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Research Note

Evaluation studies of hot pepper hybrids (*Capsicum annuum* L.) for yield and quality characters

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Abstract
Chilli is the most important worldwide grown and consumed vegetable and spice because of its colour, taste, pungency, flavor and aroma. Hybridization has assumed commercial dimensions in numerous vegetable crops. Hot pepper offers great scope for improvement through this method. Diallel mating design is useful to select a suitable cross combination from large number of germplasm. Hence, present study was carried out to find out degree of heterosis in chilli hybrids. Six homozygous inbreds of hot pepper *viz*., Arka Lohit, K 1, LCA 334, LCA 625, PKM 1 and Pusa Jwala were crossed in June 2013 by making direct and reciprocal crosses for yield and quality aspects at the Department of Vegetable Crops, HC&RI, TNAU, India. From the present study, the hybrids were selected on the basis of high *per se* performance and heterosis. Marked heterosis was observed for all the ten characters studied. 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, 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 × K 1, K 1 × Arka Lohit and Pusa Jwala × PKM 1 could be particularly exploited for dry pod yield, since they also had improved economic traits besides good fruit quality parameters. The best hybrids might be utilized for further chilli improvement programme.

Key words
Dry pod, hot pepper, heterosis, quality, yield

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. It belongs to the family Solanaceae and originated from South and Central America, where it was domesticated around 7000 BC. 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 1600 kg per hectare (Indian Horticulture Database, 2015). In India chilli pepper is the widely used vegetable cum spice crop with lot of additional importance of contributing outstanding job and income generating opportunities for huge number of small and middle farmers in the country. 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. Fresh green chilli contains more vitamin C than citrus fruits and fresh red chilli has more vitamin A than carrot. Chilli with bright colour and less pungency are preferred in Europe and in the West (Sharanakumar *et al*., 2011). Chillies are in different sizes, shapes and colours and have two important qualities, the presence of biting pungency attributed to an alkaloid capsaicin and captivating red colour due to a pigment capsanthin. Capsaicin, the pungent principle due to a crystalline acrid volatile alkaloid present in the placenta of fruit, has diverse prophylactic and therapeutic uses in allopathic and ayurvedic medicines. It is used in the preparation of balms, whereas the colour extracts find use as colour additives in food industry, poultry and prawn feed industry. The oleoresins of chilli are used by food industries, in the preparations of processed products and also for incorporation into a number of pharmaceutical formulations. Chillies are considered to be rich source of ascorbic acid (Vitamin ‘C’) in food and beverage industries and minerals. Apart from this, chilli is credited with many virtues, since it has a great medicinal value. Hence, chilli has diverse uses as spice, condiment, culinary supplement, medicines, vegetable and ornamental plant.

Application of diallel technique in a chilli crop for improving yield and quality may be appropriate. Heterosis in this crop has been demonstrated for various traits by the introduction of novel genes to the present day cultivars (Patel *et al*. 2010). Heterosis for yield reflects through the heterosis in the individual component characters. The relative power and the potency of heterosis breeding in increasing the productivity of crop plants in general are more prospective. Based on the comparison used, heterosis has been defined as improvement of F_1 over the mid, better and best parent values.

Heterosis has been widely used in agriculture to increase yield and quality and adaptability of hybrid and is applied to an increasing number of crop species. Exploitation of heterosis was indicated in increasing yield and other economic traits in hot pepper (Munish, 2012). Heterosis and development of hybrids for various traits has been reported earlier by Patel *et al*. (2010) for number of fruit, Patil *et al*. (2012) for fruit yield, Sharma *et al*. (2013) for capsaicin and colour and Khalil and Hatem (2014) for ascorbic acid and TSS.

The success of any breeding programme primarily depends on the correct choice of parents. Parents with high order of per se performance would be useful in producing better genotypes. Development of dual purpose chilli hybrids for fresh market as well as processing also needs an improvement in quality traits *viz*., ascorbic acid, capsaicin, capsanthin, oleoresin and total soluble solids, which helps in value addition. Therefore, there is a need for breeding chilli to improve traits concerning to processed forms with high nutritive value. The nutritional and industrial importance of this crop indicates the need to formulate breeding programme and develop cultivars rich in capsaicin, capsanthin, processing traits with high quality of fruit (Munish, 2012). Considering the importance of hot pepper, the present investigation was undertaken to identify parents that can be used for the exploitation of hybrid vigor in the commercial production of F_1 seed and for the development of heterotic populations from which superior progenies can be selected and developed into new varieties.

