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Research Note

Heterosis for quality parameters in direct and reciprocal crosses of dual purpose pigeonpea

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Abstract
A field experiment was undertaken with a view to know the extent of heterosis for quality parameters *viz*., protein content and TSS content in dual purpose pigeonpea [*Cajanus cajan* (L.) Millsp.]. The hybrids were developed by adopting complete diallel mating design (including reciprocals) involving a set of six parents which includes two parental lines *viz*., vegetable purpose released variety GT-1 and grain purpose released variety Vaishali as checks. The experiments were conducted at three locations *viz*., Bharuch, Hansot and Navsari. Significant heterobeltiosis and standard heterosis over GT-1 and Vaishali for protein content and TSS content suggested that there is a good scope of exploiting heterosis and also possibilities of isolating desirable segregants for quality purpose in dual type pigeonpea. The hybrids, AVPP-1 x SKNP-11-19 and SKNP-11-19 x ICPL- 87119 among direct crosses and ICPL- 87119 x AVPP-1 and ICPL- 87119 x SKNP-11-19 among reciprocals recorded significant heterotic values for both protein content and TSS content in dual type pigeonpea which can be worked upon for the future breeding programme to improve quality parameters of dual type pigeonpea.

Key words
Dual purpose pigeonpea, complete diallel, protein content, TSS content

Pigeonpea [*Cajanus cajan* (L.) Millspaugh] is a short-lived perennial member of family *Fabaceae* and it is invariably cultivated as an annual crop. Pigeonpea is an often cross pollinated crop (20 – 70 per cent cross pollination) (Saxena and Sharma, 1990) with 2n = 2x = 22 diploid chromosome number. It is widely grown on the Indian subcontinent. Pigeonpea offers many benefits to subsistence farmers as a food and cash crop and also ensures stable crop yields in times of drought. Recently, multiple harvest potential of dual purpose pigeonpea (Vegetable as well as seed purpose) is popularized by rendering first two pickings for green pods and remaining for the harvesting of dry seeds which will give extra benefits to farmers and they are taking the cultivation more seriously than before. So, breeding for dual purpose pigeonpea is being considered as a life line of subsistence agriculture. This has brought the attention of pigeonpea breeders to develop high yielding dual purpose varieties with superior grain qualities. Soluble sugars and protein content are the important quality constituents of the dual purpose pigeonpea and it was rated as the best as far as its biological value was concerned Manimekalai *et al.* (1979) and Singh *et al.* (1984) reported large variability for various chemical constituents and nutritive value of pigeonpea. It is to be noted that besides inherent genotypic differences, some degree of variation in protein content and solunle sugars can also arise due to differences in environmental conditions where the crop was grown, methods of sampling and analyses, seed storage conditions and its duration. Considering this the investigation was undertaken to identify heterotic crosses with superior dual type quality.

The present investigation was carried out to elicit information on magnitude of heterobeltiosis and standard heterosis for quality parameters in dual purpose pigeonpea. The experimental material for the present investigation consisted of 36 entries including six parents *viz*., two vegetable purpose released varieties GT-1 and AVPP-1; two grain purpose released varieties Vaishali and ICPL-87119 as well as two dual type promising cultures SKNP-11-19 and BP-06-33 and their resultant 30 hybrids. For obtaining hybrid seeds, the crossing block was raised at Pulses Research Station, NAU, Navsari during *Rabi* 2013-14 and all possible single crosses (including reciprocals) were made to complete the 6 x 6 full diallel set. The evaluation trials were conducted in Randomized Block Design with three replications at three locations *viz.*, National Agricultural Research Project Farm, College of Agriculture, Bharuch; Cotton Wilt Research Sub-station, Hansot (Dist-Bharuch) and Pulses Research Station, Navsari Agricultural University, Navsari with 36 entries including two checks, GT-1 and Vaishali during *kharif* 2014. Observations were recorded for the two important quality parameters of dual purpose pigeonpea *viz*., protein content and TSS content. TSS content was measured using handheld refractometer which measure the refractive index of a solution to calculate a soluble solid concentration (Mitcham *et al*., 1996). °Brix values are a measure of the soluble solids content and sugars are the most abundant soluble solids in vegetable juices (Kleinhenz and Bumgarner, 2012). Total protein content was estimated by Kjeldahl method using Gerhardt nitrogen digestion (turbotherm) and distillation (vapodest) apparatus from Bio-incorporation, India (Roopa and Premavalli 2008). The mean values of the same were subjected to statistical analysis. Replication wise mean value for all the characters were analysed manually by making spreadsheet in Microsoft Excel, for computing mean, variance and heterosis. To test the variation among genotypes, the data obtained for each character were analyzed separately for each environment as well as pooled over environments by the usual statistical procedure (Panse and Sukhatme, 1985). Heterosis expressed as per cent increase or decrease in the mean value of F1 hybrid over better parent (heterobeltiosis) and over standard check (standard heterosis) was calculated for quality parameters over environments following procedure given by Fonseca and Patterson (1968).

