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REGULAR ARTICLE

ASCORBIC ACID HETEROSIS IN CHILI PEPPERS (*CAPSICUM* L.)

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SUMMARY

Chili pepper is the most important worldwide grown and consumed spice and vegetable crop because of its colour, taste, pungency, flavour and aroma. The nutritive value of chili pepper is largely determined by ascorbic acid content. The fruits at five ripening stages viz. M1, M2, M3, M4 and M5 from 18 parents and 40 F1 hybrids were analyzed for ascorbic acid content and per cent heterosis over mid and better parents. Among the parents and hybrids CA2 (208.0±0.68(M1), 231.0±0.66(M2), 280.0±0.31(M3), 253.0±0.34(M4) and 173.7±0.27(M5)) and H37 (211.0±0.45(M1), 248.6±0.32(M2), 298.0±0.35(M3), 272.3±0.70(M4) and 188.0±0.17(M5)) showed higher ascorbic acid content (mg/100g) FW. Hybrid H27 (CA25XCA10) manifested highest per cent heterosis over mid parent (92.34%) and better parent (79.32%) respectively. The results revealed that ascorbic acid content increased from green to red while, decreased in red partially dried and red fully dried fruits. Crosses H37, H27, H25, H26, H36, H35 and H31 were best for ascorbic acid content and per cent heterosis over mid and better parents could be suggested for further evaluation programmes to develop chili pepper varieties with good nutritive values.

Keywords: *Capsicum* L., ascorbic acid, heterosis, ripening, 2,4. dinitrophenylhydrazine.

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1. Introduction

Chili pepper (*Capsicum* L.) spice cum vegetable crop belongs to the family solanaceae and has chromosome number of 2n=24 grown in tropical and subtropical regions of the world. The genus comprises about 25-30 species and only five species are cultivated [1]. Chili pepper fruit is consumed as a fresh vegetable or dehydrated for use as spice. They are extremely popular for the abundance content of vitamin C larger than other vegetables and fruits commonly known as a source of this substance [2-3]. The ascorbic acid (Vitamin C) content in chili peppers has been reported by few workers [4-8]. Ascorbic acid content was increases with fruit ripening while, losses during post harvest handlings [9]. In view of its importance considerable attention has been paid to obtain high ascorbic acid containing varieties throughout the world. In consequence, the per cent heterosis for ascorbic acid content in F_1 hybrids of chili peppers has been reviewed by Matsubara et al [10] Kumar and Lal [11] Malathi et al [12] Geleta et al [13-14]. Despite many reports of ascorbic acid content and its heterosis in chili peppers is inadequate. Hence the present study is undertaken to estimate the content of ascorbic acid and its hybrid vigour during ripening in eighteen genotypes of chili peppers and their 40 F_1 hybrids and to suggest the F_1 hybrids having high content of ascorbic acid for evaluation of new chili pepper genotypes.

2. Materials and Methods

Seventeen cultivars of *C. annuum* L. and one cultivar of *Capsicum frutescens* L. were obtained from National Bureau of Plant Genetic Resources, New Delhi, India and were selfed and maintained for several generations at the experimental farm of Andhra University, Visakhapatnam before the hybridization programme was began. All possible crosses were attempted between, *C. annuum* X *C. annuum* and *C. annuum* X *C. frutescens* respectively. 39 F_1 intraspecific hybrids (*C. annuum* X *C. annuum*) and 1 F_1 interspecific hybrid (*C. annuum* X *C. frutescens*) were obtained and these along with their parents provided fruit material for the present study. The healthy fruits were harvested at five ripening stages viz., Green (M1), Breaker (M2), Red (M3), Red partially dried (M4) and Red fully dried (M5). The fruits were washed with tap water and cut into small pieces and homogenized with the help of mortar and pestle by adding 5 ml of 4% oxalic acid. The homogenates were centrifuged at 5000 rpm for 10 minutes then the supernatants were filtered with 541 Whatmann filter paper, the obtained residues were made up to 25 ml with 4% oxalic acid. The ascorbic acid content was estimated by using 2, 4. dinitrophenylhydrazine reagent in conjunction with spectrophotometer at 540 nm [15] five samples from each lot were analyzed. Heterosis was determined as follows:

$$\text{Mid – parent heterosis (MPH) (\%)} = \frac{F_1 - MP}{MP} \text{ X 100}$$

$$\text{Better – parent heterosis (BPH) (\%)} = \frac{F_1 - BP}{BP} \text{ X 100}$$

Where, F_1 is the F_1 performance, MP = (P1 + P2)/2 in which P1 and P2 are the performances of inbred parents and BP is the better parent value [13].