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The present study was carried out in the experimental farm of Department of Vegetable Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam during 2012-15, which is situated at 10 ^{0}N latitude and 77 ^{0}E longitude with an altitude of 300 m above mean sea level.

Plant materials : The genetic materials comprised of six homozygous inbred. These six parents were maintained as inbreds by selfing for six generations. These parents *viz*., Arka Lohit, K 1, LCA 334, LCA 625, PKM 1 and Pusa Jwala. Hybrid CO CH 1 obtained from Department of Vegetable Crops, TNAU, Coimbatore was used as standard check.

Transplant production: The seeds were treated with *Trichoderma viride* @ 4 g kg^{-1} of seeds, twenty-four hours before sowing and sown in raised beds. The nursery beds were irrigated twice a day using rosecan to facilitate quick germination and good growth of seedlings. The beds were kept moist, but not wet, to avoid dampling – off of seedlings. After seed germination the seedling were treated with 0.3% urea when 10 cm tall for their better growth and were transplanted around 40-45 days old. Irrigation to the seedlings was held 3-4 days before transplanting, watering was applied to the nursery bed prior to removal of seedlings for transplanting. Seedlings of six parents were transplanted in the field to produce hybrids in all possible combination 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 and 30:60:30 kg/ ha NPK 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. Fifty plants each of 30 F_1s, six of parents were planted at a distance of 60 x 45 cm in randomized block design with three replications during November 2014 to April 2015. Soil moisture was maintained during the growing season with flood irrigation at 5 days intervals.

Observations were recorded in ten randomly selected plants. Data were collected from individual plants of F_1 generation of chilli for five quantitative and five qualitative traits *viz*., branches / plant, fruits / plant, fruit girth (cm), individual dry pod weight (g), dry pod yield per plant (g), ascorbic acid (mg/100g) , capsaicin (per cent), colour value (ASTA), oleoresin (per cent) and total soluble solids (°Brix).

The mean data of all the hybrids and their parents for each character were tabulated and subjected to analysis of variance (Panse and Sukhatme, 1957).

The magnitude of heterosis in hybrids was expressed as percentage of increase or decrease of a character over standard hybrid and was estimated by following formulae

Standard heterosis (diii) = $\dfrac{\overline{F}_1 - \overline{SV}}{\overline{SV}} \times 100$

Where, $\overline{F1}$ = mean value of hybrid, $\overline{SV}$ = mean value of standard check hybrid The significance of standard heterosis were tested by the following formulae.

't' for standard heterosis = $\dfrac{\overline{F}_1 - \overline{SV}}{\sqrt{\dfrac{Me}{r} \times 2}}$

Where, Me = error variance, r = Number of replication.

These calculated values were compared with the table value for error degrees of freedom at both 5 and 1 per cent levels.

In any crop breeding programme, 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 programme. *Per se* performance should be given an equal importance while judging the hybrid combinations for exploitation of heterosis. The analysis of variance revealved significant difference among treatments for all the yield and quality characters indicating the presence of appreciable genetic diversity among the parents and their thirty cross combinations (Table 1).

The mean performance of parents and hybrids for fruit, yield and quality characters have been presented in table 2. This result clearly indicated that there were significant variations in mean performance among parents and their hybrids for all the characters studied. The range in mean value for parental inbreds for yield and quality traits includes 7.00 (LCA 334) to 9.38 (Pusa Jwala) for branches per plant, 80.08 (PKM 1) to 104.75 (LCA 625) for number of fruits / plant, 2.30 (Pusa Jwala) to 3.28 cm (Arka Lohit) for fruit girth, 0.54 (K 1) to 0.78 g (LCA 625) for dry pod weight, 81.11 g (LCA 625) to 53 g (PKM 1) for dry pod yield/plant, 79.54 (PKM 1) to 123.41 mg per 100 g (Arka Lohit) for ascorbic acid,0.49 (LCA 334) to 0.75 (Pusa Jwala) for capsaicin, 46.78 (PKM 1) to 81.70 ASTA unit (Pusa Jwala) for colour value, 12.47 (K1) to 14.61 (LCA 625) for oleoresin and 4.83 (PKM 1) to 7.10°brix (LCA 334) for total soluble solids.

