Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2021; 10(1): 2711-2714
Received: 19-10-2021
Accepted: 21-12-2021

SV Yamgar
Ph.D. Scholar, Department of Agricultural Botany, Mahatma Phule Agricultural University, Rahuri, Maharashtra, India

SV Pawar
Assistant Professor, Department of Agricultural Botany, Mahatma Phule Agricultural University, Rahuri, Maharashtra, India

VP Chimote
Associate Professor, Department of Agricultural Botany, Mahatma Phule Agricultural University, Rahuri, Maharashtra, India

MP Deshmukh
Associate Professor, Department of Agricultural Botany, Mahatma Phule Agricultural University, Rahuri, Maharashtra, India

GC Shinde
Associate Professor, Department of Agricultural Botany, Mahatma Phule Agricultural University, Rahuri, Maharashtra, India

CA Nimbalkar
Associate Professor, Department of Agricultural Botany, Mahatma Phule Agricultural University, Rahuri, Maharashtra, India

Corresponding Author:
SV Yamgar
Ph.D. Scholar, Department of Agricultural Botany, Mahatma Phule Agricultural University, Rahuri, Maharashtra, India

Expression of heterosis, residual heterosis and specific combining ability in yield and yield contributing characters of soybean (*Glycine max* (L.) Merrill)

SV Yamgar, SV Pawar, VP Chimote, MP Deshmukh, GC Shinde and CA Nimbalkar

Abstract
Development of hybrids in Soybean is difficult because of its small delicate flower structure and there is no that much differences in degree dominance in soybean in F_1, F_2 and later generations due to very low frequency of out crossing, small genetic load. An attempt has been made to estimate the magnitude and direction of heterosis, residual heterosis and their specific combing ability for eight yield and yield contributing characters in F_1, F_2 and F_3 generations of four crosses in soybean. The experimental material consists of four rust resistant donor parents (JS 335 x SDP 10, JS 335 x SDP 18, JS 335 x SDP 30 and JS 335 x SDP 36 crossed with common female JS335 in line x tester manner. Resulting F_1, F_2 and F_3 generations of four crosses) along with parents were studied to evaluate mid parent (MPH), Better parent (BPH) heterosis and specific combing ability (SCA). The material was sown in randomized block design in three replications at Agriculture research station, Kasbe Digraj, Sangli, MPKV, Rahuri in summer 2019. The observations were recorded on eight quantitative characters. The analysis of data showed highly significant differences for all the traits under study. The obtained results showed that F_1 of JS335 x SDP 30 exhibited highest mid and better parent heterosis for days to flowering (-14.36%),days to maturity (-6.83%), primary branches per plant (32.20%), number of pods per plant (31.42,64.85%) and 100 seed weight (34.83, 20.92%). The cross JS335 x SDP18 expressed highest heterosis for plant height (25.08,21.21%), Cross JS335 x SDP10 exihibited for number of pods per cluster(18.37,16.0%) and yield per plant in JS335 x SDP36 (32.90, 41.57%). However, among the F_2 generations of four crosses, highest residual heterosis over mid and better- parent was recorded in JS335 x SDP18 for plant height (21.17,17.42%), number of primary branches per plant(16.40 % MPH),100 seed weight (21.81%) and yield per plant (37.09, 53.87%).The F_2 of JS335 x SDP10 exhibited residual heterosis for number of pod per cluster(14.03%MPH).The F_2 of JS335 x SDP 30 exhibited highest residual heterosis for number of pods per plant (22.72 and 53.93%) and 100 seed weight(20.61%MPH). In F_3 generations, high amount residual heterobeltosis was recorded in JS335 x SDP18 for plant height (19.22, 15.53%), Pod per plant (24.40% BPH), 100 seed weight (21.81%MPH) and yield per plant in JS335 x SDP30 (37.40%BPH).

