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Performance Evaluation of Chilli Hybrids for Yield Traits through Hybridization (*Capsicum annuum* L.)

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Abstract A study was conducted on performance evaluation of chilli hybrids for yield traits during 2013-14. The investigation was carried out with six selected genotypes of chilli namely Arka Lohit, K 1, LCA 334, LCA 625, PKM 1 and Pusa Jwala. The diallel technique was employed for the evaluation of these genotypes as parents and their thirty F_1 hybrids. The parameters such as mean performance of parents and F_1 hybrids were computed by appropriate biometrical approaches. The *per se* performance of parents revealed that all the six parents have excelled in one or more traits of the study. On the basis of high *per se* performance, thus, the potential hybrids viz., LCA 625 × K 1, PKM 1 × LCA 625, Pusa Jwala × PKM 1, Pusa Jwala × K 1, K 1 × Arka Lohit and Arka Lohit × LCA 334 were identified for number of fruits, fresh fruit and dry pod weight, fruit quality and high yield. These F_1 hybrids could be tested in different seasons over different locations for assessing their stability for high yield and quality. The hybrids LCA 625 × K1 (165.58 g), K 1 × Arka Lohit (157.25 g) and Pusa Jwala × PKM 1 (156.54 g) could be particularly exploited for dry pod yield, since they also had improved economic traits besides good fruit quality parameters.

Keywords Chilli, Evaluation, Quality, Performance, Yield.

Introduction

Chilli (*Capsicum annuum* L.) is an important vegetable cum spice crop grown in almost all parts of tropical and sub-tropical regions of the world [1]. It belongs to the family Solanaceae and originated from South and Central America, where it was domesticated around 7000 BC. The genus *Capsicum* includes 30 species, five of which are cultivated: *Capsicum annuum* L., *Capsicum frutescens* L., *Capsicum chinense, Capsicum pubescens* and *Capsicum baccatum* L. [2]. Chilli is the first largest commodity in the international trade. India contributes one-fourth of the world production of chilli with an average annual production of 1,304,000 tonnes from an area of 7, 94,000 hectares with productivity of 1,600 kg per hectare [3]. Andhra Pradesh, Karnataka, Maharashtra, Odisha and Tamil Nadu account for three fourths of

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the total cropped area [4]. It has attained a status of high value crop in India and occupies a unique place among vegetables in Indian cuisine because of its delicate taste and pleasant flavor coupled with rich content of ascorbic acid and other vitamins and minerals. Chillies are low in sodium and cholesterol free, rich in vitamin A, vitamin C, vitamin E, a good source of potassium and folic acid. Fresh green chilli contains more vitamin C than citrus fruits and fresh red chilli has more vitamin A than carrot [5, 6].

The success of any breeding program primarily depends on the correct choice of parents. Parents with high order of *per se* performance would be useful in producing better genotypes [7]. *Per se* performance should be given an equal importance while judging the hybrid combinations for exploitation of heterosis [8]. Increased yield of chilli owing to the manifestation of hybrid vigor was observed earlier by various worker [9—11]. Savitha [12] reported highest fresh fruit (682.30 g) and dry pod yield per plant (170.23 g) in the hybrid CA 197 × Kashi Anmol. Patil et al. [13] evaluated 28 F_1, hybrids and recorded the highest yield per plant in cross Phule Mukta × AC-2 (1930 g). Munish [14] observed the highest fresh fruit yield and dry pod yield per plant in the hybrid LCA 436 × Pant Cl (615.23 and 70.59 g). Recently, Sharma et al. [15] observed the highest fruit yield per plant in cross PRC 1 × Rani Sel 1 (1.37 kg).

Availability of F_1 hybrids in chilli suitable for both fresh and processed forms is much limited. Hence there is on immense need to develop hybrids in chilli for fresh market as well as processing type. In view of this, it is essential to identify the lines possessing good fruiting, quality and yield. Keeping in view of the consumer's preference, vegetable breeder has to initiate any breeding program in chilli, for quality as well as quantity. Keeping the importance of this crop, a trial was conducted to evaluate the performance of thirty F_1 hybrids for yield characters.