The range in mean value of F_1 hybrid include 7.00 (LCA 334 × Arka Lohit) to 14.67 (LCA 625 × K 1) for branches/ plant, 2.57 (LCA 625 × Arka Lohit) to 3.97 cm (K1 × Arka Lohit) for fruit girth, 0.52 g (Pusa Jwala × LCA 334) to 0.92 g (K1 × Arka Lohit) for dry pod weight, 58.13 g (Pusa Jwala × LCA 334) to 165. 58 g × (LCA 625 × K1) for dry pod yield, 85.70 in K 1 × PKM 1 to 164.28 mg per100 g in Pusa Jwala × PKM 1 for ascorbic acid, 0.47 (LCA334 × K 1) to 0.93 per cent (K 1 × Arka Lohit) for capsaicin, 68.25 (Arka Lohit × PKM 1) to 121.68 ASTA unit Pusa Jwala × LCA 625) for colour value, 12.46 (PKM 1× LCA 334) to 16.35 percent (PKM 1 × Arka Lohit) for oleoresin content and 5.43 to (LCA 334 × K1) to 7.63 °brix (K 1 × LCA 625) for Total soluble solid. Grafius (1959), who had suggested that 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. The increased fruit yield of first generation hybrids obtained in the present study also correlates with the findings of Patel et al. (2010) and Munish (2012).

Considering the *per se* performance, LCA 625, Pusa Jwala and Arka Lohit were identified as best parents for further exploitation in breeding programme. 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. Out of six hybrids, K 1× Arka Lohit and Pusa Jwala × PKM 1 showed high capsaicin content. Moreover, the hybrid K 1 × Arka Lohit may also be exploited for processing purpose because of their high TSS.

Selection of hybrids based on heterosis for yield and quality traits: Hybrid vigor is a direct property of heterozygosity and is due to superior gene content possible in a hybrid contributed by both the parents. Hybrid vigor, the phenomenon of heterosis, was the basis for improvement in crop yields achieved during 20th century in many crops. Rapid advances in plant breeding with regard to exploitation of heterosis have served in many ways to develop hybrids with increased yield per hectare along with good quality characters.

The estimates of heterosis were computed for ten traits studied in the 30 cross combinations and expressed in percentage over check hybrid CO CH1 (Table 3). Branches per plant influence the yield to a significant extent through facilitating the production of more number of flowers. The crosses involving Pusa Jwala, LCA 625 and PKM 1 as parents surpassed in their heterotic vigor. The hybrids LCA 625 × K 1(22.19%) and Arka Lohit × LCA 334 (12.47%) also proved their superiority over check hybrid. Patel *et al*. (2010) recorded ×that the magnitude of heterobeltiosis and standard heterosis in desirable direction was the highest for number of secondary branches per plant. Patil *et al.* (2012) observed that heterosis for total yield was the highest for number of fruits. The heterosis over check hybrid was registered in the hybrids LCA 625 × K 1 (13.37%), PKM 1 × LCA 625 (9.33%), Pusa Jwala x PKM 1 (3.78%), Pusa Jwala × K1 (2.58%), K 1 x Arka Lohit(1.76%) and Arka Lohit x LCA 334 (1.05%) due to over dominance coupled with non-additive gene action. The number of fruits per plant is a major yield contributing character and heterosis for this trait has been studied by Rodrigues *et al*. (2012) and Barhate *et al.* (2013).

