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Elucidating heterosis in opium poppy (*Papaver somniferum* L.) for seed yield and it's component traits

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Abstract
Opium poppy is a valuable multipurpose crop, with long standing legacy of medicinal and pharmaceutical utilities and have also been emerged as a model crop by virtue of it's versatility and uniqueness. Keeping in mind, the requirements of genetic enhancement and better breeding advancements of the poppy, a line × tester analysis was carried out to assess the heterosis, heterobeltiosis and economic heterosis of forty five F1 hybrids developed by crossing 15 lines/females and 3 testers/males of diverse parents along with two suitable checks for thirteen viable economical traits in *Papaver somniferum* L. The hybrids were evaluated in a randomized block design during Rabi 2023-2024 at Instructional farm, RCA, MPUAT, Udaipur. The analysis of variance the mean squares due to genotypes were found significant for all the characters under investigation. On partition of genotypic variance into parents, crosses, parents v/s crosses showed the presence of significant differences between parents and parents v/s crosses, indicating the presence of considerable amount of genetic diversity in the experimental material. The estimates of relative heterosis for seed yield per plant revealed that out of forty five crosses, twelve crosses exhibited positive significant relative heterosis which ranged from 15.94 (UOP-790 x UOP-16) to 39.25 (UOP-98 x UOP-79). Nine crosses showed positive significant heterobeltosis and the magnitude varied from 17.85 (UOP-32 x UOP-79) to 34.42 (UOP-98 x UOP-79). While UOP-86 x UOP-79 showed significant positive economic heterosis for this character over the best check JOP-540. Therefore, these promising crosses can be recommended for exploitation of heterosis to obtain appropriate segregants for crop improvement program in opium poppy.

Keywords: Heterosis, Heterobeltiosis, Economic heterosis, Opium poppy, *Papaver somniferum* L.

1. Introduction
The opium poppy, scientifically named *Papaver somniferum* L., has a chromosome count of 2n=22 and belongs to the Papaveraceae family. A close relative and likely ancestor, *Papaver somniferum* L. (2n=44), shares its lineage within the genus Papaver, which encompasses around 100 species. The section Mecones within this genus includes five species (Hammer and Fritsch, 1977) [6]. It is an annual herb characterized by lactiferous systems or latex tissue and it is typically grown as a *Rabi* crop.

Although primarily self-pollinated (Kumar, 2007) [10], it also exhibits cross-pollination rates ranging from 10% to 37% (Patra *et al*., 1992) [12], Opium poppies are upright annual plants featuring alternating leaves and a terminal blossom that can be white, purple or pink. Opium poppy (*Papaver somniferum* L.) is one of the oldest cultivated plant species. Archaeological evidence shows that poppy has been cultivated and used for thousands of years, dating back to the earliest Neolithic ages (Askitopoulou *et al*. 2002, Salavert *et al*. 2018) [1, 13]. These plants produce large, vibrant flowers with numerous stamens and abundant pollen, attracting many pollinators, especially bees. The wind may also be responsible for moving pollen from one flower to another (Patra *et al*., 1992) [12]. The petals of the opium poppy flowers, typically five or more are fairly large and resemble tissue paper. As the immature fruit capsule matures, the petals encircle it before eventually falling off. The opium poppy's typical fruit form is a unilocular capsule. Beneath the stigmatic disc which sits at top of the capsules are dehiscent pores or valves.

In India, *Papaver somniferum* is extensively cultivated for its milky juice, obtained by lancing the mature green capsules. This large-scale crop serves three main purposes: firstly, to produce edible seeds rich in oleic and linolenic acids, with up to 50% edible oil content. Secondly, it is cultivated to supply opium for the pharmaceutical industry. Thirdly, it is grown to yield other alkaloids like thebaine and oripavine which are crucial in the production of medications such as hydrocodone and oxycodone. The opium poppy plays a vital role in medicinal plant cultivation as it is the primary source of raw opium and several alkaloids with therapeutic properties, including morphine, codeine, narcotine and papaverine. These alkaloids and their derivatives are essential for pharmaceutical companies in manufacturing a range of life-saving medications, including analgesics, antipyretics, antispasmodics, and vasodilators. Raw opium and its alkaloids are harvested from the fully developed but still green capsules of the plant. Poppy cultivars used in food applications are required to contain no or negligible amounts of alkaloids. The availability of commercial cultivars with specific alkaloid profiles is also vital to meet the needs of the pharmaceutical industry and subsequent consumers (EFSA, 2018) [4].

Materials and methods

The experimental material employed in the present investigation comprised of 18 lines/females and 3 testers/males *viz.*, UOP-20, UOP-30 and UOP-80. Further 54 F1 hybrids or cross combinations were developed using line × tester mating design by crossing 18 lines and 3 testers and were sown in randomized block design (RBD) with three replications along with two check varieties; Chetak Aphim and JOP-540 during the Rabi season 2022-23 at the Instructional farm of Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India, located at 24.35° N latitude and 73.42° E longitude and 582.17 m above mean sea level. Morpho-metric data were recorded on five competitive randomly selected plants of each line for the following thirteen traits- days to 50 percent flowering, days to maturity, peduncle length (cm), plant height (cm), number of leaves per plant, diameter of main capsule (mm), seed yield per plant (g), capsule husk yield per plant (g), harvest index for seed yield (%), number of stigmatic rays per capsule, length of the main capsule (cm), capsule size (cm^2) and the number of effective capsules per plant.

The analysis of variance was carried out for each character in accordance with the guidelines provided by Panse and Sukhatme (1985) [11] for the randomized block design (RBD). The recorded mean values for the all the thirteen characters were put for the analysis of heterosis by using the method suggested by Shull (1908) [14], heterobeltiosis/better parent and economic heterosis was estimated as per the procedures given by Fonesca & Patterson (1968) [5], respectively.

Results and Discussion

Upon the analysis of variance, the mean squares due to genotypes were found significant for all the characters under investigation (Table 1). On partition of genotypic variance into parents, crosses, parents v/s crosses showed the presence of significant differences between parents and parents v/s crosses. Significant variation among parents was observed for all the character except days to 50% flowering, peduncle length, plant height and length of main capsule while none of the characters exhibited non significance among the crosses subjected to analysis. The characters *viz.*, number of leaves per plant, capsule husk yield per plant, number of stigmatic rays per capsule and number of effective capsule per plant were found to show significant variation amongst parents v/s crosses. This ensured the existence of considerable variation in experimental material for the characters under study. These results are in accordance with the findings of Khatik *et al*. (2017) [7].

