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Study of Heterosis Using Wild Abortive (WA) CMS Lines on Yield, Quality and Drought Related Traits in Rice (*Oryza sativa* L.)

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To study the heterosis using wild abortive(WA) CMS lines on yield, quality and drought related traits in rice, 56 experimental hybrids were produced using Three WA CMS lines (Pusa 6A, IR79156A and IR 68897A) and 31 male genotypes. The present study showed that superior performance for all characters was not expressed in a single hybrid combination. However, different cross combinations were found to be superior for various characters. The top two high yielding crosses estimated on the basis of significant standard heterosis over SH (Arize6444) and SV (NDR-97) are Pusa-6A x HUR-105 and Pusa-6A x Pantdhan-12. The hybrids Pusa-6A x IR-36 and Pusa6A x HUR-105 showed relatively significant desirable heterosis for the quality traits *viz.*, hulling recovery, milling recovery, kernel length, kernel breadth, kernel length breadth ratio. The hybrids IR 79156A x Danteshwari and Pusa6A x NDR-359 exhibited significant standard heterosis in desired direction for quality aspects along with higher magnitude of standard heterosis for yield. The hybrids Pusa6A x NDR-359 and Pusa6A x Pantdhan-12 showed relatively higher significant desirable standard heterosis over SH (Arize-6444 Gold) for the drought traits *viz.*, chlorophyll content (at 90 DAS) and proline content.

Introduction

Rice is one of the most important staple food crops of India (Singh *et al.*, 2014). In March 2016, United State department of Agriculture (USDA) estimated that the world rice production 2015-2016 will be 471.09 million tons, around 1.59 million tons more than previous month's projection. The production of rice in China is 145,770,000 metric tons, while India's is 103,000,000 metric tons. In India the rice production in different states is West Bengal (15023.68), U.P (14416), A.P and Telangana (11510). The production and productivity of rice became stagnant from past few years. Hybrid rice technology is one of the most practically feasible tools to break the yield barriers. In China, the first hybrid rice variety for commercial cultivation was released by Yuan Long Ping in 1976. India also started this programme in 1989 and released 65 hybrid rice varieties till 2014 (Singh *et al.*, 2015). Hybrid rice offers an opportunity to boost the yield potential of rice with yield advantage of 15-20% over conventional high-yielding varieties (Dar *et al.*, 2014). A major challenge in *indica* rice hybrid breeding is to ensure that the heterotic rice hybrids possess grain quality that is at least comparable, if not superior, to that of inbred check varieties grown by farmers. The grain quality of rice hybrids depends on the grain quality of parents. It is therefore important that only parents that show consumer acceptability are chosen to make hybrids.

Thus, identification of restorers among elite quality cultivars can serve as important tool for the development of better quality rice hybrids. In many instances biotic and Abiotic stresses (mainly drought) are the reason for lower yield in hybrids. Now there is a requirement of producing hybrids which shows stable performance even under drought conditions. Therefore, the present study was undertaken to assess the hybrids for *per se* performance and heterosis with respect to yield, quality traits and drought related traits involving CMS lines and restorer lines in rice.

Materials and Methods

The experimental hybrids(56) were developed during *Kharif* 2014 by using Three Wild Abortive (WA) CMS lines viz., Pusa 6A, IR79156A and IR 68897A crossed with 31 male genotypes. Only 56 cross combinations could be made perfectly. Hence, the experiment was conducted during *Kharif* 2015 with these 56 experimental hybrids grown along with parents and checks at the Agricultural Research Farm, Institute of Agricultural Sciences, BHU, Varanasi, in a single row of 3 m with spacing of 20x15 cm^2 between row to row and plant to plant respectively in R.B.D. with 3 replications. All the recommended agronomic practices were adopted to raise the crop under rainfed condition. No irrigation was provided to the crop after transplanting. In all the hybrids observations were recorded on five randomly selected plants for estimation of magnitude of heterosis with respect to 12 quantitative traits *viz.,* Hulling recovery, milling recovery, kernel length, Kernel breadth, kernel L/B ratio, amylose content, canopy temperature depression (CTD), stomatal conductance, leaf area index, proline content, chlorophyll content and grain yield $plant^{-1}$. The character means of each replication was subjected for analysis of variance (Panse and Sukhatme, 1967) and estimation of heterosis over better parent, standard variety and standard hybrid.