3. Results and Discussion

The data from (Table 1&2) show that a gradual increase of ascorbic acid content from green to red ripening while, decreased in the lateral stages (i.e., red partially dried and red fully dried) these results were agreed according to the data reported by Osuna- Garcia et al [3] Martinez et al [9]. The genotypes showed considerable variation in ascorbic acid content ranged from 44.3mg to 280mg/100g FW and were categorized under hot peppers in agreement with previous observations [4-8]. Among parents, *C. annuum* var.IC:119262(CA2) showed highest ascorbic acid content in all the ripening stages i.e., 208.0±0.68 (M1), 231.0±0.66(M2), 280.0± 0.31 (M3), 253.0±0.34 (M4) and 173.7±0.27 (M5). While among hybrids H37 (CA22XCA21) revealed maximum mean value of ascorbic acid i.e., 211.0±0.45 (M1), 248.6±0.32 (M2), 298.0± 0.35 (M3), 272.3±0.70 (M4) and 188.0±0.17(M5)mg/100g FW Table 1. Based on the mean ascorbic acid contents the parents and F_1 hybrids were classified into three categories viz., low (0-100mg/100gFW), medium (101- 200mg/100gFW) and high (201- 300mg/100gFW) however, the medium category was most frequently described by Khadi et al [16] Simmone et al [17]. High content of ascorbic acid was pronounced in red ripening and most of the parents and their crosses were fall under medium category of ascorbic acid content however, the lowest contents were recorded in red partially dried and red fully dried fruits.

Table 1. Mean ascorbic acid content in parents and hybrids of chili peppers (*Capsicum* L.) at five ripening stages.

	Ascorbic acid content mg/100g of fruit fresh weight				
	Stage of ripening				
Parent/Hybrid	**Green (M1)**	**Breaker (M2)**	**Red (M3)**	**Red partially dried (M4)**	**Red fully dried (M5)**
C.annuum var. IC:119243 (CA1)	122.8±0.89	139.0±0.17	197.5±0.18	168.5±0.65	103.2±0.38
C.annuum var. IC:119262 (CA2)	208.0±0.68	231.0±0.66	280.0±0.31	253.0±0.34	173.7±0.27

C.annuum var. IC:119264 (CA3)	157.0±0.64	180.2±0.38	234.0±0.41	205.0±0.70	128.5±0.18
C.annuum var. IC:119267 (CA4)	107.0±1.30	136.8±0.29	180.6±0.36	149.0±0.96	84.0±0.66
C.annuum var. IC:119578 (CA5)	150.6±0.48	175.0±0.65	227.0±0.71	200.0±0.95	133.8±0.95
C.annuum var.NIC:20901 (CA8)	130.0±0.95	140.5±0.63	210.5±0.20	185.0±0.35	110.0±0.65
C.annuum var.IC:147719 (CA10)	135.3±0.33	143.0±0.43	211.3±0.21	190.3±0.33	109.8±0.56
C.annuum var.EC:399557 (CA13)	137.0±0.28	159.0±0.67	215.8±0.31	183.4±0.64	111.0±0.40
C.annuum var.G-4 (CA16)	171.3±0.31	203.0±0.42	250.0±0.96	225.8±0.26	142.7±0.24
C.annuum var.CA-960 (CA17)	160.5±0.35	184.0±0.41	239.6±0.20	213.5±0.65	136.0±0.11
C.annuum var. Pusa jwala (CA18)	194.0±0.63	224.0±0.64	267.0±0.63	238.2±0.57	168.6±0.65
C.annuum var.X-235 (CA19)	148.5±0.32	170.8±0.29	225.0±0.96	205.0±0.31	123.0±0.95
C.annuum var.NP-46A (CA20)	173.0±0.31	210.0±0.79	252.5±0.35	227.6±0.66	149.8±0.40
C.annuum var.LCA-206 (CA21)	176.9±0.36	216.7±0.11	254.0±0.98	235.0±0.70	152.0±0.40
C.annuum var.Trupti (CA22)	182.5±0.27	219.0±0.68	261.0±0.40	249.0±0.35	160.0±0.42
C.annuum var.PC1 (CA25)	99.3±0.54	134.0±0.32	172.5±0.15	150.9±0.42	73.2±0.63
C.annuum var. Suryamuchi cluster(CA27)	86.6±0.20	129.5±0.20	165.0±0.43	149.2±0.34	58.5±0.41
C.frutescens (CF)	72.0±0.64	96.0±0.65	137.5±0.20	104.6±0.21	44.3±0.95
CA1×CA3 (H1)	143.0±0.42	176.0±0.33	231.4±0.46	209.3±0.33	121.0±0.68
CA1×CA4 (H2)	152.5±0.18	180.8±0.27	210.8±0.36	180.8±0.71	133.4±0.22
CA1×CA16 (H3)	129.0±0.31	154.0±0.34	189.0±0.23	174.0±0.17	107.0±0.40
CA2×CA16 (H4)	198.0±0.29	226.0±0.32	248.0±0.35	230.0±0.70	180.5±0.35
CA3×CA5 (H5)	131.2±0.57	153.0±0.29	196.0±0.38	179.0±0.47	118.0±0.63
CA3×CA10 (H6)	115.0±0.52	140.0±0.31	190.0±0.64	172.2±0.65	94.6±0.20
CA3×CA13 (H7)	162.0±0.71	198.0±0.28	240.8±0.14	221.8±0.62	142.4±0.34
CA3×CA19 (H8)	110.0±0.98	146.0±0.29	188.0±0.57	167.4±0.28	88.0±0.29