Materials and Methods

The experiment was conducted in the Department of vegetable crops, Horticultural College and research institute, periyakulam, Tamil Nadu agricultural university, India, which is situated at 10°N latitude and 77°E longitude with an altitude of 300 m above mean sea level. The genetic material was comprised of six homozygous chilli inbreds viz., Arka Lohit, K 1, LCA 334, LCA 625, PKM 1 and Pusa Jwala were used as parents. Six parents and these parents were crossed in all possible combination, both direct and reciprocal, to get the maximum number of hybrids during June 2013 to October 2013. After fruit set, seeds were extracted from fully dried pods, cleaned for raising the progenies of F_1 hybrids. Selfed seeds of the parents were also obtained during the same season. The main field was prepared to a fine tilth and FYM @ 25 t ha^{-1} was applied at the last ploughing. About 2 kg/ha of *Azospirillum* and 2 kg/ha of Phosphobacteria by mixing with 20 kg of FYM. 30:60:30 kg/ha NPK in the form of urea, single super phosphate and muriate of potash, respectively was applied to the soil at the time of field preparation prior to transplanting. The seedlings were transplanted in the second week November of 2013. 50 plants each of 30 F_1s, six of parents were planted at a distance of 60 × 45 cm in randomized block design with three replications during November 2013 to April 2014. Observations were recorded in ten randomly selected plants. Data were collected from individual plants of F_1 generation of chilli for fifteen quantitative traits viz., plant height (cm), branches per plant, days to 1st flowering, days to 50% flowering, fruits/plant, fruit length (cm), fruit girth (cm), individual fresh fruit weight (g) individual dry pod weight (g), seeds per pod, pericarp weight (g), pericarp thickness (mm), 1000 seed weight (g), fresh fruit yield/plant (g) and dry pod yield per plant (g). The statistical parameters like mean, range were calculated as per the standard methods of analysis [16].

Results and Discussion

In any crop breeding program, it is essential to select parents with good *per se* performance, so that the best performing hybrids could be developed. It is equally important to select hybrids of high performance to achieve specific objectives of any breeding program. *Per se* performance should be given an equal importance while judging the hybrid combinations for exploitation of heterosis [8].

Table 1. Analysis of variance for different characters in chilli. **Significant at 1 per cent level, *Significant at 5 % level.

Characters	Mean sum of squares	
	Genotypes	Error
Plant height	263.87**	0.57
Branches per plant	9.37**	0.52
Days to first flowering	19.02**	1.68
Days to 50% flowering	20.78**	3.98
Fruits per plant	2947.32**	0.59
Fruit length	2.84**	0.13
Fruit girth	0.37**	0.01
Individual fresh fruit weight	0.97**	0.03
Individual dry pod weight	0.03**	0.00
Seeds per pod	276.72**	16.06
Fresh fruit yield per plant	87998.71**	103.33
Dry pod yield per plant	1139.79**	16.28