Results and Discussion

All crosses showed marked variations in the expression of Heterobelteosis and Standard heterosis for yield, quality and drought related traits. Heterobelteosis for grain yield/plant ranged from -18.23% (IR-79156A x URG-30) to 60.83% (Pusa- 6A x HUR-105), for Hulling recovery, milling recovery from -11.95% (IR-79156A x BPT-5204) to 2.67% (IR-79156A x URG-42), -11.84% (IR-79156A x BPT-5204) to 4.01% (Pusa-6A x HUR-105) respectively, kernel length, Kernel breadth, kernel L/B ratio from -18.99% (IR-79156A x BPT-5204) to 14.96% (Pusa-6A x Danteshwari), -13.29% (IR-79156A x BPT-5204) to 71.15% (Pusa-6A x Susksamarat), -36.39% (Pusa-6A x Susksamarat) to 7.23% (Pusa-6A x NDR-359) respectively, amylose content, canopy temp. depression (CTD), stomatal conductance from -13.73% (IR-79156A x Akshaydhan) to 2.43% (Pusa-6A x Susksamarat), -4.65% (Pusa-6A x Danteshwari) to 0.72% (Pusa-6A x URG-30), -12.19% (Pusa-6A x Pantdhan-12) to 125.13% (Pusa-6A x URG-30) respectively, leaf area index, proline content and chlorophyll content ranged from -37.02% (Pusa-6A x IR-36) to 72.74% (Pusa-6A x HUR-105), -56.47% (IR-79156A x BPT-5204) to 66.02% (Pusa-6A x Susksamarat), -10.94% (IR-79156A x URG-30) to 10.05% (Pusa-6A x NDR-359) [at 60 DAS] and -14.13% (IR-79156A x IR-36) to 14.63% (Pusa-6A x NDR-359) [at 90 DAS] respectively (Fig. 1 and Tables 1 and 2).

Table.1 ANOVA for analysis of yield, quality and drought related traits in rice

Source of Variations	df	Grain yield/ plant (g)	Hulling recovery %	Milling recovery %	Kernel length (mm)	Kernel breadth (mm)	Kernel L/B ratio	Amylose content (%)	Canopy temp. depression (CTD)^{O}C	Stomatal conductance (mmol/m²/S)	Leaf area index	Proline content(µmol/g Fresh Weight)	Chlorophyll content	
													At 60 DAS	At 90 DAS
Replicates	2	5.97	1.44	1.30	0.001	0.00	0.002	0.11	4.23	4978.83	0.14	0.07	9.67	10.72
Treatments	32	100.70***	20.19***	21.97***	0.97***	0.18***	0.86***	4.85***	1.01	92450.43***	3.35***	25.69***	13.62***	25.01***
Hybrids	16	83.88***	23.88***	25.10***	0.73***	0.21***	0.76***	4.52***	1.26	85783.75***	4.35***	23.43***	8.67**	10.08
Parents	13	43.13***	16.93***	16.35***	1.06***	0.15***	0.63***	5.63***	0.60	74172.74***	1.21***	32.05***	16.18***	33.86***
Hybrids vs. Parents	1	1193.78***	17.16*	38.47***	4.94***	0.22***	4.94***	0.14	1.03	462102.34***	15.41***	2.49***	38.30**	124.67***
Checks	1	10.64*	17.61*	37.70***	0.00	0.03**	0.07*	1.13*	3.23	117964.20***	6.47***	22.66***	14.41*	56.43**
Checks vs. Hybrids	1	324.59***	14.71*	23.57**	1.81***	0.40***	3.75***	8.59***	0.14	120531.98***	0.67**	3.78***	18.95*	43.04*
Checks vs. Parents	1	1.75	3.31	3.38	0.07**	0.16***	0.73***	7.38***	0.01	352.92	1.14***	7.17***	52.72***	1.34
Error	64	2.53	2.68	2.53	0.006	0.003	0.01	0.27	2.06	2662.47	0.09	0.10	3.56	6.48
Total	98	34.66	8.37	8.85	0.32	0.06	0.29	1.76	1.76	32028.26	1.16	8.46	6.97	12.62

* Significant at 5% level, ** significant at 1% level and *** significant at 0.1% level

Table.2 Estimates of per se performance, heterobeltosis and standard heterosis for yield, quality and drought related traits in 17 hybrids of rice