The trait wise results in percentage are summarized as under and also displayed from Table 2 to Table 6:

1. Days to 50 percent flowering

The estimates revealed that eight crosses exhibited significant negative behaviour for all three parameters of relative heterosis, heterobeltiosis and economic heterosis. The estimates of relative heterosis for the character indicated that fifteen crosses exhibited negative significant relative heterosis which ranged from -1.88 (UOP- 136 x UOP-79) to -4.40 (UOP-390 x UOP-30). The negative significant heterobeltiosis was observed in eight crosses and it ranged from -2.26 (UOP-136 x UOP-16) to -4.40 (UOP-390 x UOP-30). A total of nineteen crosses exhibited negative significant economic heterosis ranging from -2.25 (UOP-82 x UOP-79, UOP-136 x UOP- 79, UOP-148 x UOP- 30, UOP-390 x UOP- 30) to -4.49 (UOP-102 x UOP- 79) over the best check Chetak Aphim.

2. Days to maturity

Cross UOP-148 x UOP-79 (-1.54) exhibited significant negative relative heterosis for days to maturity. None of the examined crosses showed significant negative heterobeltiosis for this character. While five crosses exhibited significant negative economic heterosis ranging from -1.78 (UOP-790 × UOP-16, UOP-390 × UOP-79, UOP-15 × UOP-30, UOP-60 × UOP-30) to -2.54 (UOP-148 x UOP-79) over the best check Chetak Aphim.

3. Peduncle length

The positive significant relative heterosis for the trait was exhibited by three crosses *viz.*, UOP-390 x UOP-30 (16.67), UOP-80 x UOP-79 (16.74) and UOP-54 x UOP-16 (17.00). Whereas positive significant heterobeltosis for the trait was exhibited by cross UOP-390 x UOP-30 (14.84). While none of the crosses analysed showed positive significant economic heterosis for this character over the best check Chetak Aphim.

4. Plant height

Out of forty five crosses, twelve crosses manifested significant negative economic heterosis for plant height which ranged from ranged from -9.18 (UOP-790 x UOP-16) to -12.79 (UOP-102 x UOP-79). None of the examined crosses showed significant negative relative heterosis and heterobeltiosis for this character.

5. Number of leaves per plant

The estimates of relative heterosis for the character indicated that nineteen crosses exhibited positive significant relative heterosis which ranged from 12.13 (UOP- 54 x UOP-30) to 38.25 (UOP-790 x UOP-79). The positive significant heterobeltiosis was observed in seven crosses and it ranged from 13.66 (UOP-108 x UOP-79) to 31.34 (UOP-390 x UOP-79). While none of the crosses analysed showed positive significant economic heterosis for this character over the best check Chetak Aphim.

6. Diameter of main capsule

A total of two crosses exhibited positive significant relative heterosis for diameter of main capsule ranging from, 15.21 (UOP-82 x UOP-79) to 19.12 (UOP-86 x UOP-79). None of the

examined crosses showed significant positive heterobeltiosis and economic heterosis for this character over the best check Chetak Aphim.

7. Seed yield per plant

The estimates of relative heterosis for seed yield per plant revealed that out of forty five crosses, twelve crosses exhibited positive significant relative heterosis which ranged from 15.94 (UOP-790 x UOP-16) to 39.25 (UOP-98 x UOP-79). Nine crosses showed positive significant heterobeltosis and the magnitude varied from 17.85 (UOP-32 x UOP-79) to 34.42 (UOP-98 x UOP-79). While UOP-86 x UOP-79 showed significant positive economic heterosis for this character over the best check JOP-540.

8. Capsule husk yield per plant

The estimates of relative heterosis for the character indicated that eleven crosses exhibited positive significant relative heterosis which ranged from 22.38 (UOP- 108 x UOP-16) to 40.55 (UOP-86 x UOP-79)**.** Six crosses exhibited positive significant heterobeltosis for husk yield per plant ranging from 11.70 (UOP-108 x UOP- 79) to 25.93 (UOP-108 x UOP-30). None of the examined crosses showed significant positive economic heterosis for this character over the best check Chetak Aphim.

9. Harvest index for seed yield

The estimates of relative heterosis for the character indicated that ten crosses exhibited positive significant relative heterosis which ranged from 15.03 (UOP-108 x UOP-30) to 52.08 (UOP-98 x UOP-16). Seven crosses manifested positive significant heterobeltosis which ranged from 19.36 (UOP-86 x UOP-79) to 36.51 (UOP-390 x UOP-30). None of the crosses exhibited positive significant economic heterosis over the best check Chetak Aphim.

10. Number of stigmatic rays per capsule

The positive significant relative heterosis was observed in eleven crosses which ranged from 3.51 (UOP-98 x UOP-79) to 20.03 (UOP-102 x UOP-16). Of forty five crosses, six crosses exhibited positive significant heterobeltosis for the character and ranged from 4.79 (UOP-390 x UOP-30) to 13.74 (UOP-102 x UOP-16). A total of twenty one crosses exhibited positive significant economic heterosis ranging from 4.68 (UOP-32 x UOP-79) to 15.70 (UOP-102 x UOP- 16) over the best check Chetak Aphim.

11. Length of main capsule

Three crosses exhibited positive significant relative heterosis *viz*., UOP-390 x UOP-79 (10.79), UOP-108 x UOP-79 (14.31), UOP-148 x UOP-79 (19.11) and UOP-86 x UOP-79 (20.12). While two crosses *viz*., UOP-148 x UOP-79 (14.12) and UOP-86 x UOP-79 (16.68) exhibited positive significant heterobeltiosis for the character. None of the crosses exhibited positive significant economic heterosis over the best check Chetak Aphim.

12. Capsule size

The positive significant relative heterosis for capsule size was observed in seven crosses which ranged from 16.04 (UOP-54 x UOP-16) to 44.69 (UOP-86 x UOP-79). Three crosses exhibited positive significant heterobeltiosis *i.e*., UOP-98 x UOP-79 (18.66), UOP-108 x UOP-79 (19.28) and UOP- 86 x UOP-79 (29.79). None of the crosses exhibited positive significant economic heterosis over the best check Chetak Aphim.