The analysis of variance for the parents and hybrids in a randomized block design showed highly significant differences among the genotypes for all the characters studied (Table 1). The mean performance of six parents and 30 hybrid combinations derived through diallel mating design for all quantitative characters are presented in Table 2. Plant height is an important component by which the growth and vigor of the plants are measured. The parents K 1 (83.25 cm), LCA 625 (74.40 cm) and LCA 334 (73.58 cm) recorded better values of plant height. Among the hybrids, the crosses Pusa Jwala × K 1 (100.7 cm), Arka Lohit × LCA 334 (91.20 cm), PKM 1 × LCA 625 (88.45 cm) Pusa Jwala × PKM 1 (88.20 cm), and K 1 × Arka Lohit (86.50 cm) expressed better values of plant height. It is interesting to notice that both the tall and dwarf combinations had Pusa Jwala as one of the parents. In general, the hybrids involving Pusa Jwala or Arka Lohit as the female parent registered higher plant height. Identification of hybrids with better growth habit and spreading nature is advantageous and in such hybrids the fruiting would be greater due to continuous production of flowering truss in each node. The hybrid with dwarf plants could be utilized for high density planting. The variation in plant height might have due to specific genetic make of different hybrids, inherent properties, hormonal factor and vigor of the crop [13]. Branches per plant influence the yield to a significant extent. The primary branches as well as the secondary branches decide the spread of the plant. The number of branches was more in the parent Pusa Jwala (9.38) and LCA 625 (8.95), while the hybrids resulted by crossing these parents were above their parents. Pusa Jwala and LCA 625 would have contributed to better synthesis of cytokinin thereby helped to have architecture with more branches in its F_1 hybrids. Favorable cool temperature and fully sunny days in the January and February month also promoted the maximum vegetative growth. The hybrids 625 × K 1 (14.67), Arka Lohit × LCA 334 (13.50), K 1 × Arka Lohit (12.20), Pusa Jwala × PKM 1 (12.20) and PKM 1 × LCA 625 (11.32) recorded more number of branches per plant. The variation in number of branches per plant might have been due to own genetic makeup and also due to plant height and hormonal factor [12, 14].

Days to first flowering and days to 50% flowering are the two main attributes of earliness, which is manifested in the F_1 hybrids and most of the F_1 hybrids are grown for their early yield. The parents LCA 625 (62.92 and 69.51 days), PKM 1 (64 and 71 days) and Arka Lohit (65.50 and 70.33 days) exhibited very early flowering whereas, in hybrids, PKM 1 × LCA 625 (62 and 67 days), PKM 1 × Pusa Jwala (62.6 and 67.93 days), K 1 × Arka Lohit (64 and 67.50 days), K 1 × LCA 625 (63 and 68 days) and K 1 × PKM 1 (64 and 68 days) were found to be earlier in flower production. Desirable genotype, which produces the highest flowers in the early phase of the crop duration, would be an early variety. Now existence of positive relationship between parental *per se* and their hybrid *per se* suggest the role of nuclear gene interaction of the both the parents in imparting the earliness in the hybrids [11, 15, 17].

The selection for high yielding genotype should be based mainly on the number of fruits [18]. Among six parents, LCA 625 (104.75), Arka Lohit (98.48) and K 1 (92.00) recorded more fruits per plant. In the present study, the hybrids LCA 625 × K 1 (195), PKM 1 × LCA 625 (188.05), Pusa Jwala × PKM 1 (178.50), Pusa Jwala × K 1 (176.43) and Arka Lohit × LCA 334 (173.80). The parent LCA 625 contributed both as male and female parents to produce hybrids with high number of fruits per plant, while the parent Pusa Jwala contributed as female parent and the parent K 1 as male parent alone. The variation in number of fruits

per plant might have been due to fruit set percentage, genetic nature and their response to varying environmental conditions [15, 19]. Fruits per plant are usually greater when cool temperature occur in the flowering period [13].

Fruit length decides the individual dry fruit weight and thereby the yield. The length was the highest in the parents LCA 625 (8.62 cm), Pusa Jwala (8.53 cm) and PKM 1 (8.00 cm) was used as a female parent, the hybrids expressed better fruit length. The highest fruit length was recorded in the hybrids Pusa Jwala × K 1 (10.38 cm), K 1 × PKM 1 (9.58 cm), Pusa Jwala × PKM 1 (9.52 cm), PKM 1 × K 1 (9.40 cm) and PKM 1 × LCA 625 (9.37 cm). The parents have proved their potential in exhibiting their superiority in the respective hybrid combinations. The present results are in conformity with the earlier findings [11, 13, 20].

Fruit girth is equally important in deciding the

Table 2. *Per se* performance of parental lines and F_1 hybrids for yield and contributing characters.