Mean squares obtained from the individual environments (Table 1) indicated that, parents differed significantly for both the quality paramters. Hybrids differed significantly among themselves for both traits. Comparison of mean squares due to parents *vs*. hybrids was found to be highly significant for protein content as well as TSS content under all the three environments which suggested that parental group as a whole was quite different from their F1s indicating the presence of heterosis for both the characters under investigation.. The analysis for pooled over environments (Table 2) revealed that mean squares due to environments were highly significant for both the characters; which indicated the variable environmental conditions. Considerable amount of variability was observed among all the entries as the mean squares due to genotypes were highly significant for both the characters. Genotypes were found to interact non-significantly with the environments for protein content and TSS content indicated similar response of parents as well as hybrids with different environments.

From the perusal of the *per se* performance of parents and hybrids (Table 3) it was noted that, the protein content of the parents ranged from 13.79 (ICPL-87119) to 22.54 per cent (BP-06-33) in pooled data. Among F1s the cross Vaishali x BP-06-33 registered highest mean value (22.61 %) while, GT-1 x BP-06-33 recorded least average value (17.42 %) in pooled analysis. The reciprocal cross, BP-06-33 x GT-1 pictured maximum (22.73 %) and cross ICPL-87119 x AVPP-1 showed least (17.40 %) protein content in pooled investigations. Average protein content of reciprocal crosses (19.26 %) was higher than direct crosses (18.96 %). In general, the lowest value of protein content was recorded at Hansot (18.86 %) while, it was highest at Bharuch (19.15 %). For TSS content among the parents, ICPL-87119 possessed lowest TSS content (4.94 %), while, GT-1 had highest TSS content (10.21 %) in pooled data. The figures of TSS content for F1s fluctuated between 4.70 (Vaishali x BP-06-33) and 10.10 per cent (GT-1 x ICPL-87119) in pooled study. Among reciprocals, the highest value was recorded by AVPP-1 x GT-1 (10.07 %), while, lowest value was recorded by ICPL-87119 x Vaishali (4.64 %) in pooled investigations. Highest TSS content (7.27 %) was observed at Navsari closely followed by Bharuch (7.21 %) and Hansot (6.79 %). The comparative study of most heterotic hybrids for quality parameters indicated that superiority of parents GT-1 and AVPP-1 in quality parameters reproduced in BP-06-33 x GT-1 for protein content and in AVPP-1 x GT-1 for TSS content.