13. Number of effective capsules per plant

The estimates of relative heterosis for the character exhibited positive significant relative heterosis which ranged from 17.48 (UOP-108 x UOP-30) to 57.94 (UOP-136 x UOP-79). The positive significant heterobeltiosis was observed in cross UOP-390 x UOP-30 (19.74). None of the crosses exhibited positive significant economic heterosis over the best check Chetak Aphim. Similar results on economic heterosis, heterobeltosis and relative heterosis in opium poppy on yield and yield contributing characters are observed by Dubey *et al*. (2007) [3], Yadav *et al*. (2007) [16], Kumar and Patra (2010) [8, 9], Singh and Pandey (2011) [15] and Khatik *et al*. (2017) [7].

Table 1: Analysis of variance for thirteen traits in Opium Poppy

S. N.	Characters	Rep	Genotype	Parents	Crosses	P Vs C	Error
		[2]	[64]	[17]	[44]	[1]	[128]
1	Days to 50% flowering	4.34	7.99**	9.72**	7.04**	0.19	1.24
2	Days to Maturity	3.64	2.69*	2.2	2.79*	5.72	1.78
3	Peduncle length	13.64	7.73**	5.39	8.24**	1.19	3.7
4	Plant Height	29.68	37.05	9.14	43.58*	42.81	29.37
5	Number of leaves per plant	1.13	4.68**	5.18**	3.97**	28.11**	1.23
6	Diameter of main capsule(mm)	0.43	29.74**	26.79*	29.24**	13.88	13.7
7	Seed yield per plant	1.03	1.42**	1.21**	1.57**	0.02	0.27
8	Capsule husk yield per plant	0.08	2.45**	1.27**	2.83**	0.64*	0.17
9	Harvest index	2.06	168.47**	192.62**	159.20**	17.87	22.54
10	Number of stigmatic rays per capsule	0.02	1.55**	1.33**	1.68**	0.02	0.1
11	Length of main capsule	0.05	0.33**	0.09	0.41**	1.06**	0.06
12	Capsule size (cm2)	6.22	117.58**	49.03**	144.03**	12.9	19.76
13	Number of effective capsule per plant	0.22	2.13**	1.80**	2.20**	0.62*	0.1

*, ** Significant at 5% and 1% respectively [] Degrees of freedom

Table 2: Extent of heterosis for Days to 50% flowering, Days to Maturity and Peduncle length

S. N.	Crosses	Days to 50% flowering			Days to Maturity			Peduncle length		
		Het	Hb	EH	Het	Hb	EH	Het	Hb	EH
1.	UOP-15 x UOP-16	0.58	-	-1.87	-0.51	-0.26	-1.53	-3.78	-	-
2.	UOP-32 x UOP-16	0.75	-	0.00	0.13	-	-1.02	2.77	-	-
3.	UOP-54 x UOP-16	-1.31	-1.13	-1.50	1.16	-	-0.25	17.00**	12.98	0.00
4.	UOP-60 x UOP-16	4.40**	-	-	-0.26	0.00	-1.27	12.06	9.92	-
5.	UOP-82 x UOP-16	0.76	-	-0.37	0.90	-	-0.25	-5.49	-	-
6.	UOP-86 x UOP-16	-0.57	-	-1.87	-0.13	-	-1.27	8.11	6.87	-
7.	UOP-91 x UOP-16	-0.00	-	-0.75	-0.13	0.00	-1.02	-2.22	-	-
8.	UOP-98 x UOP-16	-2.81**	-2.63*	-3.00**	0.77	-	-	4.09	-	-
9.	UOP-102 x UOP-16	2.48**	-	-	-0.77	-0.51	-1.27	-2.58	-	-
10.	UOP-108 x UOP-16	-0.19	-	-2.62*	1.80*	-	-	5.45	0.69	-
11.	UOP-136 x UOP-16	-2.44**	-2.26*	-2.62*	0.00	0.00	-0.76	4.40	3.21	-
12.	UOP-144 x UOP-16	0.19	-	-1.12	0.38	-	-0.25	-1.92	-	-
13.	UOP-148 x UOP-16	0.75	-	-	-0.38	0.00	-0.76	1.14	0.76	-
14.	UOP-390 x UOP-16	2.41**	-	-	1.28	-	-	5.10	2.29	-
15.	UOP-790 x UOP-16	-0.57	-	-2.62*	-1.15	-1.03	-1.78*	-8.55	-	-
16.	UOP-15 x UOP-79	-0.38	-	-3.00**	0.91	-	-0.76	-7.81	-	-
17.	UOP-32 x UOP-79	0.57	-	-0.37	2.07**	-	-	-6.06	-	-
18.	UOP-54 x UOP-79	1.88*	-	-	1.04	-	-1.02	0.76	-	-
19.	UOP-60 x UOP-79	-1.15	-	-3.37**	1.68*	-	0.00	-8.96	-	-
20.	UOP-82 x UOP-79	-0.95	-0.38	-2.25*	1.81*	-	0.00	-2.11	-	-
21.	UOP-86 x UOP-79	-1.14	-0.38	-2.62*	1.30	-	-0.51	16.74**	10.99	6.49
22.	UOP-91 x UOP-79	-0.57	-0.38	-1.50	0.00	-	-1.53	-11.74*	-	-
23.	UOP-98 x UOP-79	-3.01**	-2.64*	-3.37**	-0.64	-	-1.53	4.56	4.20	0.68
24.	UOP-102 x UOP-79	-2.67**	-1.54	-4.49**	0.13	-	-1.02	-10.64	-	-
25.	UOP-108 x UOP-79	1.15	-	-1.50	1.16	-	-0.51	6.99	6.25	3.38
26.	UOP-136 x UOP-79	-1.88*	-1.51	-2.25*	0.39	-	-1.02	-11.11	-	-
27.	UOP-144 x UOP-79	1.52	-	0.00	0.77	-	-0.51	-8.82	-	-
28.	UOP-148 x UOP-79	-3.58**	-3.40**	-4.12**	-1.54*	-0.52	-2.54**	-10.95	-	-
29.	UOP-390 x UOP-79	-3.72**	-2.26*	-3.00**	-0.39	-	-1.78*	-6.77	-	-
30.	UOP-790 x UOP-79	0.38	-	-1.87	0.77	-	-0.51	-12.86*	-	-
31.	UOP-15 x UOP-30	-1.89*	-	-3.00**	-0.39	-0.26	-1.78*	1.41	-	-
32.	UOP-32 x UOP-30	-2.05*	-0.38	-1.50	1.29	-	-0.25	-3.20	-	-
33.	UOP-54 x UOP-30	1.11	-	-	0.52	-	-1.27	0.80	-	-
34.	UOP-60 x UOP-30	-0.00	-	-0.75	-0.39	-0.26	-1.78*	-2.36	-	-
35.	UOP-82 x UOP-30	-0.56	-	-0.37	0.78	-	-0.76	-11.11	-	-
36.	UOP-86 x UOP-30	0.37	-	-	1.55*	-	0.00	-4.69	-	-
37.	UOP-91 x UOP-30	-3.91**	-2.27*	-3.37**	0.52	-	-0.76	3.37	-	-
38.	UOP-98 x UOP-30	-2.96**	-1.87	-1.87	-0.38	-	-1.02	1.85	-	-
39.	UOP-102 x UOP-30	-1.13	-	-1.50	0.39	-	-0.51	-5.97	-	-
40.	UOP-108 x UOP-30	0.00	-	-1.12	2.19**	-	-	-7.35	-	-
41.	UOP-136 x UOP-30	-4.07**	-3.00**	-3.00**	1.16	-	0.00	-5.47	-	-
42.	UOP-144 x UOP-30	-3.00**	-0.77	-3.00**	0.51	-	-0.51	-5.43	-	-
43.	UOP-148 x UOP-30	-3.15**	-1.88	-2.25*	0.77	-	0.00	3.85	2.27	-
44.	UOP-390 x UOP-30	-4.40**	-4.40**	-2.25*	0.13	-	-1.02	16.67*	14.84*	-
45.	UOP-790 x UOP-30	-0.38	-	-1.12	-0.00	-	-1.02	-0.75	-	-