Parental genotypes and F_1 hybrids	Plant height (cm)	Branches/ plant	Days to first flowering	Days to 50% flowering	Fruits/ plant	Fruit length (cm)
P_1 (Arka Lohit)	68.72	7.28	65.50	70.33	98.48	7.49
P_2 (K 1)	83.25	8.53	68.00	72.55	92.00	7.83
P_3 (LCA 334)	73.58	7.00	70.63	76.39	86.52	6.56
P_4 (LCA 625)	75.40	8.95	62.92	69.51	104.75	8.62
P_5 (PKM 1)	70.53	8.52	64.00	71.00	80.08	8.00
P_6 (Pusa Jwala)	62.80	9.38	67.75	72.00	90.85	8.53
Arka Lohit × K 1	73.28	9.20	64.00	70.67	127.67	8.05
Arka Lohit × LCA 334	91.20	13.50	68.00	71.33	173.80	8.50
Arka Lohit × LCA 625	60.47	9.00	67.00	70.33	132.85	7.43
Arka Lohit × PKM 1	75.30	8.20	65.00	70.00	106.52	8.43
Arka Lohit × Pusa Jwala	84.06	8.63	67.00	73.00	125.50	6.16
K 1 × Arka Lohit	86.50	12.20	64.00	67.50	175.03	8.41
K 1 × LCA 334	67.23	8.00	69.00	74.00	110.65	7.77
K 1 × LCA 625	84.40	9.97	63.00	68.00	163.00	8.79
K 1 × PKM 1	71.86	8.50	64.00	68.00	138.43	9.58
K 1 × Pusa Jwala	78.10	9.20	66.00	70.00	130.72	8.75
LCA 334 × Arka Lohit	81.10	7.00	71.00	77.00	101.54	7.32
LCA 334 × K 1	77.53	8.13	69.00	74.00	98.00	8.38
LCA 334 × LCA 625	60.03	8.30	68.00	74.00	108.35	7.76
LCA 334 ×PKM 1	80.49	7.27	68.00	75.00	98.50	7.98
LCA 334 × Pusa Jwala	76.16	7.00	70.00	72.00	112.36	5.66
LCA 625 × Arka Lohit	66.98	10.32	65.00	69.00	132.00	8.27
LCA 625 × K 1	86.40	14.67	64.00	68.00	195.00	8.95
LCA 625 × LCA 334	68.93	8.07	68.00	75.00	123.00	8.48
LCA 625 × PKM 1	79.37	9.43	63.40	68.13	155.28	8.78
LCA 625 × Pusa Jwala	81.90	8.89	66.00	71.00	130.48	7.85
PKM 1 × Arka Lohit	82.63	8.13	63.00	70.00	145.00	7.79
PKM 1 × K 1	85.80	9.65	62.90	69.00	165.35	9.40
PKM 1 × LCA 335	80.30	8.00	68.00	72.33	138.53	8.64
PKM 1 × LCA 625	88.45	11.32	62.00	67.00	188.05	9.37
PKM 1 × Pusa Jwala	74.60	10.00	62.60	67.93	154.19	8.46
Pusa Jwala × Arka Lohit	58.13	9.73	65.00	68.33	145.15	7.45
Pusa Jwala × K 1	100.70	9.84	64.00	68.17	176.43	10.38
Pusa Jwala × LCA 334	78.60	8.17	67.00	70.00	112.00	6.47
Pusa Jwala × LCA 625	78.32	7.82	62.43	69.49	148.76	7.95
Pusa Jwala × PKM 1	88.20	12.20	65.00	69.00	178.50	9.52
Parents mean	72.38	8.27	66.46	71.96	92.11	7.83
Hybrids mean	78.23	9.34	65.71	70.57	139.69	8.22
SEd	0.620	0590.	1.058	1.629	0.632	0.298
CD (p=0.05)	1.236	1.178	2.111	3.249	1.260	0.595

Table 2. Continued.