In the present study, the aim of heterosis analysis was to identify best combination of parents giving high degree of useful heterosis and characterization of parents for their prospects for quality parameters of dual purpose pigeonopea. For protein content among direct crosses, three and two crosses showed positive significant heterobeltiosis and standard heterosis over check Vaishali, respectively and it ranged from -22.70 (GT-1 x BP-06-33) to 39.00 per cent (AVPP-1 x SKNP-11-19) and -17.38 (GT-1 x BP-06-33) to 7.23 per cent (Vaishali x BP-06-33), respectively in pooled analysis (Table 4). None of the direct cross had recorded significant standard heterosis over check GT-1 in desired direction in pooled investigations. The heterobeltiosis and standard heterosis over GT-1 and Vaishali for reciprocals varied from -21.87 (BP-06-33 x SKNP-11-19) to 31.86 per cent (ICPL-87119 x SKNP-11-19), -21.98 (ICPL-87119 x AVPP-1) to 1.90 per cent (BP-06-33 x GT-1) and -17.47 (ICPL-87119 x AVPP-1) to 7.80 per cent (BP-06-33 x GT-1), respectively in pooled over three environments (Table 4). In case of reciprocal crosses three crosses for heterobeltiosis, one cross for standard heterosis over GT-1 and two crosses for standard heterosis over Vaishali depicted significant and positive values over environments. For TSS content among direct crosses, four and ten crosses showed positive significant heterobeltiosis and standard heterosis over check Vaishali, respectively and it ranged from -44.89 (GT-1 x BP-06-33) to 43.06 per cent (SKNP-11-19 x BP-06-33) and -15.91 (Vaishali x BP-06-33) to 80.82 per cent (GT-1 x ICPL-87119), respectively in pooled analysis (Table 5). None of the direct cross had recorded significant standard heterosis over check GT-1 in desired direction in pooled investigations. Among reciprocals, one and eight crosses showed positive significant heterobeltiosis and standard heterosis over check Vaishali, respectively and it ranged from -41.60 (ICPL-87119 x GT-1) to 30.32 per cent (ICPL-87119 x SKNP-11-19) and -16.94 (ICPL-87119 x Vaishali) to 80.34 per cent (AVPP-1 x GT-1), respectively in pooled analysis (Table 5). None of the reciprocal cross had recorded significant standard heterosis over check GT-1 in desired direction in pooled investigations. Heterosis for quality parameters in pigeonpea was also reported by Patel and Tikka (2008) and Acharya *et al.* (2009).

Considering dual purpose pigeonpea, AVPP-1 x SKNP-11-19 and SKNP-11-19 x ICPL- 87119 among direct crosses recorded significant heterotic values for both protein content and TSS content which can be worked upon for the future breeding programme to improve quality parameters of dual type pigeonpea. Reciprocal differences were also observed and crosses *viz*., and ICPL- 87119 x AVPP-1 and ICPL-87119 x SKNP-11-19 performed good in terms of *per se* performance and heterotic expression for dual purpose pigeonpea indicating that small group of cytoplasmic genes are also playing key role and affecting the hybrid vigour. So, it is better to attempt even reciprocal crosses when direct crosses are not showing desired results. Apart from conventional approaches, identification of candidate genes associated with hybrid vigour using epigenomics and mitochondrial genome sequencing may be fruitful for further improvement programme.

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Table 1. Analysis of variance showing mean squares of individual environment for parents and hybrids (F_1's + reciprocals) in pigeonpea

Source	D.F.	Protein content (%)			TSS content (%)		
		Bharuch	Hansot	Bharuch	Hansot	Bharuch	Hansot
Treatments	35	15.50**	14.57**	15.50**	14.57**	15.50**	14.57**
Parents	5	43.11**	45.47**	43.11**	45.47**	43.11**	45.47**
Hybrids	29	11.09**	9.58**	11.09**	9.58**	11.09**	9.58**
Parent v/s Hybrids	1	5.39**	4.50*	5.39**	4.50*	5.39**	4.50*
F1's	14	9.83**	8.53**	9.83**	8.53**	9.83**	8.53**
Reciprocals	14	13.09**	11.31**	13.09**	11.31**	13.09**	11.31**
F1's v/s Reciprocals	1	0.58	0.12	0.58	0.12	0.58	0.12
Error	70	0.38	0.78	0.38	0.78	0.38	0.78

*Significant at 5% level and ** Significant at 1% level

Table 2. Analysis of variance showing pooled mean squares (parents + hybrids) for quality parameters in pigeonpea.

Source	D.F.	Protein content (%)	TSS content (%)
Environments (E)	2	0.74*	2.42**
Genotypes (G)	35	14.38**	9.61**
G x E	70	0.19	0.19
Error	210	0.18	0.17

*Significant at 5% level and ** Significant at 1% level

Table 3. *Per se* performance (parents + hybrids) for quality parameters in pigeonpea