*,** Significant at 5% and 1% respectively

Table 3: Extent of heterosis for Plant Height, Number of leaves per plant and Diameter of main capsule

S. N.	Crosses	Plant Height			Number of leaves per plant			Diameter of main capsule		
		Het	Hb	EH	Het	Hb	EH	Het	Hb	EH
1.	UOP-15 x UOP-16	-4.18	-3.51	-9.84*	-6.62	-	-	-6.03	-	-
2.	UOP-32 x UOP-16	-1.22	-0.70	-6.89	-0.87	-	-	0.51	-	-
3.	UOP-54 x UOP-16	0.53	-	-4.42	7.44	5.88	-	-2.92	-	-
4.	UOP-60 x UOP-16	2.25	-	-3.28	3.46	-	-	-7.99	-	-
5.	UOP-82 x UOP-16	0.17	-	-4.26	14.05*	12.90	-	4.59	-	-
6.	UOP-86 x UOP-16	-2.05	-1.04	-6.23	4.83	-	-	4.68	-	-
7.	UOP-91 x UOP-16	-3.74	-2.08	-7.21	0.00	-	-	4.07	-	-
8.	UOP-98 x UOP-16	5.24	-	-1.31	13.05*	9.00	-	2.70	-	-
9.	UOP-102 x UOP-16	-3.16	-1.78	-9.51*	4.23	3.84	-	-6.67	-	-
10.	UOP-108 x UOP-16	5.57	-	-0.66	14.74*	12.97	-	10.47	3.33	1.81
11.	UOP-136 x UOP-16	3.46	-	-1.97	10.28	6.01	-	3.50	-	-
12.	UOP-144 x UOP-16	-4.33	-4.17	-9.51*	-4.75	-	-	-10.32	-	-
13.	UOP-148 x UOP-16	3.65	-	-2.30	12.88*	8.89	-	14.04	0.83	-
14.	UOP-390 x UOP-16	-0.85	-	-4.92	12.47*	7.89	-	-11.13	-	-

15.	UOP-790 x UOP-16	-5.54	-4.15	-9.18*	30.12**	19.97**	0.94	-18.31**	-	-
16.	UOP-15 x UOP-79	-3.46	-2.11	-8.52	-5.89	-	-	-11.65	-	-
17.	UOP-32 x UOP-79	-3.28	-2.10	-8.20	-1.62	-	-	-5.02	-	-
18.	UOP-54 x UOP-79	0.68	-	-3.61	-0.53	-	-	-8.52	-	-
19.	UOP-60 x UOP-79	-6.71	-5.90	-11.15*	21.11**	13.83*	-	-3.91	-	-
20.	UOP-82 x UOP-79	2.56	-	-1.31	16.08**	15.61*	-	15.21*	5.04	2.63
21.	UOP-86 x UOP-79	6.12	-	-	9.73	0.54	0.41	19.12*	4.20	1.81
22.	UOP-91 x UOP-79	-4.39	-3.41	-7.21	-0.43	-	-	-16.36*	-	-
23.	UOP-98 x UOP-79	6.77	-	-	12.54*	7.89	-	10.41	2.52	0.16
24.	UOP-102 x UOP-79	-7.32	-5.34	-12.79**	8.38	7.32	-	-14.64*	-	-
25.	UOP-108 x UOP-79	2.77	-	-2.62	16.12**	13.66*	-	5.18	-	-
26.	UOP-136 x UOP-79	2.06	-	-2.62	1.19	-	-	-4.81	-	-
27.	UOP-144 x UOP-79	-6.71	-5.90	-11.15*	-10.65	-	-	-11.11	-	-
28.	UOP-148 x UOP-79	-2.59	-1.40	-7.54	12.57*	7.97	-	-1.52	-	-
29.	UOP-390 x UOP-79	0.17	-	-3.28	36.13**	31.34**	9.18	-3.64	-	-
30.	UOP-790 x UOP-79	-2.12	-1.37	-5.25	38.25**	28.17**	6.55	-16.95*	-	-
31.	UOP-15 x UOP-30	2.81	-	-3.93	-5.19	-	-	-8.62	-	-
32.	UOP-32 x UOP-30	-3.33	-3.16	-9.51*	0.40	-	-	3.66	-	-
33.	UOP-54 x UOP-30	-6.25	-5.26	-11.48**	12.13*	7.87	-	-1.19	-	-
34.	UOP-60 x UOP-30	-2.27	-1.75	-8.20	15.45*	5.47	-	-12.86	-	-
35.	UOP-82 x UOP-30	-6.04	-4.56	-10.82*	13.27*	9.44	-	-4.87	-	-
36.	UOP-86 x UOP-30	-3.10	-1.40	-7.87	-18.36**	-	-	-3.69	-	-
37.	UOP-91 x UOP-30	-7.19	-4.91	-11.15*	5.76	-	-	-0.58	-	-
38.	UOP-98 x UOP-30	-0.88	-0.53	-7.70	2.95	1.70	-	-14.12	-	-
39.	UOP-102 x UOP-30	-4.06	-3.38	-10.98*	5.36	3.20	-	-8.86	-	-
40.	UOP-108 x UOP-30	3.16	-	-3.61	15.24**	14.19*	0.96	2.43	-	-
41.	UOP-136 x UOP-30	-0.35	-	-6.23	-6.91	-	-	-7.43	-	-
42.	UOP-144 x UOP-30	-0.52	0.00	-6.56	9.19	8.60	-	-15.69*	-	-
43.	UOP-148 x UOP-30	0.53	-	-5.90	-9.63	-	-	-6.08	-	-
44.	UOP-390 x UOP-30	5.34	-	-	18.48**	11.02	-	14.43	8.70	0.16
45.	UOP-790 x UOP-30	-4.21	-2.11	-8.52	16.72**	5.23	-	-1.99	-	-