The hybrids K 1 × Arka Lohit (16.08%), Pusa Jwala × K 1 (11.89%), K 1 ×Pusa Jwala (6.43%) and Arka Lohit × LCA 334 (6.24%) were heterotic over checks in the present study for fruit girth. Significant and positive heterosis for fruit girth was reported by Rodrigues *et al*. (2012). Positive and significant heterosis over the check hybrid was recorded in the hybrids K1 × Arka Lohit (11.79%), Pusa Jwala × PKM 1 (7.72%) and LCA 625 × K 1 (7.32%). The parents Pusa Jwala and K 1 also proved themselves as better parents in developing hybrids with better dry pod weight. The high heterotic response as observed in these crosses further supported the predominant role of non-additive components in the inheritance of the characters. Khalil and Hatem (2014) reported highly significant positive heterosis values over better parent with high potence value. The hybrids LCA 625 × K 1 (18.12%), K 1 × Arka Lohit (12.17%), Pusa Jwala × PKM 1 (11.67%), PKM 1 × LCA 625 (11.09%) and Pusa Jwala × K 1 (5.15%) showed the significant and the highest heterosis over the check hybrid. Here, the hybrid and their parents recorded better *per se* values also. The higher amount of heterosis manifested in the F_1 hybrids for yield traits indicated the prevalence of dominant gene action in controlling these traits and usefulness of the hybrids to develop varieties for improving the crop. Similar result for pronounced hybrid vigour for total fruit yield were obtained Hasanuzzaman *et al*. (2013)

The trait ascorbic acid, the hybrids Pusa Jwala × PKM 1 (45.38%), Pusa Jwala × K 1 (31.72%), LCA 334 × Pusa Jwala (40.36%), PKM 1× LCA 625 (33.52%) and LCA 625 × K 1 (19.32%) showed superiority over check hybrid and these hybrids also exhibited better per se performance. If the parents are widely different in certain character, the results of F_1 show high heterosis value. Higher per cent of standard heterosis might be due to desirable genetic complementation between the inbred genotypes a similar view point is also shared by Sharma *et al*. (2013); Khalil and Hatem (2014). One of the attributes which is the most typical in chillies is its pungency determined by the capsaicin content. For capsaicin, eight hybrids showed positive significant heterosis over check hybrid for this trait viz., K 1×Arka Lohit (52.17%), LCA 625× K 1 (24.42%), Pusa Jwala × PKM 1 (28.80%), K 1 × PKM 1 (22.83%), Arka Lohit × Pusa Jwala (19.02%), Pusa Jwala × Arka Lohit (17.93%), Arka Lohit × K 1 (10.87%) and Pusa Jwala × K 1 (9.78%). Further it was also noted that these hybrids recorded better per se values. Pungency was segregated between their male and female parents, revealing that the trait was polygenically controlled with mainly dominant gene action. The results are in corroboration with findings of Patel *et al*. (2010) and Ghosh and Pugalendhi (2012).

Total extractable colour forms an inevitable quality parameter since it is directly related to the output of chilli type oleoresin for food colorant. Among thirty hybrids only four hybrids viz., Pusa Jwala × LCA 625 (27.44%), K 1 × LCA 625 (17.09%), PKM 1 × Pusa Jwala (10.68%) and Pusa Jwala × K 1 (9.06%) were found to be positive and significantly heterotic over the check hybrid CO CH1 (Table 4). Ghosh and Pugalendhi (2012) recorded the maximum positive and significant standard heterosis values for capsanthin (7.59%). The results are similar to the findings of and Munish (2012) and Khalil and Hatem (2014).Regarding the oleoresin content, which is a quality factor of equal importance, hybrid combinations PKM 1 × Arka Lohit (11.65%), LCA 625 × Arka Lohit (9.86%), K 1 × LCA 625 (9.06%), K 1 × Arka Lohit (6.31%), Pusa Jwala × LCA 334 (5.69%) and Pusa Jwala × PKM 1 (4.80%) recorded positive significant heterosis over check hybrid for this trait. These results are in accordance with the findings of Ghosh and Pugalendhi (2012); Khalil and Hatem (2014). Total soluble solids are the main quality component of chilli fruits. The reducing sugars, glucose and fructose are the major components of the soluble solids. In this study, the hybrids K 1 × LCA 625 (10.26%) and Arka Lohit × LCA 334 (9.54%) were significant and heterotic over check hybrid for this trait. The parents Arka Lohit, K 1 and LCA 625 were found to be better in developing hybrids with the highest TSS values. Supporting evidences for results were available from the earlier studies of Agarwal *et al*. (2014) and Khalil and Hatem (2014).