CA4×CA5 (H9)	157.0±0.66	182.0±0.40	235.0±0.64	220.9±0.30	138.0±0.66
CA4×CA10 (H10)	161.0±0.45	186.6±0.32	243.0±0.42	229.4±0.14	146.0±0.39
CA8×CA5 (H11)	131.0±0.20	160.0±0.69	200.0±0.97	182.6±0.84	110.0±0.23
CA10×CA16 (H12)	119.5±0.20	136.0±0.35	208.0±0.37	180.2±0.97	95.8±0.28
CA10×CA27 (H13)	124.3±0.24	138.0±0.35	196.0±0.95	179.0±0.33	100.9±0.36
CA16×CA3 (H14)	108.0±1.00	132.4±0.20	160.8±0.40	146.5±0.18	77.0±0.96
CA16×CA4 (H15)	132.0±0.42	166.0±0.33	216.0±0.64	197.0±0.64	109.8±0.31
CA18×CA16 (H16)	139.0±0.64	172.6±0.20	229.0±0.64	213.7±0.27	116.0±0.35
CA18×CA17 (H17)	152.0±0.40	193.0±0.34	221.0±0.33	200.6±0.36	134.0±0.27
CA19×CA4 (H18)	161.0±0.64	174.0±0.40	230.0±0.69	209.6±0.20	138.0±0.38
CA19×CA10 (H19)	129.0±0.41	140.0±0.36	209.0±0.98	187.2±0.23	104.3±0.21
CA19×CA17 (H20)	164.6±0.20	199.0±0.34	248.0±0.27	230.5±0.35	119.0±0.40
CA19×CA18 (H21)	162.8±0.27	200.0±0.40	240.6±0.32	223.0±0.94	135.9±0.36
CA19×CA25 (H22)	117.0±0.32	148.0±0.39	192.0±0.64	175.0±0.28	97.0±0.64
CA19×CA27 (H23)	126.0±0.67	151.0±0.32	189.0±0.34	170.4±0.64	105.2±0.35
CA20×CA21(H24)	149.0±0.20	189.0±0.30	225.0±0.64	207.4±0.59	123.0±0.33
CA20×CA22 (H25)	198.4±0.52	230.0±0.66	290.0±0.38	269.0±0.65	177.0±0.95
CA21×CA22 (H26)	193.8±0.40	226.0±0.42	288.0±0.64	272.0±0.63	168.0±0.64
CA25×CA10 (H27)	203.0±0.95	243.0±0.96	293.4±0.28	270.6±0.33	176.0±0.65
CA4×CA1 (H28)	132.0±0.40	137.0±0.31	174.0±0.38	150.0±0.95	119.5±0.18
CA10×CA3 (H29)	99.0±0.29	129.0±0.98	154.0±0.40	139.0±0.65	74.0±0.94
CA10×CA4 (H30)	135.0±0.49	175.4±0.22	254.0±0.29	229.8±0.40	114.0±0.27
CA16×CA1(H31)	181.4±0.20	213.0±0.36	257.0±0.30	234.0±0.95	154.0±0.29
CA16×CA10(H32)	92.0±0.40	118.0±0.70	147.0±0.66	129.0±0.70	68.0±0.33
CA18×CA19 (H33)	146.0±0.41	181.0±0.42	221.0±0.94	207.0±0.34	127.5±0.18
CA19×CA3 (H34)	129.0±0.65	164.6±0.38	223.0±0.40	209.3±0.21	109.0±0.27
CA21×CA20 (H35)	200.0±0.42	239.0±0.32	285.0±0.63	264.0±0.70	162.0±0.23
CA22×CA20 (H36)	202.8±0.11	242.0±0.40	287.8±0.41	268.7±0.38	168.0±0.35
CA22×CA21(H37)	211.0±0.45	248.6±0.32	298.0±0.35	272.3±0.70	188.0±0.17
CA27×CA10 (H38)	137.0±0.28	149.0±0.36	187.0±0.64	159.0±0.18	118.6±0.24
CA27×CA19 (H39)	50.0±0.42	173.0±0.44	210.0±0.47	188.5±0.20	128.0±0.67
CA19×CF(H40)	141.0±0.68	160.0±0.30	206.0±0.69	183.4±0.49	117.0±0.24