Sl. No.	Parents/crosses	Protein content (%)			
		Bharuch	Hansot	Navsari	Pooled
	Parents				
1	GT-1	21.64	22.03	23.24	22.30
2	AVPP-1	15.56	15.83	14.48	15.29
3	SKNP-1119	16.61	15.96	15.51	16.03
4	Vaishali	21.23	20.74	21.28	21.08
5	ICPL-87119	13.82	13.24	14.30	13.79
6	BP-06-33	23.03	22.63	21.94	22.54
	Parental mean	**18.65**	**18.41**	**18.46**	**18.50**
	F_1s				
7	GT-1 x AVPP-1	20.29	19.92	19.73	19.98
8	GT-1 x SKNP-11-19	17.25	17.50	17.55	17.43
9	GT-1 x Vaishali	18.79	18.33	17.95	18.35
10	GT-1 x ICPL- 87119	18.05	17.67	17.71	17.81
11	GT-1 x BP-06-33	17.40	17.36	17.50	17.42
12	AVPP-1 x SKNP-11-19	22.59	22.38	21.86	22.28
13	AVPP-1 x Vaishali	19.59	19.48	18.77	19.28
14	AVPP-1 x ICPL- 87119	19.82	19.36	19.26	19.48
15	AVPP-1 x BP-06-33	17.56	17.35	17.64	17.52
16	SKNP-11-19 x Vaishali	18.49	17.91	17.98	18.13
17	SKNP-11-19 x ICPL- 87119	17.78	17.53	17.12	17.48
18	SKNP-11-19 x BP-06-33	20.18	19.68	19.50	19.79
19	Vaishali x ICPL- 87119	17.15	17.76	18.00	17.64
20	Vaishali x BP-06-33	22.89	22.47	22.47	22.61
21	ICPL- 87119 x BP-06-33	19.65	19.05	18.99	19.23
	F_1s mean	**19.17**	**18.92**	**18.80**	**18.96**
	Reciprocals				
22	AVPP-1 x GT-1	20.82	20.15	20.45	20.47
23	SKNP-11-19 x GT-1	21.72	21.44	21.15	21.44
24	SKNP-11-19 x AVPP-1	17.52	17.07	17.83	17.47
25	Vaishali x GT-1	17.98	17.42	17.51	17.64
26	Vaishali x AVPP-1	20.11	19.75	19.65	19.84
27	Vaishali x SKNP-11-19	17.43	17.63	18.40	17.82
28	ICPL- 87119 x GT-1	17.58	17.50	19.79	18.29
29	ICPL- 87119 x AVPP-1	17.28	17.42	17.51	17.40
30	ICPL- 87119 x SKNP-11-19	21.42	20.98	21.00	21.14
31	ICPL- 87119 x Vaishali	17.42	17.28	18.51	17.74
32	BP-06-33 x GT-1	22.98	22.38	22.82	22.73
33	BP-06-33 x AVPP-1	17.74	17.42	17.91	17.69
34	BP-06-33 x SKNP-11-19	17.55	17.09	18.18	17.61
35	BP-06-33 x Vaishali	22.35	21.68	21.97	22.00
36	BP-06-33 x ICPL- 87119	19.99	19.62	19.40	19.67
	Reciprocals mean	**19.33**	**18.99**	**19.47**	**19.26**
	General Mean	**19.15**	**18.86**	**19.02**	**19.01**
	CD @ 5%	**1.00**	**1.44**	**1.14**	**0.71**
	C.V. (%)	**3.21**	**4.68**	**3.69**	**2.28**