S. No.	Characters	Hulling recovery				Milling recovery				Kernel length				Kernel breadth			
	Crosses	Mean	BP	NDR-97	Arize 6444 Gold	Mean	BP	NDR-97	Arize 6444 Gold	Mean	BP	NDR-97	Arize 6444 Gold	Mean	BP	NDR-97	Arize 6444 Gold
1	IR-79156A x Akshaydhan	78.62	1.93	2.23	6.99**	70.67	2.78	1.54	9.43**	7.00	-3.00**	10.30**	10.13**	1.87	11.31**	-13.02**	-6.81**
2	IR-79156A x IR-36	73.49	-2.64	-4.45*	0.00	65.76	-2.43	-5.51**	1.83	7.37	2.17*	16.18**	16.00**	1.72	2.58	-19.84**	-14.12**
3	IR-79156A x URG-42	77.49	2.67	0.76	5.46**	69.85	3.65	0.37	8.17**	6.42	-11.04**	1.16	1.00	1.56	-6.94*	-27.29**	-22.09**
4	IR-79156A x Danteshwari	79.29	1.04	3.10	7.91**	69.85	-0.52	0.36	8.16**	7.13	-1.20	12.35**	12.17**	1.57	-6.75*	-27.13**	-21.93**
5	IR-79156A x URG-30	74.27	-1.60	-3.43	1.08	66.38	-1.51	-4.62*	2.79	7.04	-2.36*	11.04**	10.86**	1.69	0.79	-21.24**	-15.61**
6	IR-79156A x BPT-5204	69.43	-11.95**	-9.72**	-5.51**	62.49	-11.84**	-10.20**	-3.23	5.84	-18.99**	-7.88**	-8.03**	1.46	-13.29**	-32.25**	-27.41**
7	Pusa-6A x Akshaydhan	76.93	-2.38	0.02	4.69*	69.93	-1.17	0.48	8.28**	6.35	-1.81	0.05	-0.10	1.88	20.73**	-12.40**	-6.15*
8	Pusa-6A x IR-36	79.48	0.87	3.35	8.17**	73.41	3.75*	5.48**	13.67**	6.81	4.93**	7.41**	7.24**	1.76	12.61**	-18.29**	-12.46**
9	Pusa-6A x URG-42	74.80	-5.07**	-2.74	1.80	67.56	-4.51*	-2.92	4.62*	6.58	1.75	3.68**	3.52**	1.79	14.96**	-16.59**	-10.63**
10	Pusa-6A x Danteshwari	79.48	0.87	3.35	8.17**	69.87	-1.24	0.40	8.20**	7.66	14.96**	20.70**	20.51**	1.78	14.10**	-17.21**	-11.30**
11	Pusa-6A x URG-30	73.59	-6.62**	-4.32*	0.14	65.46	-7.49**	-5.94**	1.36	6.20	-4.13**	-2.31*	-2.47*	2.06	32.05**	-4.19	2.66
12	Pusa-6A x HUR-105	79.13	0.42	2.89	7.69**	73.59	4.01*	5.74**	13.95**	7.09	4.47**	11.82**	11.65**	1.76	13.03**	-17.98**	-12.13**
13	Pusa-6A x IET-22202	78.70	-0.12	2.33	7.10**	71.95	1.70	3.39	11.42**	7.36	-0.90	16.03**	15.84**	1.78	14.10**	-17.21**	-11.30**
14	Pusa-6A x Susksamarat	77.22	-2.00	0.41	5.09**	70.70	-0.07	1.59	9.48**	7.05	5.85**	11.19**	11.02**	2.67	71.15**	24.19**	33.06**
15	Pusa-6A x IR-64	77.00	-2.28	0.12	4.79*	69.32	-2.03	-0.39	7.34**	7.19	11.19**	13.29**	13.12**	1.92	23.29**	-10.54**	-4.15
16	Pusa-6A x NDR-359	78.64	-0.21	2.25	7.01**	68.88	-2.64	-1.02	6.66**	7.42	11.63**	16.97**	16.79**	1.67	7.05*	-22.33**	-16.78**
17	Pusa-6A x Pantdhan-12	78.88	0.11	2.57	7.35**	70.42	-0.48	1.18	9.04**	7.29	5.86**	14.92**	14.74**	1.75	12.39**	-18.45**	-12.62**
	Mean	76.85	-1.59	-0.08	4.58	69.18	-1.18	-0.59	7.13	6.93	1.14	9.23	9.06	1.81	13.13	-15.99	-9.99
	Range	69.43 to 79.48	-11.95 to 2.67	-9.72 to 3.35	-5.51 to 8.17	62.49 to 73.59	-11.84 to 4.01	-10.20 to 5.74	-3.23 to 13.95	5.84 to 7.66	-18.99 to 14.96	-7.88 to 20.70	-8.03 to 20.51	1.46 to 2.67	-13.29 to 71.15	-32.25 to 24.19	-27.41 to 33.06