Parental genotypes and F_1 hybrids	Fruit girth (cm)	Individual fresh fruit weight (g)	Individual dry pod weight (g)	Seeds/ pod	Fresh fruit yield plant^{-1} (g)	Dry pod yield plant^{-1} (g)
P_1 (Arka Lohit)	3.28	2.85	0.75	72.00	276.84	73.50
P_2 (K 1)	2.58	2.42	0.54	78.00	221.64	49.68
P_3 (LCA 334)	2.72	2.35	0.62	70.00	201.50	55.18
P_4 (LCA 625)	3.07	3.21	0.78	84.00	332.45	81.11
P_5 (PKM 1)	3.10	2.47	0.66	82.00	197.60	53.03
P_6 (Pusa Jwala)	2.30	2.32	0.72	68.00	208.80	64.80
Arka Lohit × K 1	2.85	3.38	0.80	73.10	420.94	98.28
Arka Lohit × LCA 334	3.63	3.81	0.84	87.50	657.20	143.10
Arka Lohit × LCA 625	3.29	2.90	0.83	82.43	379.92	102.28
Arka Lohit × PKM 1	3.23	3.04	0.70	84.98	320.14	73.51
Arka Lohit × Pusa Jwala	2.95	2.63	0.68	78.75	327.61	85.63
K 1 × Arka Lohit	3.97	4.32	0.92	93.30	750.53	157.25
K 1 × LCA 334	3.08	2.72	0.74	80.39	295.82	81.29
K 1 × LCA 625	3.30	3.80	0.84	95.00	615.93	132.37
K 1 × PKM 1	3.50	3.81	0.82	87.45	525.73	110.85
K 1 × Pusa Jwala	3.64	3.79	0.83	82.40	493.83	102.00
LCA 334 × Arka Lohit	3.06	3.02	0.70	77.38	305.50	70.19
LCA 334 × K 1	3.05	2.85	0.69	83.43	279.67	66.53
LCA 334 × LCA 625	3.20	2.76	0.66	80.00	295.10	70.85
LCA 334 ×PKM 1	3.27	2.93	0.70	75.36	280.23	68.80
LCA 334 × Pusa Jwala	2.85	3.05	0.53	68.54	340.13	59.47
LCA 625 × Arka Lohit	2.57	3.32	0.76	91.63	435.33	99.27
LCA 625 × K 1	3.54	4.02	0.88	108.42	780.60	165.58
LCA 625 × LCA 334	3.21	2.98	0.67	87.58	360.13	81.83
LCA 625 × PKM 1	3.17	3.78	0.79	92.95	526.40	120.67
LCA 625 × Pusa Jwala	2.95	2.85	0.72	76.53	369.92	93.03
PKM 1 × Arka Lohit	3.22	3.08	0.60	88.95	443.01	86.67
PKM 1 × K 1	3.51	3.50	0.74	86.43	575.22	121.48
PKM 1 × LCA 335	3.25	2.65	0.63	81.23	356.04	87.22
PKM 1 × LCA 625	3.44	3.85	0.83	91.67	720.60	155.73
PKM 1 × Pusa Jwala	3.32	3.82	0.78	89.63	585.50	125.72
Pusa Jwala × Arka Lohit	3.17	2.48	0.62	68.54	358.94	89.23
Pusa Jwala × K 1	3.83	3.92	0.85	92.83	687.23	147.40
Pusa Jwala × LCA 334	2.74	2.43	0.52	62.47	272.16	58.13
Pusa Jwala × LCA 625	3.06	3.21	0.73	83.00	470.64	108.04
Pusa Jwala × PKM 1	3.59	4.10	0.88	96.50	728.83	156.54
Parents mean	2.84	2.60	0.67	75.66	239.80	62.88
Hybrids mean	3.24	3.29	0.74	84.27	465.29	103.96
SEd	0.099	0.146	0.035	3.272	8.299	3.294
CD (p=0.05)	0.199	0.292	0.071	6.526	16.553	6.571