Table 3. Contd.,

Sl. No.	Parents/crosses	TSS content (%)			
	Parents				
1	GT-1	10.77	10.05	9.82	10.21
2	AVPP-1	8.48	8.96	9.57	9.00
3	SKNP-1119	5.12	5.49	5.98	5.53
4	Vaishali	6.20	5.04	5.51	5.58
5	ICPL-87119	5.19	4.53	5.09	4.94
6	BP-06-33	5.07	5.96	6.54	5.86
	Parental mean	**6.80**	**6.67**	**7.09**	**6.85**
	F_1s				
7	GT-1 x AVPP-1	10.15	10.15	9.72	10.01
8	GT-1 x SKNP-11-19	8.90	8.58	8.99	8.82
9	GT-1 x Vaishali	8.84	7.81	8.34	8.33
10	GT-1 x ICPL- 87119	10.20	9.98	10.11	10.10
11	GT-1 x BP-06-33	6.48	5.02	5.39	5.63
12	AVPP-1 x SKNP-11-19	10.06	9.76	9.58	9.80
13	AVPP-1 x Vaishali	9.47	7.72	8.14	8.44
14	AVPP-1 x ICPL- 87119	6.05	6.50	7.23	6.59
15	AVPP-1 x BP-06-33	5.16	5.53	6.11	5.60
16	SKNP-11-19 x Vaishali	8.77	7.31	7.74	7.94
17	SKNP-11-19 x ICPL- 87119	7.37	6.35	6.72	6.81
18	SKNP-11-19 x BP-06-33	9.01	7.89	8.24	8.38
19	Vaishali x ICPL- 87119	4.79	4.63	5.18	4.87
20	Vaishali x BP-06-33	4.55	4.39	5.15	4.70
21	ICPL- 87119 x BP-06-33	5.79	5.05	5.55	5.46
	F_1s mean	**7.71**	**7.11**	**7.48**	**7.43**
	Reciprocals				
22	AVPP-1 x GT-1	10.00	9.98	10.23	10.07
23	SKNP-11-19 x GT-1	8.65	7.45	7.94	8.01
24	SKNP-11-19 x AVPP-1	6.84	6.38	7.23	6.82
25	Vaishali x GT-1	8.87	8.99	9.63	9.16
26	Vaishali x AVPP-1	5.72	5.44	6.09	5.75
27	Vaishali x SKNP-11-19	5.46	4.38	5.15	5.00
28	ICPL- 87119 x GT-1	6.71	5.39	5.80	5.97
29	ICPL- 87119 x AVPP-1	6.45	5.40	6.03	5.96
30	ICPL- 87119 x SKNP-11-19	7.09	6.90	7.62	7.20
31	ICPL- 87119 x Vaishali	4.38	4.37	5.16	4.64
32	BP-06-33 x GT-1	7.62	8.70	9.33	8.55
33	BP-06-33 x AVPP-1	7.77	7.64	8.16	7.86
34	BP-06-33 x SKNP-11-19	5.77	5.70	6.42	5.96
35	BP-06-33 x Vaishali	6.36	5.96	6.32	6.21
36	BP-06-33 x ICPL- 87119	5.37	5.20	5.89	5.49
	Reciprocals mean	**6.87**	**6.52**	**7.13**	**6.84**
	General Mean	**7.21**	**6.79**	**7.27**	**7.09**
	CD @ 5%	**1.08**	**1.18**	**1.26**	**0.71**
	C.V. (%)	**9.20**	**10.63**	**10.64**	**6.17**

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Table 4. Estimation of heterobeltiosis (BP) and standard heterosis (SC1 over GT-1 and SC2 over Vaishali) for protein content in different environments and pooled over environments in pigeonpea

Sl. no.	Crosses	Bharuch			Hansot			Navsari			Pooled		
		BP	SC1	SC2	BP	SC1	SC2	BP	SC1	SC2	BP	SC1	SC2
F_1s													
1	GT-1 x AVPP-1	-6.21**	-6.21**	-4.42	-9.61**	-9.61**	-3.97	-15.10**	-15.10**	-7.28**	-10.41**	-10.41**	-5.23**
2	GT-1 x SKNP-11-19	-20.26**	-20.26**	-18.73**	-20.59**	-20.59**	-15.63**	-24.48**	-24.48**	-17.52**	-21.83**	-21.83**	-17.31**
3	GT-1 x Vaishali	-13.16**	-13.16**	-11.50**	-16.82**	-16.82**	-11.63**	-22.78**	-22.78**	-15.67**	-17.71**	-17.71**	-12.95**
4	GT-1 x ICPL- 87119	-16.56**	-16.56**	-14.97**	-19.82**	-19.82**	-14.81**	-23.79**	-23.79**	-16.77**	-20.14**	-20.14**	-15.52**
5	GT-1 x BP-06-33	-24.45**	-19.58**	-18.04**	-23.29**	-21.21**	-16.29**	-24.71**	-24.71**	-17.77**	-22.70**	-21.90**	-17.38**
6	AVPP-1 x SKNP-11-19	36.04**	4.42	6.42**	40.21**	1.59	7.93*	40.92**	-5.93*	2.73	39.00**	-0.11	5.67**
7	AVPP-1 x Vaishali	-7.74**	-9.47**	-7.74**	-6.06	-11.57**	-6.06	-11.80**	-19.24**	-11.80**	-8.56**	-13.56**	-8.56**
8	AVPP-1 x ICPL- 87119	27.40**	-8.38**	-6.63**	22.30**	-12.15**	-6.67	33.08**	-17.12**	-9.48**	27.43**	-12.66**	-7.60**
9	AVPP-1 x BP-06-33	-23.74**	-18.83**	-17.27**	-23.32**	-21.24**	-16.33**	-19.60**	-24.09**	-17.10**	-22.25**	-21.45**	-16.90**
10	SKNP-11-19 x Vaishali	-12.89**	-14.53**	-12.89**	-13.64**	-18.71**	-13.64**	-15.50**	-22.63**	-15.50**	-14.02**	-18.72**	-14.02**
11	SKNP-11-19 x ICPL- 87119	7.08*	-17.81**	-16.24**	9.83*	-20.42**	-15.46**	10.35**	-26.34**	-19.55**	9.05**	-21.63**	-17.10**
12	SKNP-11-19 x BP-06-33	-12.38**	-6.73**	-4.95*	-13.04**	-10.68**	-5.11	-11.14**	-16.10**	-8.37**	-12.20**	-11.29**	-6.15**
13	Vaishali x ICPL- 87119	-19.22**	-20.74**	-19.22**	-14.36**	-19.39**	-14.36**	-15.42**	-22.55**	-15.42**	-16.35**	-20.93**	-16.35**
14	Vaishali x BP-06-33	-0.63	5.78*	7.80**	-0.71	1.98	8.35*	2.40	-3.32	5.58*	0.33	1.37	7.23**
15	ICPL- 87119 x BP-06-33	-14.70**	-9.20**	-7.46**	-15.82**	-13.54**	-8.14*	-13.48**	-18.31**	-10.78**	-14.68**	-13.79**	-8.80**