* Significant at 1% level

Table 2. Per cent heterosis of ascorbic acid content in 40 F_1 hybrids of chili peppers (*Capsicum* L.) at five ripening stages

	Ascorbic acid content mg/100g of fruit fresh weight									
	Stage of ripening									
	Green (M1)		Breaker (M2)		Red (M3)		Red partially dried (M4)		Red fully dried (M5)	
Hybrid	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
CA1×CA3 (H1)	2.21	−8.91	10.27	−2.33	7.25	−1.11	12.07	2.09	4.44	-5.83
CA1×CA4 (H2)	32.72	23.77	31.10	30.07	11.50	6.73	13.88	7.29	42.52	28.88
CA1×CA16 (H3)	−12.27	−24.69	−9.94	−24.13	−15.53	−24.40	-11.74	-22.94	-12.99	-25.01
CA2×CA16 (H4)	4.40	−4.80	4.14	−2.16	−6.41	−11.42	-3.92	-9.09	14.07	3.91
CA3×CA5 (H5)	−14.69	−16.75	−13.85	−15.09	−14.96	−16.23	-11.60	-12.68	-10.02	-11.80
CA3×CA10 (H6)	−21.31	−26.75	−13.36	−22.30	−14.66	−18.80	-12.87	-16.00	-20.60	-26.38
CA3×CA13 (H7)	10.20	3.18	14.44	9.87	7.06	2.90	14.21	8.19	18.91	10.81
CA3×CA19 (H8)	−27.98	−29.93	−16.80	−18.97	−18.08	−19.65	-18.34	-18.34	-30.01	-31.51
CA4×CA5 (H9)	21.89	4.24	16.74	4.00	15.30	3.52	26.59	10.45	26.72	3.139
CA4×CA10 (H10)	32.89	18.99	33.38	30.48	24.01	15.00	35.21	20.54	50.67	32.96
CA8×CA5 (H11)	−6.62	−13.01	1.42	−8.57	−8.57	−11.89	-5.14	-8.70	-9.76	-17.78
CA10×CA16 (H12)	−22.04	−30.23	−21.38	−33.00	−9.82	−16.80	-13.38	-20.19	-24.11	-32.86
CA10×CA27 (H13)	12.03	−8.13	1.28	−3.49	4.17	−7.24	5.44	-5.93	19.90	-8.10
CA16×CA3 (H14)	−34.20	−36.95	−30.89	−34.77	−33.55	−35.68	-31.98	-35.11	-43.21	-46.04
CA16×CA4 (H15)	−5.13	−22.94	−2.29	−18.22	0.32	−13.60	5.122	-12.75	-3.13	-23.05
CA18×CA16 (H16)	−23.89	−28.35	−19.15	−22.94	−19.78	−14.23	-7.88	-10.28	-25.47	-31.19
CA18×CA17 (H17)	−14.24	−21.64	−5.39	−13.83	−12.75	−17.22	-11.17	-15.78	-12.01	-20.52
CA19×CA4 (H18)	26.02	8.41	13.13	1.87	13.41	2.22	18.41	2.24	33.33	12.19
CA19×CA10 (H19)	−9.09	−13.13	−10.77	−18.03	−4.19	−7.11	-5.28	-8.68	-10.39	-15.20
CA19×CA17 (H20)	6.53	2.55	12.17	8.15	6.75	3.50	10.15	7.96	-8.10	-12.50
CA19×CA18 (H21)	−4.93	−16.08	1.31	−10.71	−2.19	−9.88	0.63	-6.38	-6.79	-19.39
CA19×CA25 (H22)	−5.56	−21.21	−2.88	−13.34	−3.39	−14.66	-1.65	-14.63	-1.12	-21.13
CA19×CA27 (H23)	7.18	−15.15	0.56	−11.59	−3.07	−16.00	-3.78	-16.87	15.92	-14.47
CA20×CA21(H24	−14.83	−15.77	−11.41	−12.78	−11.15	−11.41	-10.33	-11.74	-18.48	-19.07
CA20×CA22 (H25)	11.61	8.71	7.22	5.02	12.95	11.11	12.88	8.03	14.26	10.62
CA21×CA22 (H26)	7.84	6.19	3.74	3.19	11.84	10.34	12.52	9.35	7.69	5.00
CA25×CA10 (H27)	73.06	50.03	75.45	69.93	52.89	38.85	58.61	79.32	92.34	60.29
CA4×CA1 (H28)	14.88	7.49	−0.65	−1.43	−7.96	−11.89	-5.51	-10.97	27.67	15.79
CA10×CA3 (H29)	−32.26	−36.94	−20.17	−28.41	−30.83	−34.18	-29.67	-32.19	-37.89	-42.41