*,** Significant at 5% and 1% respectively

Table 4: Extent of heterosis for Plant Height, Number of leaves per plant and Diameter of main capsule

S. N.	Crosses	Plant Height			Number of leaves per plant			Diameter of main capsule		
		Het	Hb	EH	Het	Hb	EH	Het	Hb	EH
1.	UOP-15 x UOP-16	-4.18	-3.51	-9.84*	-6.62	-	-	-6.03	-	-
2.	UOP-32 x UOP-16	-1.22	-0.70	-6.89	-0.87	-	-	0.51	-	-
3.	UOP-54 x UOP-16	0.53	-	-4.42	7.44	5.88	-	-2.92	-	-
4.	UOP-60 x UOP-16	2.25	-	-3.28	3.46	-	-	-7.99	-	-
5.	UOP-82 x UOP-16	0.17	-	-4.26	14.05*	12.90	-	4.59	-	-
6.	UOP-86 x UOP-16	-2.05	-1.04	-6.23	4.83	-	-	4.68	-	-
7.	UOP-91 x UOP-16	-3.74	-2.08	-7.21	0.00	-	-	4.07	-	-
8.	UOP-98 x UOP-16	5.24	-	-1.31	13.05*	9.00	-	2.70	-	-
9.	UOP-102 x UOP-16	-3.16	-1.78	-9.51*	4.23	3.84	-	-6.67	-	-
10.	UOP-108 x UOP-16	5.57	-	-0.66	14.74*	12.97	-	10.47	3.33	1.81
11.	UOP-136 x UOP-16	3.46	-	-1.97	10.28	6.01	-	3.50	-	-
12.	UOP-144 x UOP-16	-4.33	-4.17	-9.51*	-4.75	-	-	-10.32	-	-
13.	UOP-148 x UOP-16	3.65	-	-2.30	12.88*	8.89	-	14.04	0.83	-
14.	UOP-390 x UOP-16	-0.85	-	-4.92	12.47*	7.89	-	-11.13	-	-
15.	UOP-790 x UOP-16	-5.54	-4.15	-9.18*	30.12**	19.97**	0.94	-18.31**	-	-
16.	UOP-15 x UOP-79	-3.46	-2.11	-8.52	-5.89	-	-	-11.65	-	-
17.	UOP-32 x UOP-79	-3.28	-2.10	-8.20	-1.62	-	-	-5.02	-	-
18.	UOP-54 x UOP-79	0.68	-	-3.61	-0.53	-	-	-8.52	-	-
19.	UOP-60 x UOP-79	-6.71	-5.90	-11.15*	21.11**	13.83*	-	-3.91	-	-
20.	UOP-82 x UOP-79	2.56	-	-1.31	16.08**	15.61*	-	15.21*	5.04	2.63
21.	UOP-86 x UOP-79	6.12	-	-	9.73	0.54	0.41	19.12*	4.20	1.81
22.	UOP-91 x UOP-79	-4.39	-3.41	-7.21	-0.43	-	-	-16.36*	-	-
23.	UOP-98 x UOP-79	6.77	-	-	12.54*	7.89	-	10.41	2.52	0.16
24.	UOP-102 x UOP-79	-7.32	-5.34	-12.79**	8.38	7.32	-	-14.64*	-	-
25.	UOP-108 x UOP-79	2.77	-	-2.62	16.12**	13.66*	-	5.18	-	-
26.	UOP-136 x UOP-79	2.06	-	-2.62	1.19	-	-	-4.81	-	-
27.	UOP-144 x UOP-79	-6.71	-5.90	-11.15*	-10.65	-	-	-11.11	-	-
28.	UOP-148 x UOP-79	-2.59	-1.40	-7.54	12.57*	7.97	-	-1.52	-	-
29.	UOP-390 x UOP-79	0.17	-	-3.28	36.13**	31.34**	9.18	-3.64	-	-
30.	UOP-790 x UOP-79	-2.12	-1.37	-5.25	38.25**	28.17**	6.55	-16.95*	-	-
31.	UOP-15 x UOP-30	2.81	-	-3.93	-5.19	-	-	-8.62	-	-

32.	UOP-32 x UOP-30	-3.33	-3.16	-9.51*	0.40	-	-	3.66	-	-
33.	UOP-54 x UOP-30	-6.25	-5.26	-11.48**	12.13*	7.87	-	-1.19	-	-
34.	UOP-60 x UOP-30	-2.27	-1.75	-8.20	15.45*	5.47	-	-12.86	-	-
35.	UOP-82 x UOP-30	-6.04	-4.56	-10.82*	13.27*	9.44	-	-4.87	-	-
36.	UOP-86 x UOP-30	-3.10	-1.40	-7.87	-18.36**	-	-	-3.69	-	-
37.	UOP-91 x UOP-30	-7.19	-4.91	-11.15*	5.76	-	-	-0.58	-	-
38.	UOP-98 x UOP-30	-0.88	-0.53	-7.70	2.95	1.70	-	-14.12	-	-
39.	UOP-102 x UOP-30	-4.06	-3.38	-10.98*	5.36	3.20	-	-8.86	-	-
40.	UOP-108 x UOP-30	3.16	-	-3.61	15.24**	14.19*	0.96	2.43	-	-
41.	UOP-136 x UOP-30	-0.35	-	-6.23	-6.91	-	-	-7.43	-	-
42.	UOP-144 x UOP-30	-0.52	0.00	-6.56	9.19	8.60	-	-15.69*	-	-
43.	UOP-148 x UOP-30	0.53	-	-5.90	-9.63	-	-	-6.08	-	-
44.	UOP-390 x UOP-30	5.34	-	-	18.48**	11.02	-	14.43	8.70	0.16
45.	UOP-790 x UOP-30	-4.21	-2.11	-8.52	16.72**	5.23	-	-1.99	-	-

