enormous variation among the parents, hybrids and standard check. The parents varied from 4.23 cm (EC391087) to 22.77 cm (Shankeshwar) for fruit length. Among F₁ hybrids fruit length ranged from 5.11 cm (Byadgi Dabbi x EC391087) to 18.35 cm (Shankeshwar x IC284628). The results are in line with the work of Savitha et al. [32], Spaldon et al. [27], Naresh et al. [33], Abrham et al. [20], and Vijeth et al. [24].

3.7 Fruit Width

In the trait fruit width mean values among chilli genotypes varied significantly from 0.69 cm (Shankeshwar) to 2.22 cm (EC391087) for parents and among the F₁ hybrid crosses it varied from 0.58 cm (Shankeshwar x Punjab Sindhuri) to 2.02 cm (Byadgi Dabbi x EC391087). Similar results were obtained by Mopidevi et al. [28], Silva et al. (2017), Shumbulo et al. [34], Ganefianti and Fahrurrozi [29] and Vijeth et al. [24].

3.8 Green Fruit Yield

The fruit yield is the ultimate requirement for the farmers for attaining effective economic profit. The average fruit yield per plant varied from 440.76 g (EC391087) to 1413.44 g (Punjab Surkh) among parents and 340.74 g (Shankeshwar x EC391087) to 1686.92 g

(Byadgi Kaddi x Punjab Lal) within F₁ hybrid crosses. These results are in agreement with the works of Rao et al. [21], Mopidevi et al. [28], Chakrabarty et al. [30], Vijeth et al. [24] and Nikornpun et al. [31].

The per cent disease index and disease reaction of all the chilli hybrids and genotypes are presented in the Table 5. There was high phenotypic variation for leaf curl virus disease incidence among chilli hybrids and parents in both natural and artificial screening. PDI during natural screening ranged from 4.50% (Punjab Lal) to 99.50% (Byadgi Dabbi) among parents and it ranged from 14% (Byadgi Kaddi x Punjab Surkh) to 88% (Shankeshwar x IC284628) among chilli hybrids. During artificial screening PDI ranged from 8% (Punjab Lal) to 99% (Byadgi Kaddi) among parents and it ranged from 17% (Byadgi Kaddi x Punjab Surkh) to 82% (Shankeshwar x EC391087) among hybrids. The variation in virus incidence among different genotypes may be due to tolerance of differential load of virus infection based on the morphological, biochemical or nutritional factors which act as a defence mechanism against the virus infection. The chilli hybrids and parents were categorized into 6 groups based on their reaction to leaf curl virus and the data is presented in the Table 6. From per cent disease incidence, it is evident that hybrid Byadgi Kaddi x Punjab Surkh and Byadgi Dabbi x Punjab Surkh were found to be resistant to leaf curl virus showing least PDI compared to other hybrids in both natural and artificial screening. Parents EC 391087, Punjab Lal, Punjab Surkh was observed to be highly resistant to leaf curl virus in both natural and artificial screening. Similar results were observed by Ahmad et al. [35], Dhaliwal et al. [36], Awasthi and Kumar [37].

4. CONCLUSION

Twenty-four hybrids along with their eleven parents were screened for leaf curl virus for identification of resistant hybrids having good yield potential. The results obtained from disease screening revealed that leaf curl virus infection ranged from 4.50 to 99.50 per cent among parents and it ranged from 14.00 to 88.00 per cent among hybrids.

Chilli genotypes and hybrids exhibited variation in fruit yield. Highest yield was observed in Punjab Surkh followed by Punjab Tej. Among hybrids highest fruit yield was recorded in Byadgi Kaddi x Punjab Lal followed by Byadgi Dabbi x

Punjab Lal. The lowest per cent of virus disease incidence among hybrids was observed in Byadgi Kaddi x Punjab Surkh and Byadgi Dabbi x Punjab Surkh because of resistance reaction in Punjab Surkh is due to monogenic dominance nature. The hybrid crosses Byadgi Dabbi x Punjab Lal and Byadgi Kaddi x Punjab Lal exhibited susceptible reaction towards virus infection due to monogenic recessive nature for resistance to leaf curl virus in donor parent *i.e.*, Punjab Lal.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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