S. No.	Characters	Kernel L/B ratio				Amylose content				Canopy temp. depression (CTD)				Stomatal conductance			
	Crosses	**Mean**	**BP**	**NDR-97**	**Arize 6444 Gold**	**Mean**	**BP**	**NDR-97**	**Arize 6444 Gold**	**Mean**	**BP**	**NDR-97**	**Arize 6444**	**Mean**	**BP**	**NDR-97**	**Arize 6444**
1	IR-79156A x Akshaydhan	3.75	-12.87**	26.86**	18.19**	20.73	-13.73**	-10.37**	-13.61**	31.33	-3.29	-4.37	0.11	533.67	45.25**	9.61	158.52**
2	IR-79156A x IR-36	4.28	-0.39	45.03**	35.12**	22.23	-7.49**	-3.89*	-7.36**	31.40	-2.48	-4.17	0.32	814.40	121.67**	67.27**	294.51**
3	IR-79156A x URG-42	4.11	-4.50	39.05**	29.55**	21.57	-10.26**	-6.77**	-10.14**	31.27	-2.70	-4.58	-0.11	423.13	51.57**	-13.09	104.97**
4	IR-79156A x Danteshwari	4.55	5.89*	54.18**	43.64**	24.33	1.25	5.19**	1.39	32.50	-1.42	-0.81	3.83	419.07	119.48**	-13.93	103.00**
5	IR-79156A x URG-30	4.17	-3.10	41.08**	31.44**	21.27	-11.51**	-8.07**	-11.39**	31.27	-1.88	-4.58	-0.11	416.27	102.46**	-14.50	101.65**
6	IR-79156A x BPT-5204	4.02	-6.59**	36.00**	26.71**	23.23	-3.33	0.43	-3.19	30.97	-2.82	-5.49	-1.06	336.10	105.06**	-30.97**	62.81**
7	Pusa-6A x Akshaydhan	3.37	-18.80**	14.11**	6.31*	22.90	-1.72	-1.01	-4.58*	32.63	0.10	-0.41	4.26	886.30	98.89**	82.04**	329.34**
8	Pusa-6A x IR-36	3.88	-6.43**	31.49**	22.50**	20.17	-13.45**	-12.82**	-15.97**	32.53	-0.20	-0.71	3.94	484.80	25.37*	-0.42	134.85**
9	Pusa-6A x URG-42	3.67	-11.57**	24.27**	15.77**	21.80	-6.44**	-5.76**	-9.17**	31.30	-3.99	-4.48	0.00	407.30	45.90**	-16.34	97.30**
10	Pusa-6A x Danteshwari	4.30	3.69	45.71**	35.75**	23.60	-0.42	2.02	-1.67	31.43	-4.65	-4.07	0.43	373.87	95.81**	-23.21**	81.11**
11	Pusa-6A x URG-30	3.01	-27.55**	1.81	-5.15	20.90	-10.30**	-9.65**	-12.92**	32.83	0.72	0.20	4.90	462.87	125.13**	-4.93	124.22**
12	Pusa-6A x HUR-105	4.03	-2.97	36.34**	27.02**	23.00	-3.09	-0.58	-4.17*	32.37	-0.72	-1.22	3.41	537.73	81.44**	10.45	160.49**
13	Pusa-6A x IET-22202	4.14	-0.16	40.29**	30.70**	22.40	-3.86*	-3.17	-6.67**	31.73	-2.66	-3.15	1.38	398.87	110.97**	-18.07*	93.22**
14	Pusa-6A x Susksamarat	2.64	-36.39**	-10.61**	-16.72**	23.87	2.43	3.17	-0.56	32.47	-0.41	-0.92	3.73	782.43	34.52**	60.71**	279.02**
15	Pusa-6A x IR-64	3.74	-9.88**	26.64**	17.98**	20.93	-10.16**	-9.51**	-12.78**	31.23	-4.19	-4.68	-0.21	327.10	-9.00	-32.82**	58.45**
16	Pusa-6A x NDR-359	4.45	7.23**	50.68**	40.38**	23.37	0.29	1.01	-2.64	32.77	0.51	0.00	4.69	444.47	30.51*	-8.71	115.31**
17	Pusa-6A x Pantdhan-12	4.16	0.24	40.86**	31.23**	22.83	-4.99**	-1.30	-4.86**	31.80	-2.45	-2.95	1.60	391.97	-12.19	-19.49*	89.88**
	Mean	3.90	-7.30	31.99	22.97	22.30	-5.69	-3.59	-7.08	31.87	-1.91	-2.73	1.83	496.49	68.99	1.98	140.51
	Range	2.64 to 4.55	-36.39 to 7.23	-10.61 to 54.18	-16.72 to 43.64	20.17 to 24.33	-13.73 to 2.43	-12.82 to 5.19	-15.97 to 1.39	30.97 to 32.83	-4.65 to 0.72	-5.49 to 0.20	-1.06 to 4.90	327.10 to 886.30	-12.19 to 125.13	-32.82 to 82.04	58.45 to 329.34