*Significant at 5% level and **Significant at 1% level

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Sl. no.	Crosses	Bharuch			Hansot			Navsari			Pooled		
		BP	SC1	SC2	BP	SC1	SC2	BP	SC1	SC2	BP	SC1	SC2
Reciprocals													
16	AVPP-1 x GT-1	-3.77	-3.77	-1.93	-8.55*	-8.55*	-2.84	-12.01**	-12.01**	-3.91	-8.21**	-8.21**	-2.90**
17	SKNP-11-19 x GT-1	0.39	0.39	2.30	-2.68	-2.68	3.40	-9.00**	-9.00**	-0.62	-3.88**	-3.88**	1.68
18	SKNP-11-19 x AVPP-1	5.47	-19.04**	-17.49**	6.93	-22.53**	-17.69**	14.95**	-23.27**	-16.20**	9.01**	-21.66**	-17.12**
19	Vaishali x GT-1	-16.88**	-16.88**	-15.30**	-20.95**	-20.95**	-16.02**	-24.66**	-24.66**	-17.72**	-20.93**	-20.93**	-16.35**
20	Vaishali x AVPP-1	-5.28*	-7.06**	-5.28*	-4.77	-10.36**	-4.77	-7.65**	-15.44**	-7.65**	-5.91**	-11.06**	-5.91**
21	Vaishali x SKNP-11-19	-17.90**	-19.44**	-17.90**	-14.99**	-19.98**	-14.99**	-13.54**	-20.83**	-13.54**	-15.48**	-20.10**	-15.48**
22	ICPL- 87119 x GT-1	-18.73**	-18.73**	-17.18**	-20.59**	-20.59**	-15.63**	-14.85**	-14.85**	-7.01*	-18.00**	-18.00**	-13.25**
23	ICPL- 87119 x AVPP-1	11.03**	-20.15**	-18.62**	10.06*	-20.94**	-16.00**	20.94**	-24.68**	-17.74**	13.83**	-21.98**	-17.47**
24	ICPL- 87119 x SKNP-11-19	28.99**	-0.99	0.91	31.44**	-4.77	1.18	35.36**	-9.65**	-1.32	31.86**	-5.24**	0.25
25	ICPL- 87119 x Vaishali	-17.95**	-19.49**	-17.95**	-16.68**	-21.57**	-16.68**	-13.01**	-20.35**	-13.01**	-15.87**	-20.47**	-15.87**
26	BP-06-33 x GT-1	-0.21	6.22**	8.26**	-1.09	1.59	7.93*	-1.83	-1.83	7.21**	0.85	1.90*	7.80**
27	BP-06-33 x AVPP-1	-22.96**	-17.99**	-16.43**	-23.01**	-20.92**	-15.99**	-18.40**	-22.96**	-15.86**	-21.50**	-20.68**	-16.09**
28	BP-06-33 x SKNP-11-19	-23.78**	-18.87**	-17.32**	-24.50**	-22.45**	-17.61**	-17.14**	-21.77**	-14.56**	-21.87**	-21.06**	-16.49**
29	BP-06-33 x Vaishali	-2.97	3.28	5.26*	-4.18	-1.59	4.55	0.10	-5.49*	3.22	-2.38**	-1.37	4.34**
30	BP-06-33 x ICPL- 87119	-13.20**	-7.61**	-5.84*	-13.29**	-10.94**	-5.38	-11.61**	-16.54**	-8.86**	-12.71**	-11.81**	-6.71**
	S.E.(d) ±	0.50	0.50	0.50	0.72	0.72	0.72	0.57	0.57	0.57	0.20	0.20	0.20
	CD @ 0.05	1.00	1.00	1.00	1.44	1.44	1.44	1.14	1.14	1.14	0.40	0.40	0.40
	CD @ 0.01	1.33	1.33	1.33	1.91	1.91	1.91	1.52	1.52	1.52	0.53	0.53	0.53