*,** Significant at 5% and 1% respectively

Table 5: Extent of heterosis for Seed yield per plant, Capsule husk yield/ plant and Harvest index

S. N.	Crosses	Seed yield per plant			Capsule husk yield/ plant		Harvest index			
		Het	Hb	EH	Het	Hb	EH	Het	Hb	EH
1.	UOP-15 x UOP-16	5.28	1.99	-	-24.37**	-	-	9.80	-	-
2.	UOP-32 x UOP-16	28.87**	26.13**	7.90	-24.69**	-	-	25.66**	23.72**	2.79
3.	UOP-54 x UOP-16	26.62**	18.02*	0.96	34.06**	14.67*	7.40	19.17**	14.62	-
4.	UOP-60 x UOP-16	0.78	-	-	-30.87**	-	-	-3.62	-	-
5.	UOP-82 x UOP-16	-0.78	-	-	0.68	-	-	1.58	-	-
6.	UOP-86 x UOP-16	-6.31	-	-	-8.33	-	-	-8.39	-	-
7.	UOP-91 x UOP-16	-11.79	-	-	-21.23**	-	-	-23.07**	-	-
8.	UOP-98 x UOP-16	33.36**	27.44**	9.02	24.69**	5.09	-	52.08**	22.33**	1.64
9.	UOP-102 x UOP-16	-11.15	-	-	-9.40	-	-	-5.81	-	-
10.	UOP-108 x UOP-16	27.63**	26.05**	10.57	22.38**	8.38	1.51	26.30**	24.01**	3.03
11.	UOP-136 x UOP-16	10.37	10.22	-	13.66*	-	-	10.72	10.38	-
12.	UOP-144 x UOP-16	-12.61*	-	-	-20.89**	-	-	-17.62**	-	-
13.	UOP-148 x UOP-16	-0.54	-	-	30.52**	14.97*	7.68	-5.18	-	-
14.	UOP-390 x UOP-16	-5.91	-	-	-26.18**	-	-	-15.88*	-	-
15.	UOP-790 x UOP-16	15.94*	14.81	0.16	-31.08**	-	-	5.57	5.21	-
16.	UOP-15 x UOP-79	12.51	7.90	-	-26.15**	-	-	21.47**	5.54	-
17.	UOP-32 x UOP-79	19.16**	17.85*	-	-16.92**	-	-	4.66	0.50	-
18.	UOP-54 x UOP-79	-4.73	-	-	-27.17**	-	-	-16.93*	-	-
19.	UOP-60 x UOP-79	-10.54	-	-	19.96**	8.77	4.32	-19.03**	-	-
20.	UOP-82 x UOP-79	17.24*	13.06	1.98	-1.11	-	-	8.23	7.55	-
21.	UOP-86 x UOP-79	20.01**	8.19	12.87*	40.55**	14.62*	9.93	22.39**	19.36**	9.85
22.	UOP-91 x UOP-79	-14.91*	-	-	-20.30**	-	-	-19.33**	-	-
23.	UOP-98 x UOP-79	39.25**	34.42**	12.60	27.50**	6.43	2.08	51.65**	19.67*	4.68
24.	UOP-102 x UOP-79	-4.77	-	-	-8.47	-	-	-23.92**	-	-
25.	UOP-108 x UOP-79	31.57**	28.61**	12.81	27.42**	11.70*	7.12	28.04**	22.62**	7.27
26.	UOP-136 x UOP-79	1.55	0.63	-	9.88	-	-	-12.22	-	-
27.	UOP-144 x UOP-79	-14.45*	-	-	-12.38*	-	-	-22.58**	-	-
28.	UOP-148 x UOP-79	-13.07*	-	-	10.06	-	-	-16.98**	-	-
29.	UOP-390 x UOP-79	-14.87*	-	-	-29.04**	-	-	-23.04**	-	-
30.	UOP-790 x UOP-79	-2.97	-	-	-25.89**	-	-	-6.86	-	-
31.	UOP-15 x UOP-30	-4.23	-	-	4.59	4.42	-	3.60	-	-
32.	UOP-32 x UOP-30	-0.44	-	-	-7.41	-	-	-13.96	-	-
33.	UOP-54 x UOP-30	6.49	3.84	-	-0.33	-	-	-6.55	-	-
34.	UOP-60 x UOP-30	6.83	3.27	-	-9.43	-	-	-3.77	-	-
35.	UOP-82 x UOP-30	0.69	-	-	-19.64**	-	-	-9.14	-	-
36.	UOP-86 x UOP-30	-6.13	-	-	6.09	-	-	-5.48	-	-
37.	UOP-91 x UOP-30	-1.19	-	-	-18.47**	-	-	-15.97*	-	-
38.	UOP-98 x UOP-30	18.00*	17.88*	-	2.96	-	-	17.23	-	-
39.	UOP-102 x UOP-30	-0.06	-	-	7.62	0.82	-	-4.46	-	-
40.	UOP-108 x UOP-30	12.84	6.45	-	29.40**	25.93**	-	15.03*	12.43	-
41.	UOP-136 x UOP-30	2.06	-	-	-3.45	-	-	-2.38	-	-
42.	UOP-144 x UOP-30	-20.66**	-	-	-12.13	-	-	-25.38**	-	-
43.	UOP-148 x UOP-30	-18.93**	-	-	0.12	-	-	-22.12**	-	-
44.	UOP-390 x UOP-30	30.88**	20.87**	11.00	21.78**	15.95*	-	38.31**	36.51**	4.38
45.	UOP-790 x UOP-30	5.99	0.24	-	-9.89	-	-	-1.34	-	-

*,** Significant at 5% and 1% respectively

Table 6: Extent of heterosis for Number of stigmatic rays per capsule, Length of main capsule and Capsule size (cm^2)