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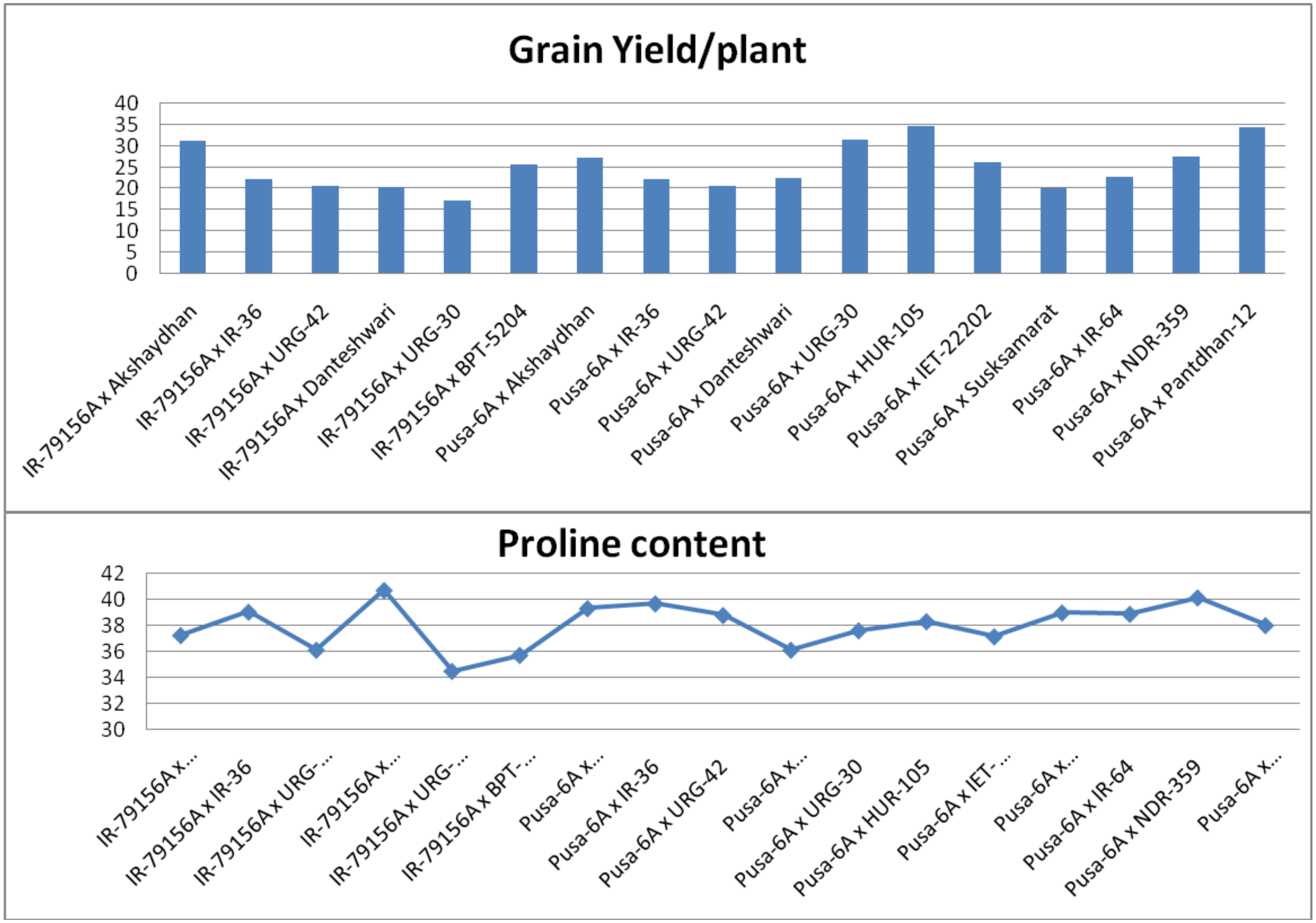
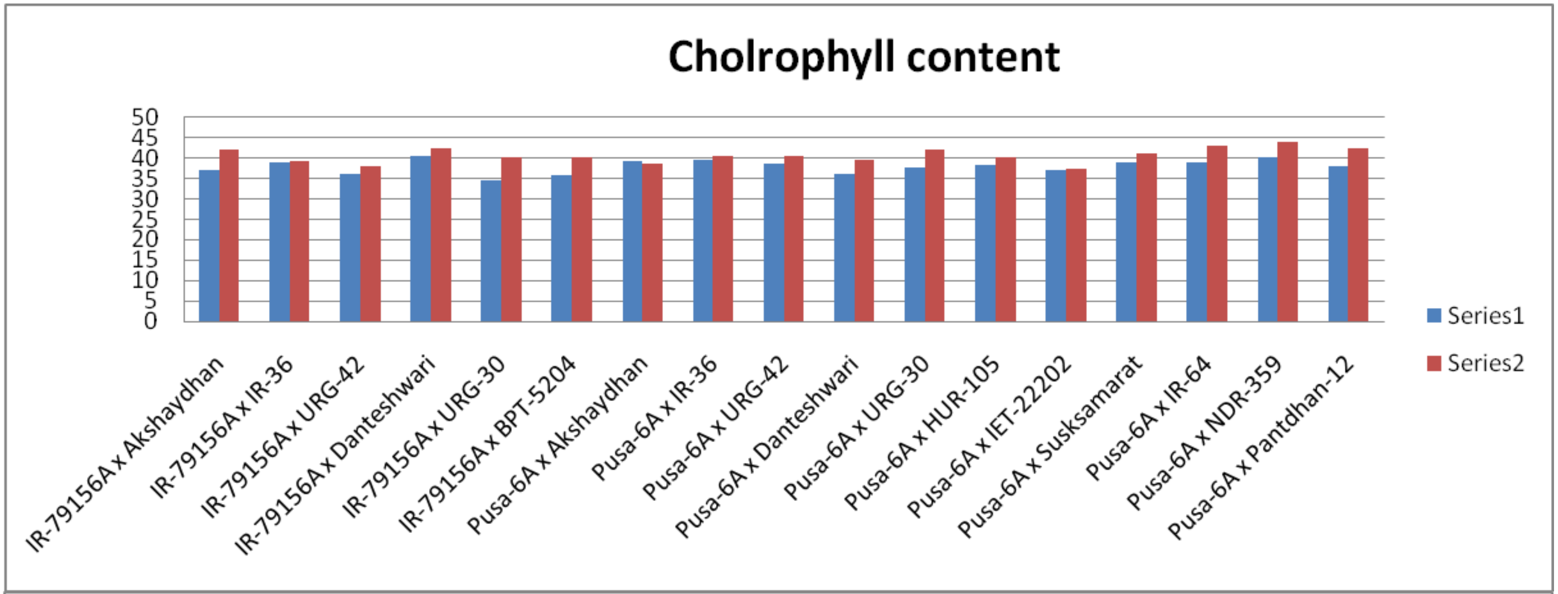
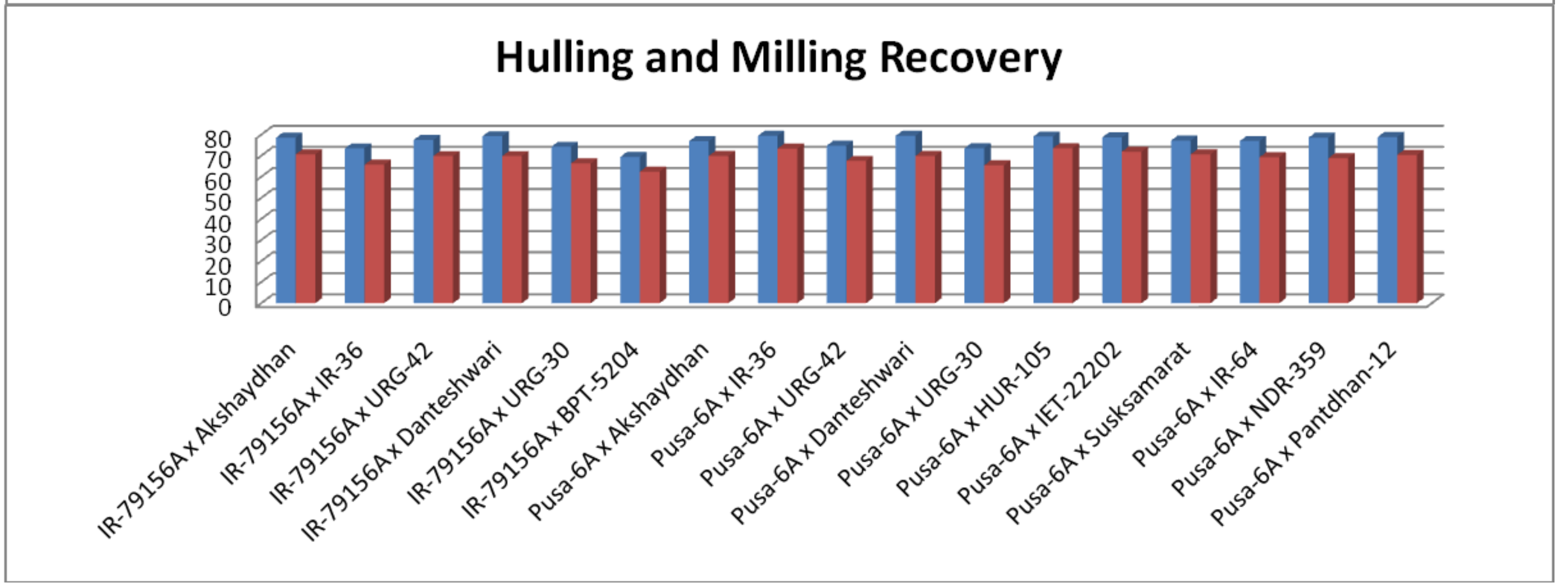
S. No.	Characters	Leaf area index				Proline content				Chlorophyll content							
										At 60 DAS				At 90 DAS			
	Crosses	Mean	BP	NDR-97	Arize 6444 Gold	Mean	BP	NDR-97	Arize 6444 Gold	Mean	BP	NDR-97	Arize 6444 Gold	Mean	BP	NDR-97	Arize 6444 Gold
1	IR-79156A x Akshaydhan	1.84	-29.90**	10.42	-50.89**	14.59	-15.17**	7.12**	49.90**	37.23	-3.79	-10.14**	-2.87	42.07	5.78	2.77	20.88**
2	IR-79156A x IR-36	2.12	-19.08*	27.45	-43.32**	12.47	-27.52**	-8.47**	28.08**	39.03	0.86	-5.79	1.83	39.30	-14.13**	-3.99	12.93*
3	IR-79156A x URG-42	1.78	-32.06**	7.01	-52.41**	8.56	-50.21**	-37.13**	-12.02**	36.10	-6.72	-12.87**	-5.83	38.00	-4.44	-7.17	9.20
4	IR-79156A x Danteshwari	2.90	10.81	74.55**	-22.37**	15.52	-9.79**	13.93**	59.42**	40.70	3.12	-1.77	6.17	42.47	-0.78	3.75	22.03**
5	IR-79156A x URG-30	2.60	-0.64	56.51**	-30.39**	8.65	-49.73**	-36.51**	-11.16**	34.47	-10.94**	-16.81**	-10.09*	40.23	1.17	-1.71	15.61*
6	IR-79156A x BPT-5204	2.92	11.58	75.75**	-21.84**	7.49	-56.47**	-45.03**	-23.08**	35.70	-7.75	-13.84**	-6.87	40.13	0.92	-1.95	15.33*
7	Pusa-6A x Akshaydhan	2.08	-24.88**	25.25	-44.30**	11.49	10.20**	-15.64**	18.05**	39.30	5.27	-5.15	2.52	38.63	-1.86	-5.62	11.02
8	Pusa-6A x IR-36	1.75	-37.02**	5.01	-53.30**	12.49	9.78**	-8.27**	28.36**	39.67	2.94	-4.26	3.48	40.43	-11.65*	-1.22	16.19**
9	Pusa-6A x URG-42	3.13	12.74	87.98**	-16.40*	12.61	35.12**	-7.44**	29.52**	38.77	6.31	-6.44	1.13	40.50	5.84	-1.06	16.38**
10	Pusa-6A x Danteshwari	2.66	-4.09	59.92**	-28.88**	12.45	-4.38*	-8.59**	27.91**	36.10	-8.53*	-12.87**	-5.83	39.57	-7.55	-3.34	13.70*
11	Pusa-6A x URG-30	1.98	-28.73**	18.84	-47.15**	12.40	13.31**	-8.93**	27.43**	37.60	3.11	-9.25*	-1.91	42.13	8.50	2.93	21.07**
12	Pusa-6A x HUR-105	5.60	72.74**	236.47**	49.64**	10.63	-32.20**	-21.98**	9.18**	38.30	0.79	-7.56*	-0.09	40.23	5.14	-1.71	15.61*
13	Pusa-6A x IET-22202	5.37	52.99**	222.85**	43.58**	10.41	-40.86**	-23.54**	6.99*	37.13	-2.28	-10.38**	-3.13	37.33	-2.44	-8.79	7.28
14	Pusa-6A x Susksamarat	3.10	11.90	86.57**	-17.02*	15.49	66.02**	13.73**	59.14**	38.97	6.86	-5.95	1.65	41.30	4.56	0.90	18.68**
15	Pusa-6A x IR-64	3.99	43.87**	139.88**	6.68	14.44	-3.20	6.00**	48.32**	38.87	0.43	-6.19	1.39	43.17	12.80*	5.46	24.04**
16	Pusa-6A x NDR-359	4.44	59.98**	166.73**	18.63**	17.46	2.07	28.19**	79.38**	40.13	10.05*	-3.14	4.70	43.87	14.63**	7.17	26.05**
17	Pusa-6A x Pantdhan-12	3.67	32.21**	120.44**	-1.96	15.64	46.82**	14.81**	60.65**	38.00	4.20	-8.29*	-0.87	42.50	6.78	3.83	22.13**
	Mean	3.05	7.79	83.63	-18.34	12.52	-6.25	-8.10	28.59	38.00	0.23	-8.28	-0.86	40.70	1.37	-0.57	16.95
	Range	1.75 to 5.60	-37.02 to 72.74	5.01 to 236.47	-53.30 to 49.64	7.49 to 17.46	-56.47 to 66.02	-45.03 to 28.19	-23.08 to 79.38	34.47 to 40.70	-10.94 to 10.05	-16.81 to -1.77	-10.09 to 6.17	37.33 to 43.87	-14.13 to 14.63	-7.17 to 7.17	7.28 to 26.05