The mean performance of F_1 hybrids and their heterotic response has strong positive association (Table 4). The hybrids LCA 625 × K 1, K 1 × Arka Lohit and Pusa Jwala × PKM 1 show evidence of high mean performance for dry pod yield and also exhibited highly significant heterosis compared with the standard check (Table 5). Likewise the same trends were observed in some crosses for yield and quality traits. The maximum heterosis for quality traits K 1 x Arka Lohit, K 1 x LCA 625, PKM 1 x Arka Lohit, Pusa Jwala x K 1, LCA 625 x K 1 and PKM 1 x LCA 625, there was a reasonable ground to suggest that the heterotic expression for quality traits in all these six cross combinations was due to additive and additive x additive type of gene effects as the crosses involved one parent with best general combining ability. In such a situation the selection process could be deferred to later generations in order to exploit both additive and non-additive effects as suggested by Agarwal *et al*. (2014)

Quality improvement coupled with yield enhancement, the crosses LCA 625 × K 1, K 1 × Arka Lohit and Pusa Jwala × PKM 1 was found to be better one as evidenced from the present investigation. These results suggested that hybrid vigor is available for commercial production of chilli hybrids and that isolation of pure lines from the progenies of heterotic F_1s is a possible way to enhance fruit yield and fruit quality.

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Table 1. Analysis of variance for yield and quality traits in chilli

Characters	Mean sum of squares	
	Genotypes	Error
Branches per plant	9.37**	0.52
Fruits per plant	2947.32**	0.59
Fruit girth	0.37**	0.01
Individual dry pod weight	0.03**	0.00
Dry pod yield per plant	1139.79**	16.28
Ascorbic acid	1220.86**	4.44
Capsaicin	0.02**	0.00
Colour value	660.56**	15.13
Oleoresin	3.02**	0.17
Total soluble solids	1.47**	0.10

*, ** Significant at 5 and 1 per cent level respectively.

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Table 2. Mean performance of parental genotypes and F_1 hybrids for yield and quality traits