S. N.	Crosses	Stigmatic rays/ capsule			Length of main capsule			Capsule size		
		Het	Hb	EH	Het	Hb	EH	Het	Hb	EH
1.	UOP-15 x UOP-16	3.18	0.83	2.57	-1.87	-	-	-7.86	-	-
2.	UOP-32 x UOP-16	-0.64	-	2.57	5.50	4.74	-	16.04*	7.01	-
3.	UOP-54 x UOP-16	4.84**	2.28	9.38**	-9.61*	-	-	-12.33	-	-
4.	UOP-60 x UOP-16	-3.05	-	3.80	-2.14	-	-	-10.00	-	-
5.	UOP-82 x UOP-16	-0.35	-	2.60	0.28	-	-	4.67	-	-
6.	UOP-86 x UOP-16	-7.67**	-	-	7.96	7.21	0.78	12.97	-	-
7.	UOP-91 x UOP-16	-0.27	-	1.75	-0.36	-	-	3.92	-	-
8.	UOP-98 x UOP-16	7.72**	6.31**	11.05**	7.38	6.28	-	10.47	1.08	-
9.	UOP-102 x UOP-16	20.03**	13.74**	15.70**	-8.06	-	-	-13.93	-	-
10.	UOP-108 x UOP-16	-5.26**	-	-	5.26	1.72	2.52	19.37**	15.28	6.81
11.	UOP-136 x UOP-16	-5.60**	-	-	8.89	7.58	1.13	12.55	1.81	-
12.	UOP-144 x UOP-16	1.91	-	6.54**	3.42	2.13	-	-6.84	-	-
13.	UOP-148 x UOP-16	-6.44**	-	-	2.57	1.82	-	16.99*	4.07	-
14.	UOP-390 x UOP-16	-14.08**	-	-	-18.09**	-	-	-26.77**	-	-
15.	UOP-790 x UOP-16	-1.22	-	0.90	-16.23**	-	-	-31.77**	-	-
16.	UOP-15 x UOP-79	-1.92	-	2.63	7.86	5.30	-	-4.76	-	-
17.	UOP-32 x UOP-79	-3.48*	-	4.68*	-2.28	-	-	-6.84	-	-
18.	UOP-54 x UOP-79	-3.63*	-	5.58*	5.69	1.00	-	-2.23	-	-
19.	UOP-60 x UOP-79	-2.33	-	9.68**	1.35	-	-	-2.49	-	-
20.	UOP-82 x UOP-79	-3.67*	-	4.21	-0.29	-	-	11.45	4.57	-
21.	UOP-86 x UOP-79	-4.40**	-	6.95**	20.12**	16.68**	8.17	44.69**	29.79**	10.93
22.	UOP-91 x UOP-79	3.26	-	10.75**	-5.13	-	-	-19.79*	-	-
23.	UOP-98 x UOP-79	3.51*	-	12.12**	8.33	5.57	-	24.92**	18.66*	1.42
24.	UOP-102 x UOP-79	3.63	-	5.31*	-24.39**	-	-	-35.86**	-	-
25.	UOP-108 x UOP-79	4.37*	-	9.68**	14.31**	6.72	7.56	19.87**	19.28*	2.96
26.	UOP-136 x UOP-79	0.13	-	6.95**	-3.59	-	-	-8.61	-	-
27.	UOP-144 x UOP-79	-12.63**	-	-	-8.30	-	-	-18.46*	-	-
28.	UOP-148 x UOP-79	-2.27	-	6.54**	19.11**	14.12**	8.86	17.85*	8.69	-
29.	UOP-390 x UOP-79	4.98**	-	11.30**	10.79*	4.49	3.04	7.80	5.02	-
30.	UOP-790 x UOP-79	-4.24*	-	2.82	-9.97*	-	-	-25.18**	-	-
31.	UOP-15 x UOP-30	-9.18**	-	-	-12.41**	-	-	-20.32**	-	-
32.	UOP-32 x UOP-30	-3.29	-	-	-5.70	-	-	-2.27	-	-
33.	UOP-54 x UOP-30	-2.43	-	1.78	-2.97	-	-	-4.49	-	-
34.	UOP-60 x UOP-30	-2.64	-	4.21	-10.22*	-	-	-21.70**	-	-
35.	UOP-82 x UOP-30	10.28**	8.95**	13.51**	-3.64	-	-	-8.57	-	-
36.	UOP-86 x UOP-30	-4.21*	-	2.13	-4.13	-	-	-8.01	-	-
37.	UOP-91 x UOP-30	0.56	0.24	2.57	-32.13**	-	-	-32.35**	-	-
38.	UOP-98 x UOP-30	2.18	0.81	5.31*	-8.47	-	-	-21.44**	-	-
39.	UOP-102 x UOP-30	-0.31	-	-	-15.21**	-	-	-23.08**	-	-
40.	UOP-108 x UOP-30	10.96**	8.96**	10.78**	-9.73*	-	-	1.87	-	-
41.	UOP-136 x UOP-30	5.04**	4.92*	6.67**	-5.98	-	-	-13.16	-	-
42.	UOP-144 x UOP-30	5.99**	3.18	10.78**	-27.20**	-	-	-38.72**	-	-
43.	UOP-148 x UOP-30	-7.58**	-	-	-31.64**	-	-	-35.85**	-	-
44.	UOP-390 x UOP-30	5.73**	4.79*	6.54**	-8.93*	-	-	9.41	1.54	-
45.	UOP-790 x UOP-30	-1.70	-	0.38	-17.56**	-	-	-11.54	-	-

*,** Significant at 5% and 1% respectively

Table 7: Extent of heterosis for Number of effective capsule per plant

S. N.	Crosses	Effective capsule / plant		
		Het	Hb	EH
1.	UOP-15 x UOP-16	-14.30	-	-
2.	UOP-32 x UOP-16	-34.29**	-	-
3.	UOP-54 x UOP-16	45.92**	4.80	-
4.	UOP-60 x UOP-16	-43.07**	-	-
5.	UOP-82 x UOP-16	7.83	6.11	-
6.	UOP-86 x UOP-16	-38.14**	-	-
7.	UOP-91 x UOP-16	-48.91**	-	-
8.	UOP-98 x UOP-16	31.53**	2.10	-
9.	UOP-102 x UOP-16	-44.18**	-	-
10.	UOP-108 x UOP-16	12.15	0.70	-
11.	UOP-136 x UOP-16	40.46**	3.20	-
12.	UOP-144 x UOP-16	-50.37**	-	-
13.	UOP-148 x UOP-16	31.02**	0.00	-
14.	UOP-390 x UOP-16	-45.92**	-	-