S. No.	Characters	Grain yield/ plant			
	Crosses	**Mean**	**BP**	**NDR-97**	**Arize 6444 Gold**
1	IR-79156A x Akshaydhan	31.26	40.19**	94.67**	66.98**
2	IR-79156A x IR-36	22.18	3.77	38.11**	18.46**
3	IR-79156A x URG-42	20.79	-1.55	29.43**	11.02
4	IR-79156A x Danteshwari	20.31	-3.82	26.44**	8.46
5	IR-79156A x URG-30	17.26	-18.23**	7.49	-7.80
6	IR-79156A x BPT-5204	25.72	21.83**	60.17**	37.39**
7	Pusa-6A x Akshaydhan	27.37	22.72**	70.40**	46.16**
8	Pusa-6A x IR-36	22.32	3.27	39.00**	19.23**
9	Pusa-6A x URG-42	20.78	-3.89	29.37**	10.97
10	Pusa-6A x Danteshwari	22.49	4.04	40.04**	20.12**
11	Pusa-6A x URG-30	31.56	45.98**	96.49**	68.54**
12	Pusa-6A x HUR-105	34.77	60.83**	116.48**	85.69**
13	Pusa-6A x IET-22202	26.16	21.00**	62.87**	39.70**
14	Pusa-6A x Susksamarat	20.23	-6.43	25.94**	8.03
15	Pusa-6A x IR-64	22.73	5.15	41.53**	21.40**
16	Pusa-6A x NDR-359	27.44	21.75**	70.88**	46.57**
17	Pusa-6A x Pantdhan-12	34.49	59.54**	114.74**	84.19**
	Mean	25.17	16.24	56.71	34.42
	Range	17.26 to 34.77	-18.23 to 60.83	7.49 to 116.48	-7.80 to 85.69