Keywords: heterosis, line x tester, residual heterosis, specific combining ability, soybean

Introduction
Soybean, *Glycine max* (L.) Merrill, is a member of the family *Leguminasae* and sub- family *Papilionaceae* with chromosome number 2n = 40**.** It has become a miracle crop well known as 'Golden bean'.Soybean seed contains approximately 37-41 per cent protein, 18-21 per cent oil, 30-40 per cent carbohydrate, and 4-5 per cent ash (Hulse, 1996) [10]. However, Soybean is highly self-pollinated crossed so it is difficult to exploit heterosis in soybean due to unavailability of male sterility system, less number of pollen vector, delicate flower structure, there is no that much differences in degree dominance in soybean in F_1, F_2 and later generations due to very low frequency of out crossing, small genetic load, highly inbred. Heterosis is estimated for amount number of genes and with dominance effect it is easier to obtain a hybrid than a line with superior genotypes. The most accepted hypotheses to explain heterosis involve dominance and the over dominance, besides epistatic effects.
The superior performance of F_1 generations over better-parent is more helpful for determining the feasibility of heterosis whether it commercial exploitable or not. However it also showed potent parental combinations for producing the highest level of transgressive segregants. Transgressive segregation is result of heterotic effect of residual dominant genes from F_2, F_3 to onward generations. Line x tester analysis which provide information of GCA, SCA and variance their effect, In this study specific combing ability estimated which provides information of best cross combination for particular character and predominant dominant gene

governing for this trait. However, this experiment reveals the information of amount of heterosis over mid parent and better parent in F_1 and residual heterosis from F_2 and F_3 with amount of specific combining ability ability in eight yield and yield contributing character of Soybean.

Materials and Methods

The present investigation on estimation of heterosis and residual heterosis for yield as well as yield contributing character in soybean was conducted at Agricultural Research Station, Kasbe Digraj, Sangli (MPKV, Rahuri) during 2017-2018 and 2018-2019. Experimental material consisted four rust resistant male donors (SDP 10, SDP 18, SDP 30 and SDP 36) crossed with common female JS 335 in line x tester design given by Kempthorne (JS 335 x SDP 10, SDP 18, SDP 30 and SDP 36). The resulting three generations F_1, F_2, and F_3 of each cross with parents were sown with raw to raw spacing 45 cm and plant to plant on 16 February 2019 (Summer) under irrigated regime. The experiment was conducted in randomized block design 10 seeds of F_1, 40 seeds of F_2 and 20 seeds of F_3 were sown in three replications. The fertilizer dose of 50 kg N and 75 kg P_2O_5 per ha was incorporated as basal dose. The crop was raised following recommended package of practices. Observations were recorded on eight biometrical traits, namely days to first flowering, days to maturity, plant height (cm), number of primary branches per plant, number of pod per cluster, number of pod per plant, 100 seed weight (g) and seed yield per plant (g). The mean of F_1 hybrids over replication were utilized for the estimation of mid and better-parents heterosis. The mean value of F_1 hybrids over three replication were utilized for the estimation of mid and better-parents heterosis. The residual heterosis was worked out in F_2 and F_3 generation by combining mean data of individuals plants progeny as per the formula given below:

The residual heterosis was worked out in F_2 and F_3 generation by combining mean data of individuals plants progeny as per the formula given below

Kind of heterosis	Generations		
	F_1	F_2	F_3
Mid parent Heterosis	$\{(F_1\text{-MP})/MP\} \times 100$	$\{(F_2\text{-MP})/MP\} \times 100$	$\{(F_3\text{-MP})/MP\} \times 100$
Better parent Heterosis	$\{(F_1\text{-BP})/BP\} \times 100$	$\{(F_2\text{-BP})/BP\} \times 100$	$\{(F_3\text{-BP})/BP\} \times 100$

MP = mid parent heterosis; P1 +P 2/2 BP = Better parent heterosis

Results and Discussion

The analysis of variance for estimation of Hetetrosis, residual heterosis over mid parent and better parent with specific combining ability for eight yield and yield contributing character in soybean revealed that the crosses was significant for all character except days to flowering, Line effect also significant for all character except seed yield. Tester effect significant for all character except 100 seed weight and seed yield however, Line x tester effect significant only for seed yield. It indicating thereby considerable amount of variability for all the characters (Table 1).

The mean performance, estimated heterosis, residual heterosis over their mid parent and better parent with specific combining ability of P_1, P_2, F_1, F_2 and F_3 four crosses was presented (Table 2). Specific combining ability was non - significant for all traits.

The early flowering and maturity are desirable attributes in soybean crop. Therefore, significant negative heterosis was considered as desirable for this character. Among the F_1 generations of four crosses, F_1 of JS335 x SDP 30 have significant better parent heterosis -14.63% and -6.83% for maturity.