15.	UOP-790 x UOP-16	-39.13**	-	-
16.	UOP-15 x UOP-79	-41.34**	-	-
17.	UOP-32 x UOP-79	-35.60**	-	-
18.	UOP-54 x UOP-79	-36.25**	-	-
19.	UOP-60 x UOP-79	40.52**	4.47	1.03
20.	UOP-82 x UOP-79	1.80	-	-
21.	UOP-86 x UOP-79	32.71**	-	-
22.	UOP-91 x UOP-79	-25.23**	-	-
23.	UOP-98 x UOP-79	32.19**	1.55	-
24.	UOP-102 x UOP-79	-42.98**	-	-
25.	UOP-108 x UOP-79	12.39	-	-
26.	UOP-136 x UOP-79	57.94**	14.97	11.18
27.	UOP-144 x UOP-79	-36.04**	-	-
28.	UOP-148 x UOP-79	-32.60**	-	-
29.	UOP-390 x UOP-79	-33.33**	-	-
30.	UOP-790 x UOP-79	-42.55**	-	-
31.	UOP-15 x UOP-30	-25.47**	-	-
32.	UOP-32 x UOP-30	-40.40**	-	-
33.	UOP-54 x UOP-30	-29.05**	-	-
34.	UOP-60 x UOP-30	-33.53**	-	-
35.	UOP-82 x UOP-30	-31.64**	-	-
36.	UOP-86 x UOP-30	-41.81**	-	-
37.	UOP-91 x UOP-30	-51.18**	-	-
38.	UOP-98 x UOP-30	-18.59	-	-
39.	UOP-102 x UOP-30	-32.16**	-	-
40.	UOP-108 x UOP-30	17.48*	14.27	-
41.	UOP-136 x UOP-30	-24.12*	-	-
42.	UOP-144 x UOP-30	2.19	-	-
43.	UOP-148 x UOP-30	-30.50**	-	-
44.	UOP-390 x UOP-30	39.18**	19.74*	-
45.	UOP-790 x UOP-30	-47.91**	-	-

*,** Significant at 5% and 1% respectively

Conclusion

Based on investigation, among crosses, cross UOP-86 × UOP-79 showed maximum mean value for seed yield per plant (7.05 g/plant). Other crosses *viz.*, UOP-108 × UOP-79 (7.04 g/plant), UOP-98 × UOP-79 (7.03 g/plant), UOP-390 × UOP-30 (6.93 g/plant) and UOP-108 × UOP-16 (6.90 g/plant) also showed higher mean for seed yield per plant.The maximum mean value for peduncle length, plant height, capsule husk yield per plant and harvest index for seed yield was observed in cross UOP-86 × UOP-79. Cross UOP-390 × UOP-79 showed maximum mean values for number of leaves per plant while crosses UOP-82 × UOP-79 and UOP-102 × UOP-16 showed maximum mean values for diameter of the main capsule and the number of stigmatic rays per capsule. Whereas cross UOP-148 × UOP-79 showed maximum mean value for length of the main capsule. As a whole, close association between economic heterosis, per se performance and sca effects for seed yield was manifested by the hybrid UOP-86 x UOP-79. It appears to be a promising combination for actual exploitation of heterosis and could be recommended for further advancement of generations and multilocation trials.

References

1. Askitopoulou H, Ramoutsaki IA, Konsolaki E. Archaeological evidence on the use of opium in the Minoan world. International Congress Series; c2002. p. 23-29.
2. Bernáth J, Németh É. Poppy. In: Oil crops; c2010. p. 449-468.
3. Dubey RB, Jain SK, Maloo SR. Combining ability and heterosis for latex yield, seed yield and other agronomic traits in opium poppy (*Papaver somniferum* L.). The Indian Journal of Genetics and Plant Breeding. 2007;67(4):392-395.
4. EFSA Panel on Contaminants in the Food Chain (CONTAM), Knutsen HK, Alexander J, Barregård L, Bignami M, Brüschweiler B, Vleminckx C. Update of the scientific opinion on opium alkaloids in poppy seeds. EFSA Journal, 2018, 16(5).
5. Fonesca S, Patterson FL. Hybrid vigour in seven parent diallel crosses in common wheat (*Triticum aestivum* L.). Crop Science. 1968;8:85-89.
6. Hammer K, Fritsch R. The question of ancestral species of cultivated Opium poppy (*Papaver somniferum* L.). Kulturpflanze. 1977;25:113-124.
7. Khatik CL, Sharma SP, Dodiya NS, Maloo SR, Joshi A, Jain HK, *et al*. Estimate heterosis for latex yield and its related traits in opium poppy (*Papaver somniferum* L.). Electronic Journal of Plant Breeding. 2017;8(1):288-293.
8. Kumar B, Patra NK. Genetic analysis of capsule and its associated economic traits in opium poppy (*Papaver somniferum* L.). Journal of Heredity. 2010;101:657-660.
9. Kumar B, Singh HP, Patra NK. Inheritance of quantitative traits in opium poppy (*Papaver somniferum* L.). Communications in Biometry and Crop Science. 2010;5(1):11-18.
10. Kumar B. Study on genetic architecture of opium poppy (*Papaver somniferum* L.) in relevance to yield improvement. Ph.D. Thesis, Lucknow University, Lucknow; c2007. India.
11. Panse VG, Sukhatme PV. Statistical methods for agriculture workers. ICAR, New Delhi; c1985. p. 14-33.
12. Patra NK, Ram RS, Chauhan SP, Singh AK. Quantitative studies on the mating system of opium poppy (*Papaver somniferum* L.). Theoretical and Applied Genetics. 1992;84:299-302.
13. Salavert A, Martin L, Antolín F, Zazzo A. The opium poppy

in Europe: Exploring its origin and dispersal during the Neolithic. Antiquity. 2018;92:364.
14. Shull GH. What is heterosis. Genetics. 1908;33:439-446.
15. Singh R, Pandey RM. Combining ability and heterosis in opium poppy (*Papaver somniferum* L.). Current Advances in Agricultural Sciences. 2011;3(2):130-134.
16. Yadav HK, Singh S, Singh SP. Genetic divergence in parental genotypes and its relation with heterosis, F_1 performance and general combining ability (GCA) in opium poppy (*Papaver somniferum* L.). Euphytica. 2007;157:123-130.