Parental genotypes and F_1 hybrids	Branches / plant	Fruits / plant	Fruit girth (cm)	Individual dry pod weight (g)	Ascorbic acid (mg/100g)	Capsaicin (per cent)	Colour value (ASTA)	Oleoresin (%)	Total soluble solid (°Brix)	Dry pod yield plant -1 (g)
P_1 (Arka Lohit)	7.28	98.48	3.28	0.75	123.41	0.71	71.82	14.58	6.30	73.50
P_2 (K1)	8.53	92.00	2.58	0.54	120.28	0.53	58.59	12.47	5.63	49.68
P_3 (LCA 334)	7.00	86.52	2.72	0.62	108.37	0.49	67.80	13.18	7.10	55.18
P_4 (LCA 625)	8.95	104.75	3.07	0.78	116.55	0.66	78.18	14.61	5.86	81.11
P_5 (PKM1)	8.52	80.08	3.10	0.66	79.54	0.50	46.78	12.69	4.83	53.03
P_6 (Pusa Jwala)	9.38	90.85	2.30	0.72	112.85	0.75	81.70	13.56	6.26	64.80
Arka Lohit × K 1	9.20	127.67	2.85	0.80	104.61	0.68	83.54	13.57	6.87	98.28
Arka Lohit × LCA 334	13.50	173.80	3.63	0.84	132.90	0.65	72.83	14.87	7.58	143.10
Arka Lohit × LCA 625	9.00	132.85	3.29	0.83	125.02	0.61	92.10	14.60	7.07	102.28
Arka Lohit ×PKM 1	8.20	106.52	3.23	0.70	98.45	0.66	68.25	13.41	6.18	73.51
Arka Lohit × Pusa Jwala	8.63	125.50	2.95	0.68	115.53	0.73	94.98	13.06	6.93	85.63
K 1× Arka Lohit	12.20	175.03	3.97	0.92	138.57	0.93	92.65	15.57	7.29	157.25
K 1 × LCA 334	8.00	110.65	3.08	0.74	138.32	0.61	86.10	13.70	6.30	81.29
K 1 ×LCA 625	9.97	163.00	3.30	0.84	124.46	0.63	111.79	15.97	7.63	132.37
K 1 × PKM 1	8.50	138.43	3.50	0.82	85.70	0.75	76.83	14.46	6.50	110.85
K1 × Pusa Jwala	9.20	130.72	3.64	0.83	130.68	0.58	95.50	14.10	6.07	102.00
LCA 334 ×Arka Lohit	7.00	101.54	3.06	0.70	110.41	0.54	91.48	14.58	6.28	70.19
LCA 334 × K 1	8.13	98.00	3.05	0.69	97.62	0.47	75.69	14.27	5.43	66.53
LCA 334 ×LCA 625	8.30	108.35	3.20	0.66	138.35	0.58	87.91	14.45	6.37	70.85
LCA 334× PKM 1	7.27	98.50	3.27	0.70	122.67	0.64	80.10	13.59	5.58	68.80
LCA 334 × Pusa Jwala	7.00	112.36	2.85	0.53	158.39	0.62	94.62	13.84	6.84	59.47
LCA 625 × Arka Lohit	10.32	132.00	2.57	0.76	147.08	0.61	93.94	16.09	6.60	99.27
LCA 625 × K 1	14.67	195.00	3.54	0.88	143.52	0.76	99.53	15.08	7.06	165.58
LCA 625 × LCA 334	8.07	123.00	3.21	0.67	128.59	0.65	92.04	14.91	7.27	81.83
LCA 625 ×PKM 1	9.43	155.28	3.17	0.79	127.51	0.60	81.42	14.73	6.73	120.67
LCA 625 ×Pusa Jwala	8.89	130.48	2.95	0.72	134.59	0.65	95.25	14.98	7.07	93.03
PKM 1 ×Arka Lohit	8.13	145.00	3.22	0.60	137.45	0.59	72.83	16.35	6.90	86.67
PKM 1 × K 1	9.65	165.35	3.51	0.74	106.50	0.53	84.08	13.86	5.73	121.48
PKM 1 × LCA 335	8.00	138.53	3.25	0.63	101.86	0.48	78.58	12.46	4.83	87.22
PKM 1 ×LCA 625	11.32	188.05	3.44	0.83	155.62	0.55	101.17	14.68	6.74	155.73
PKM 1× Pusa Jwala	10.00	154.19	3.32	0.78	103.71	0.63	105.68	12.74	7.30	125.72
Pusa Jwala ×Arka Lohit	9.73	145.15	3.17	0.62	124.54	0.72	94.42	14.95	7.18	89.23
Pusa Jwala × K 1	9.84	176.43	3.83	0.85	158.48	0.67	104.13	13.76	6.37	147.40
Pusa Jwala × LCA 334	8.17	112.00	2.74	0.52	117.67	0.58	88.04	15.48	5.80	58.13
Pusa Jwala ×LCA 625	7.82	148.76	3.06	0.73	136.25	0.61	121.68	14.38	6.73	108.04
Pusa Jwala ×PKM 1	12.20	178.50	3.59	0.88	164.28	0.79	98.72	15.35	6.51	156.54
SE d	0590.	0.632	0.099	0.035	1.722	0.026	3.176	0.339	0.266	3.294
CD (P= 0.05)	1.178	1.260	0.199	0.071	3.434	0.053	6.335	0.677	0.530	6.571

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Table 3. Heterosis (%) over standard check (CO CH 1) for yield and quality traits in hot pepper