individual fruit weight. High fruit girth leads to increased fruit yield. In parents, Arka Lohit (3.28 cm), PKM 1 (3.10 cm) and LCA 625 (3.07 cm) had fruit girth more than 3 cm, on the other hand, hybrids K 1 × Arka Lohit (3.97 cm), Pusa Jwala × K1 (3.83 cm), K 1 × Pusa Jwala (3.64 cm), Arka Lohit × LCA 334 (3.63 cm) and Pusa Jwala × PKM 1 (3.59 cm) had more fruit girth. The variation in fruit length and fruit girth might have due to genetic nature, environmental factor and vigor of the crop [17, 20].

Fruit weight is the most important component that contributes directly to the yield in chilli. Among six parents, LCA 625 (3.07 and 0.78 g) and Arka Lohit (2.85 and 0.75 g) registered the highest individual fresh fruit weight and individual dry pod weight. In case of hybrids, the crosses K 1 × Arka Lohit (4.32 and 0.92 g), Pusa Jwala × PKM 1 (4.10 and 0.88 g), LCA 625 × K

1 (4.02 and 0.88 g). Pusa Jwala × K 1 (3.92 and 0.85 g), PKM 1 × LCA 625 (3.85 and 0.83 g) and Arka Lohit × LCA 334 (3.81 and 0.84 g) registered higher values for this trait. The highest fruit weight in these crosses may be due to its hybrid vigor and adoptability to agro-climatic conditions by the place of the experiment [15, 19].

The number of seeds is important characters which influence the individual fruit weight [9, 10]. The parents LCA 625 (84), PKM 1 (82) and K 1 (78) recorded higher seeds per pod. The cross combinations LCA 625 × K 1 (108.42), Pusa Jwala × PKM 1 (96.50), K 1 × LCA 625 (95), K 1 × Arka Lohit (93.30) and LCA 625 × PKM 1 (92.95) were found to be superior for number of seeds per pod.

Yield is a composite character and is dependent on many constituent traits. Any change in these constituent traits would reflect on total yield. Except PKM 1, all the parents recorded fresh fruit yield per plant of more than 200 g per plant and except K 1 the entire parents recorded dry pod yield per plant of more than 50 g per plant. Based on their *per se* performance, the hybrids LCA 625 × K 1 (780.60 and 165.58 g), K 1 × Arka Lohit (750.53 and 157.25 g), Pusa Jwala × PKM 1 (728.83 and 156.54 g), PKM 1 × LCA 625 (720.60 and 155.73 g) and Pusa Jwala × K 1 (687.23 and 147.40 g) have been identified as the best F_1 cross conbinations in the present investigation. The parents P_2 (K 1), P_4 (LCA 625) and P_5 (PKM 1) contributed much as both female and male parents in developing better hybrids of higher fruit yield. The parent Pusa Jwala acted as best female parent and produced high yielding hybrid combinations. There could be no separate gene system for yield *per se* as yield is an end product of multiplicative interactions between its component characters. The variation in fruit yield per plant might have been due to fruit set percentage, number of fruits per plant, fruit length, fruit girth, genetic nature, environmental factor and vigor of the crop [21].

Conclusion

Considering the *per se* performance, LCA 625, Pusa Jwala and Arka Lohit were identified as best parents for further exploitation in breeding program. Six promising hybrids K 1 × Arka Lohit, LCA 625 × K 1, Pusa Jwala × K 1, Pusa Jwala × PKM 1, PKM 1 × LCA 625 and Arka Lohit × LCA 334 were selected on the basis of *per se* performance. These six hybrids could be exploited for table purpose due to higher weight and number of fruits along with high yield. Moreover, the hybrid K 1 × Arka Lohit may also be exploited for processing purpose because of their high pericarp weight and pericarp thickness.

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