*Significant at 5% level and **Significant at 1% level

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Table 5. Estimation of heterobeltiosis (BP) and standard heterosis (SC1 over GT-1 and SC2 over Vaishali) for TSS content in different environments and pooled over environments in pigeonpea

Sl. no.	Crosses	Bharuch			Hansot			Navsari			Pooled		
		BP	SC1	SC2	BP	SC1	SC2	BP	SC1	SC2	BP	SC1	SC2
F_1s													
1	GT-1 x AVPP-1	-5.70	-5.70	63.64**	0.96	0.96	101.38**	-1.02	-1.02	76.56**	-2.02	-2.02	79.25**
2	GT-1 x SKNP-11-19	-17.35**	-17.35**	43.43**	-14.69*	-14.69*	70.17**	-8.52	-8.52	63.20**	-13.64**	-13.64**	57.97**
3	GT-1 x Vaishali	-17.91**	-17.91**	42.45**	-22.35**	-22.35**	54.89**	-15.07*	-15.07*	51.51**	-18.45**	-18.45**	49.17**
4	GT-1 x ICPL- 87119	-5.27	-5.27	64.39**	-0.76	-0.76	97.95**	2.95	2.95	83.66**	-1.15	-1.15	80.82**
5	GT-1 x BP-06-33	-39.83**	-39.83**	4.41	-50.07**	-50.07**	-0.40	-45.13**	-45.13**	-2.12	-44.89**	-44.89**	0.82
6	AVPP-1 x SKNP-11-19	18.75**	-6.52	62.22**	8.97	-2.92	93.65**	0.08	-2.46	74.00**	8.89**	-4.04*	75.55**
7	AVPP-1 x Vaishali	11.74	-12.04*	52.63**	-13.77*	-23.18**	53.24**	-15.01*	-17.17**	47.76**	-6.20**	-17.34**	51.21**
8	AVPP-1 x ICPL- 87119	-28.61**	-43.80**	-2.48	-27.47**	-35.38**	28.90*	-24.44**	-26.37**	31.36**	-26.75**	-35.45**	18.08**
9	AVPP-1 x BP-06-33	-39.11**	-52.07**	-16.82	-38.30**	-45.03**	9.66	-36.14**	-37.77**	11.02	-37.79**	-45.17**	0.30
10	SKNP-11-19 x Vaishali	41.32**	-18.56**	41.32**	33.23**	-27.29**	45.04**	29.56**	-21.17**	40.62**	42.21**	-22.26**	42.21**
11	SKNP-11-19 x ICPL- 87119	42.04**	-31.59**	18.71*	15.74	-36.84**	25.99*	12.38	-31.63**	21.97	23.24**	-33.32**	21.97**
12	SKNP-11-19 x BP-06-33	76.15**	-16.30**	45.24**	32.25**	-21.55**	56.48**	26.01**	-16.15*	49.58**	43.06**	-17.98**	50.05**
13	Vaishali x ICPL- 87119	-22.73*	-55.47**	-22.73*	-8.07	-53.91**	-8.07	-5.93	-47.27**	-5.93	-12.80**	-52.33**	-12.80**
14	Vaishali x BP-06-33	-26.66**	-57.74**	-26.66**	-26.44**	-56.37**	-12.96	-21.21*	-47.57**	-6.48	-19.82**	-54.03**	-15.91**
15	ICPL- 87119 x BP-06-33	11.72	-46.20**	-6.63	-15.37	-49.80**	0.13	-15.15	-43.54**	0.73	-6.73*	-46.53**	-2.18