F_1 hybrids	Branches / plant	Fruits /plant	Fruit girth	Dry pod weight	Ascorbic acid	Capsaicin	Colour value	Oleoresin	Total soluble Solid	Dry pod yield / plant
Arka Lohit ✕ K 1	-23.35**	-25.77**	-16.57**	-2.44	-17.39**	10.87*	-12.05**	-7.35**	-0.72	-29.89**
Arka Lohit ✕ LCA 334	12.47*	1.05**	6.24*	2.44	4.95**	5.98	-23.72**	1.57	9.54*	2.08
Arka Lohit ✕ LCA 625	-25.02**	-22.76**	-3.90	1.22	-1.27	-0.54	-3.54	-0.32	2.17	-27.04**
Arka Lohit ✕PKM 1	-31.69**	-38.07**	-5.46*	-14.63**	-22.26**	7.61	-28.52**	-8.42**	-10.74**	-47.56**
Arka Lohit ✕ Pusa Jwala	-28.10**	-27.03**	-13.65**	-17.07**	-8.77**	19.02**	-0.52	-10.84**	0.10	-38.92**
K 1✕ Arka Lohit	1.64	1.76**	16.08**	11.79**	9.43**	52.17**	-2.96	6.31**	5.39	12.17**
K 1 ✕ LCA 334	-33.35**	-35.67**	-9.94**	-9.76**	9.23**	-0.54	-9.82**	-6.46**	-8.91*	-42.01**
K 1 ✕LCA 625	-16.94**	-5.23**	-3.51	2.44	-1.72	3.26	17.09**	9.06**	10.26**	-5.57*
K 1 ✕ PKM 1	-29.19**	-19.52**	2.34	0.41	-32.32**	22.83**	-19.53**	-1.25	-6.02	-20.93**
K1 ✕ Pusa Jwala	-23.35**	-24.00**	6.43*	1.63	3.20*	-5.43	0.02	-3.71	-12.24**	-27.24**
LCA 334 ✕Arka Lohit	-41.68**	-4.97**	-10.53**	-14.23**	-12.8**	-12.50**	-4.19	-0.43	-9.25*	-49.93**
LCA 334 ✕ K 1	-32.24**	-43.02**	-10.72**	-15.85**	-22.91**	-22.83**	-20.72**	-2.57	-21.53**	-52.54**
LCA 334 ✕LCA 625	-30.85**	-37.01**	-6.43*	-19.92**	9.25**	-5.43	-7.93*	-1.32	-7.95*	-49.46**
LCA 334 ✕ PKM 1	-39.43**	-42.73**	-4.48	-14.63**	-3.13*	4.35	-16.10**	-7.19**	-19.36**	-50.92**
LCA 334 ✕ Pusa Jwala	-41.68**	-34.67**	-16.57**	-34.96**	25.08**	1.09	-0.89	-5.51*	-1.16	-57.57**
LCA 625 ✕ Arka Lohit	-14.00**	-23.26**	-24.85**	-7.32*	16.14**	-0.54	-1.61	9.86**	-4.58	-29.18**
LCA 625 ✕ K 1	22.19**	13.37**	3.41	7.32*	13.34**	24.46**	4.25	2.98	1.97	18.12**
LCA 625 ✕ LCA 334	-32.77**	-28.49**	-6.24*	-17.89**	1.54	6.52	-3.60	1.84	5.01	-41.63**
LCA 625 ✕PKM 1	-21.41**	-9.72**	-7.21**	-4.07	0.69	-2.17	-14.72**	0.57	-2.79	-13.92**
LCA 625 ✕Pusa Jwala	-25.97**	-24.14**	-13.65**	-12.20**	6.29**	6.52	-0.24	2.30	2.17	-33.63**
PKM 1 ✕Arka Lohit	-32.27**	-15.70**	-5.85*	-26.83**	8.54**	-3.26	-23.72**	11.65**	-0.29	-38.17**
PKM 1 ✕ K 1	-19.61**	-3.86**	2.63	-10.16**	-15.90**	-13.04**	-11.94**	-5.35*	-17.20**	-13.34**
PKM 1 ✕ LCA 335	-33.35**	-19.46**	-4.87	-23.17**	-19.56**	-21.74**	-17.70**	-14.91**	-30.25**	-37.78**
PKM 1 ✕LCA 625	-5.67	9.33**	0.58	0.81	22.89**	-10.33*	5.96	0.25	-2.55	11.09**
PKM 1✕ Pusa Jwala	-16.69**	-10.35**	-2.92	-5.28	-18.10**	2.72	10.68**	-13.02**	5.49	-10.32**
Pusa Jwala ✕Arka Lohit	-18.94**	-15.61**	-7.21**	-24.39**	-1.66	17.93**	-1.11	2.07	3.81	-39.35**
Pusa Jwala ✕ K 1	-18.02**	2.58**	11.89**	3.66	25.15**	9.78*	9.06*	-6.01**	-7.95*	5.15*
Pusa Jwala ✕ LCA 334	-31.96**	-34.88**	-19.88**	-36.99**	-7.08**	-5.98	-7.79*	5.69*	-16.18**	-58.54**
Pusa Jwala ✕LCA 625	-34.85**	-13.51**	-10.53**	-10.57**	7.60**	0.00	27.44**	-1.82	-2.79	-22.93**
Pusa Jwala ✕PKM 1	1.64	3.78**	4.97	7.72*	29.73**	28.80**	3.40	4.80*	-5.92	11.67**