CA10×CA4 (H30)	11.43	−0.22	25.37	22.65	29.62	20.20	35.45	20.75	17.64	3.82
CA16×CA1(H31)	23.35	5.89	24.56	4.92	14.86	2.80	18.69	3.63	25.25	7.91
CA16×CA10(H32)	−39.98	−46.29	−31.79	−41.87	−36.26	−41.20	-37.99	-42.86	-46.13	-52.34
CA18×CA19 (H33)	−14.74	−24.74	−8.30	−19.19	−10.16	−17.22	-6.58	-13.20	-12.55	-24.37
CA19×CA3 (H34)	−15.54	−17.83	−6.21	−8.65	−2.83	−4.70	2.09	2.09	-13.32	-15.17
CA21×CA20 (H35)	14.31	13.05	12.02	10.29	12.53	12.20	14.13	12.34	7.35	6.57
CA22×CA20 (H36)	14.09	11.12	12.82	10.50	12.09	10.26	12.75	7.91	8.45	5.00
CA22×CA21(H37)	17.41	15.61	14.11	13.51	15.72	14.17	12.39	9.23	20.51	17.50
CA27×CA10 (H38)	23.47	1.25	9.35	4.19	−0.61	−11.50	-6.33	-16.44	40.93	8.01
CA27×CA19 (H39)	27.60	1.01	15.21	1.28	7.69	−6.66	6.43	-8.04	41.04	4.06
CA19×CF(H40)	0.27	−5.05	19.94	−6.32	13.65	−8.44	18.47	-10.53	39.8	-4.87

* Significant at 1% level

This may be due to decrease in the moisture content in fruits, a similar view point is also shared by Osuna-Garcia et al [3] Lalitha Kumari et al [18] Gnayfeed et al [19] Robi and Sreelatha Kumari [20] Martinez et al [9] in diverse cultivars of *Capsicum* L. Out of 40 F_1 hybrids developed, heterotic effects over their respective better parents were observed in 16 for M1, 16 for M2, 14 for M3, 16 for M4 and 17 for M5. Similar findings are in close agreement with Matsubara et al [10] Kumar and Lal [11] Malathi et al [12] Geleta et al [14]. The estimates of mid parent per cent heterosis ranged from -46.13 to 92.34% the cross H27 had maximum value at M1(73.06%), M2(75.45%), M3(52.89%), M4(58.61%) and M5(92.34%). For better parent, the per cent heterosis ranged from -52.34 to 79.32% among hybrids H27 contributed maximum per cent heterosis in all the ripening stages i.e., 50.03%(M1), 69.93%(M2), 38.85%(M3), 79.32%(M4) and 60.29%(M5) Table 2. Gelata et al [13] also found higher per cent heterosis over mid and better parents at green and red ripen fruits of chili pepper hybrids. This might be due to desirable genetic complementation between the inbred genotypes a similar view point is also shared by Dubrauil et al [21]. Our results suggests that seven cross combinations viz. H37, H27, H25, H26, H36, H35 and H31 (Table 1&2) showed best ascorbic acid and per cent heterosis values over mid and better parents can be recommended to further evaluation for high ascorbic acid containing chili pepper genotypes.

4. Conclusions

The present study reports that the ascorbic acid content in genotypes of *Capsicum* L. showed variation from one another, among the parents and hybrids CA2 and H27 showed maximum ascorbic acid content. Considerable per cent heterosis over mid and better parents was observed in the majority of crosses. The study revealed that ascorbic acid content increased from green to red while, decreased in red partially dried and red fully dried fruits. On the basis of ascorbic acid content and per cent heterosis seven crosses viz. H37, H27, H25, H26, H36, H35 and H31 were suggested for future directions.

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