*Significant at 5% level and **Significant at 1% level

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Table 5: Contd.,

Sl. no.	Crosses	Bharuch			Hansot			Navsari			Pooled		
		BP	SC1	SC2	BP	SC1	SC2	BP	SC1	SC2	BP	SC1	SC2
Reciprocals													
16	AVPP-1 x GT-1	-7.13	-7.13	61.15**	-0.76	-0.76	97.95**	4.17	4.17	85.84**	-1.42	-1.42	80.34**
17	SKNP-11-19 x GT-1	-19.68**	-19.68**	39.38**	-25.86**	-25.86**	47.88**	-19.14**	-19.14**	44.25**	-21.53**	-21.53**	43.54**
18	SKNP-11-19 x AVPP-1	-19.35**	-36.51**	10.17	-28.81**	-36.57**	26.52*	-24.44**	-26.37**	31.36**	-24.29**	-33.28**	22.05**
19	Vaishali x GT-1	-17.57**	-17.57**	43.03**	-10.58	-10.58	78.37**	-1.97	-1.97	74.88**	-10.28**	-10.28**	64.13**
20	Vaishali x AVPP-1	-32.50**	-46.87**	-7.80	-39.30**	-45.92**	7.87	-36.35**	-37.97**	10.65	-36.12**	-43.70**	2.98
21	Vaishali x SKNP-11-19	-11.97	-49.27**	-11.97	-20.17	-56.43**	-13.10	-13.78	-47.54**	-6.42	-10.48**	-51.07**	-10.48**
22	ICPL- 87119 x GT-1	-37.71**	-37.71**	8.09	-46.35**	-46.35**	7.01	-40.99**	-40.99**	5.27	-41.60**	-41.60**	6.84
23	ICPL- 87119 x AVPP-1	-23.89**	-40.09**	3.96	-39.75**	-46.32**	7.08	-37.05**	-38.65**	9.44	-33.81**	-41.67**	6.70
24	ICPL- 87119 x SKNP-11-19	36.73**	-34.15**	14.27	25.76*	-31.37**	36.90**	27.44*	-22.46**	38.32**	30.32**	-29.49**	28.99**
25	ICPL- 87119 x Vaishali	-29.39**	-59.31**	-29.39**	-13.29	-56.53**	-13.29	-6.23	-47.44**	-6.23	-16.94**	-54.59**	-16.94**
26	BP-06-33 x GT-1	-29.26**	-29.26**	22.76*	-13.49*	-13.49*	72.55**	-4.99	-4.99	69.49**	-16.31**	-16.31**	53.10**
27	BP-06-33 x AVPP-1	-8.30	-27.82**	25.26**	-14.74*	-24.04**	51.52**	-14.80*	-16.97*	48.12**	-12.74**	-23.10**	40.68**
28	BP-06-33 x SKNP-11-19	12.85	-46.38**	-6.95	-4.42	-43.30**	13.10	-1.78	-34.65**	16.59	1.85	-41.61**	6.82
29	BP-06-33 x Vaishali	2.43	-40.97**	2.43	-0.06	-40.72**	18.25	-3.37	-35.70**	14.71	6.05	-39.20**	11.23**
30	BP-06-33 x ICPL- 87119	3.60	-50.10**	-13.42	-12.74	-48.24**	3.24	-9.89	-40.04**	6.96	-6.28	-46.27**	-1.71
	S.E.(d) ±	0.54	0.54	0.54	0.59	0.59	0.59	0.63	0.63	0.63	0.20	0.20	0.20
	CD @ 0.05	1.08	1.08	1.08	1.18	1.18	1.18	1.26	1.26	1.26	0.39	0.39	0.39
	CD @ 0.01	1.43	1.43	1.43	1.56	1.56	1.56	1.67	1.67	1.67	0.52	0.52	0.52

*Significant at 5% level and **Significant at 1%