Table 4. Mean and range of heterosis over CO CH 1 for yield and quality traits in hot pepper

Characters	Mean of parents	Mean of hybrids	Range of heterosis
Branches per plant	8.27	9.34	-41.68 to 22.19
Fruits per plant	92.11	139.69	-43.02 to 13.37
Fruit girth	2.84	3.24	-24.85 to 16.08
Individual dry pod weight	0.67	0.74	- 36.99 to11.79
Dry pod yield per plant	62.88	103.96	- 58.54 to 18.12
Ascorbic acid	110.16	126.97	-32.32 to 29.73
Capsaicin	0.60	0.63	- 22.83 to 52.17
Colour value	67.47	90.24	- 28.52 to 27.44
Oleoresin	13.51	14.46	- 14.91 to 11.65
Total soluble solids	5.99	6.59	-30.25 to 10.26

Table 5. Standard heterosis and mean performance of superior crosses for yield and quality traits in hot pepper

Characters	Crosses	Heterosis	Per - se performance
Branches per plant	LCA 625 ✕ K 1	22.19	14.67
	Arka Lohit ✕ LCA 334	12.47	13.50
Fruits / plant	LCA 625 ✕ K 1	13.37	195.0
	PKM 1 ✕ LCA 625	9.33	188.05
	Pusa Jwala ✕ PKM 1	3.78	178.50
Fruit girth (cm)	K 1 ✕Arka Lohit	16.08	3.97
	Pusa Jwala ✕ K 1	11.89	3.83
	Pusa Jwala ✕ PKM 1	4.97	3.59
Dry pod weight (g)	K 1 ✕ Arka Lohit	11.79	0.92
	Pusa Jwala ✕ PKM 1	7.72	0.88
	LCA 625 ✕ K 1	7.32	0.88
Dry pod yield (g/plant)	LCA 625 ✕ K 1	18.12	165.58
	K 1 ✕ Arka Lohit	12.17	157.25
	Pusa Jwala ✕ PKM 1	11.67	156.54
Ascorbic acid (mg/100g)	Pusa Jwala ✕ PKM 1	29.73	164.28
	Pusa Jwala ✕ K 1	25.15	158.48
	LCA 334 ✕Pusa Jwala	25.08	158.39
Capsaicin (per cent)	K 1 ✕ Arka Lohit	52.17	0.93
	Pusa Jwala ✕ PKM 1	28.80	0.79
	LCA 625 ✕ K 1	24.46	0.76
Capsanthin (ASTA)	Pusa Jwala ✕ LCA 625	27.44	121.68
	K 1 ✕ LCA 625	17.09	111.79
	PKM 1 X Pusa Jwala	10.68	105.68
Oleoresin (per cent)	PKM 1 ✕ Arka Lohit,	11.65	16.35
	LCA 625 ✕ Arka Lohit,	9.86	16.09
	K 1 ✕ LCA 625	9.06	15.97
Total soluble solid (°Brix)	K 1 ✕ LCA 625	10.26	7.63
	Arka Lohit ✕ LCA 334	9.54	7.58