Fig.1 Graphical representation of per se performance of various traits




Cholrophyll content
50
45
40
35
30
25
20
15
10
5
0
IR-79156A x Akshaydhan
IR-79156A x IR-36
IR-79156A x URG-42
IR-79156A x Danteshwari
IR-79156A x URG-30
IR-79156A x BPT-5204
Pusa-6A x Akshaydhan
Pusa-6A x IR-36
Pusa-6A x URG-42
Pusa-6A x Danteshwari
Pusa-6A x URG-30
Pusa-6A x HUR-105
Pusa-6A x IET-22202
Pusa-6A x Susksamarat
Pusa-6A x IR-64
Pusa-6A x NDR-359
Pusa-6A x Pantdhan-12
Series1
Series2


Hulling and Milling Recovery
80
70
60
50
40
30
20
10
0
IR-79156A x Akshaydhan
IR-79156A x IR-36
IR-79156A x URG-42
IR-79156A x Danteshwari
IR-79156A x URG-30
IR-79156A x BPT-5204
Pusa-6A x Akshaydhan
Pusa-6A x IR-36
Pusa-6A x URG-42
Pusa-6A x Danteshwari
Pusa-6A x URG-30
Pusa-6A x HUR-105
Pusa-6A x IET-22202
Pusa-6A x Susksamarat
Pusa-6A x IR-64
Pusa-6A x NDR-359
Pusa-6A x Pantdhan-12

The standard heterosis over the best hybrid, Arize 6444 gold and over NDR-97 for grain yield per plant ranged from -7.80% (IR-79156A x URG-30) to 85.69% (Pusa-6A x HUR-105) and 7.49% (IR-79156A x URG-30) to 116.48% (Pusa-6A x HUR-105), for hulling recovery ranged from -5.51% (IR-79156A x BPT-5204) to 8.17% (Pusa-6A x IR-36 and Pusa-6A x Danteshwari) and -9.72% (IR-79156A x BPT-5204) to 3.35% (Pusa-6A x IR-36 and Pusa-6A x Danteshwari), for milling recovery ranged from -3.23% (IR-79156A x BPT-5204) to 13.95% (Pusa-6A x HUR-105) and -10.20% (IR-79156A x BPT-5204) to 5.74% (Pusa-6A x HUR-105), for kernel length ranged from -8.03% (IR-79156A x BPT-5204) to 20.51% (Pusa-6A x Danteshwari) and -7.88% (IR-79156A x BPT-5204) to 20.70% (Pusa-6A x Danteshwari), for kernel breadth ranged from -27.41% (IR-79156A x BPT-5204) to 33.06% (Pusa-6A x Susksamarat) and -32.25% (IR-79156A x BPT-5204) to 24.19% (Pusa-6A x Susksamarat), for kernel L/B ratio ranged from -16.72% (Pusa-6A x Susksamarat) to 43.64% (IR-79156A x Danteshwari) and -10.61% (Pusa-6A x Susksamarat) to 54.18% (IR-79156A x Danteshwari), for amylose content ranged from -15.97% (Pusa-6A x IR-36) to 1.39% (IR-79156A x Danteshwari) and -12.82% (Pusa-6A x IR-36) to 5.19% (IR-79156A x Danteshwari), for canopy temp. depression (CTD) ranged from -1.06% (IR-79156A x BPT-5204) to 4.90% (Pusa-6A x URG-30) and -5.49% (IR-79156A x BPT-5204) to 0.20% (Pusa-6A x URG-30), for stomatal conductance ranged from 58.45% (Pusa-6A x IR-64) to 329.34% (Pusa-6A x Akshaydhan) and -32.82% (Pusa-6A x IR-64) to 82.04% (Pusa-6A x Akshaydhan), for leaf area indexranged from-53.30% (Pusa-6A x IR-36) to 49.64% (Pusa-6A x HUR-105) and 5.01% (Pusa-6A x IR-36) to 236.47% (Pusa-6A x HUR-105), for proline content ranged from -23.08% (IR-79156A x BPT-5204) to 79.38% (Pusa-6A x NDR-359) and -45.03% (IR-79156A x BPT-5204) to 28.19% (Pusa-6A x NDR-359) and for chlorophyll content ranged from -10.09% (IR-79156A x URG-30) to 6.17% (IR-79156A x Danteshwari) [at 60 DAS] and 7.28% (Pusa-6A x IET-22202) to 26.05% (Pusa-6A x NDR-359) [at 90 DAS] and -16.81% (IR-79156A x URG-30) to -1.77% (IR-79156A x Danteshwari) [at 60 DAS] and -7.17% (IR-79156A x URG-42) to 7.17% (Pusa-6A x NDR-359)[at 90 DAS] respectively (Fig. 1). The higher heterotic effects among quality and drought related traits were observed for Kernel length, Kernel breadth, Kernel L/B ratio, Stomatal conductance, Proline content, Hulling recovery, Milling recovery and Chlorophyll content (at 90 days). The top two high yielding crosses on the basis of significant standard heterosis over SH(Arize6444) and SV(NDR-97) were Pusa-6A x HUR-105 (SH= 85.69%, SV=116.48%) and Pusa-6A x Pantdhan-12 (SH= 84.19%, SV=114.74%).Cross combinations Pusa-6A x IR-36 and Pusa6A x HUR-105 showed relatively significant desirable heterosis for the quality traits *viz.*, hulling recovery, milling recovery, kernel length, kernel breadth, kernel length breadth ratio. Hybrids IR 79156A x Danteshwari and Pusa6A x NDR-359 exhibited significant standard heterosis in desired direction for quality aspects along with higher magnitude of standard heterosis for yield. Cross combinations Pusa6A x NDR-359 and Pusa6A x Pantdhan-12 showed relatively higher significant desirable standard heterosis over SH (Arize-6444 Gold) for the drought traits *viz.*, chlorophyll content (at 90 DAS) and proline content. Cross combinations Pusa 6A x HUR-105 and Pusa6A x IET-22202 showed significant desirable heterosis for the leaf area index. The present study revealed that superior performance for all characters was not expressed in a single hybrid combination. However, different cross combinations were found to be superior for various characters.

These finding are in accordance with those of Binodh *et al.,* (2006), Reddy *et al.*, (2012),Venkanna *et al.*, (2014), Babu *et al.*, (2013), Singh *et al.*, (2013) and Sharma *et al.*, (2013), Priyanka *et al.*, (2014).

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