In soybean medium tall or tall with good number pod per plant is considered for yield view. The highest heterosis in desirable direction for plant height was reported in F_1 of JS335 x SDP 18 (25.08, 21.21%) showed significantly highest value over mid and better-parents followed by cross JS335 x SDP 30 (19.60, 13.64 %) and JS335 x SDP 36 (18.18, 7.95%) whereas residual heterosis in F_2 generations was highest in JS335 x SDP 18 (21.17, 17.42%) and JS 335 x SDP 30(17.34, 11.49%) showed significant residual hetrobeltosis over better-parent. However, in F_3 generations of all the four crosses, JS335 x SDP 18 (19.22, 15.53%) and JS 335 x SDP 30 (12.76, 7.13%) showed significant residual heterobeltosis over mid- and better-parents in desirable direction. Significant heterosis over mid and better-parent heterosis for plant height reported by Wang *et al.* (2002) and Manjarrez-Snadoval *et al.* (1997) [23].

For number of primary branches per plant, the highest heterosis over mid parent with desirable direction was recorded in F_1 of JS335 x SDP 30 (32.20% MPH) followed by JS335 x SDP18 (26.32% MPH), JS335 x SDP10 (17.83% MPH) and JS335 x SDP36 (17.76% MPH). The estimates of residual heterosis over mid-parents was highest in F_2 generations of JS335 x SDP18 (16.40% MPH), JS335 x SDP30 (14.41% MPH) and JS335 x SDP10 (11.24% MPH) and JS335 x SDP36 (12.15%). Present findings are in agreement with the findings of Ramana and Satynarayana (2006) [18].

Significant heterosis in desirable direction for number of pod per cluster over mid parent and better -parent value was highest in F_1 of JS335 x SDP10 (18.37, 16.0%). The F_1 of JS335 x SDP18 (16.0% MPH), JS335 x SDP36 (17.78% MPH) and JS335 x SDP30 (15.15% MPH) showed mid parent heterosis in desirable positive direction. However, residual mid-parent heterosis was highest reported in F_2 of JS335 x SDP10 (14.03% MPH).

Maximum number of pod per plant was desirable for gaining yield in plant. Significant highest heterosis over mid and parents was exhibited by F_1 of JS335 x SDP30 (31.42, 64.85%), JS335 x SDP 10 (27.02, 37.55%), JS335 x SDP 36 (23.12, 34.28%) and JS335 x SDP 18 (19.14, 33.84%). However, estimated residual heterosis over mid parent and better parent was recorded highest in F_2 of JS335 x SDP30 (22.72, 53.93%) followed by JS335 x SDP 10 (20.94, 30.98%) and JS335 x SDP 36(13.11, 23.36%), F_2 of JS335 x SDP18 expressed better parent heterosis, Similar findings for numbers of pods per plant were also reported by Sudaric *et al.* (2009) [20]. Among the F_3 generations of four crosses, JS335 x SDP 10 expressed highest residual mid and better parent heterosis (13.56 and 22.98%). Whereas F_3 of JS335 x SDP 18 (24.40% BPH), JS335 x SDP 36 (21.18% BPH) expressed better parent heterosis. The F_3 of JS335 x SDP 30 showed mid- parent heterosis (17.49%). Liua *et al.* (2005) [13] reported that number of pod per plant are the most important yield components of soybean. Bhosle *et al.* (2005) and Pandini *et al.* (2002) [3, 15] studied heterosis for soybean seed yield and yield components and suggested that pods/plant are suitable for indirect selection for high seed yield. Recently Alghamdi (2009) [1] studied faba bean and reported highly significant mid- and better-parent heterosis for pods/plant Ponnusamy and Harer (1998) [16] studied heterosis and combining ability in soybean and reported 91.3% mid-parent heterosis for pods/ plant.

Maximum heterosis over mid and better-parents in desirable positive direction for governing 100 seed weight was recorded highest in F_1 of SDP 30(34.83, 20.92%), SDP 18 (33.85, 19.94%), JS335 x SDP 10 (25.70, 21.69%) and JS335 x SDP 36 (13.27, 11.77%). However, among the F_2 generations, significant residual heterotic effect over mid-parent was recorded in JS335 x SDP 18 (21.81%) and JS 335 x SDP 30 (20.61% MPH). The F_3 generation of cross JS335 x SDP30 expressed significant residual heterosis over mid- parent (15.94% MPH) for 100 seed weight.

The estimated heterosis for yield per plant (g) in desirable positive direction over mid and better-parents was highest recorded in F_1 of JS335 x SDP 36 (32.90, 41.57%) followed by JS335 x SDP 10 (31.20, 39.23%) and JS 335 x SDP 30 (30.61, 59.48%). However, among the F_2 generations, significant residual heterotic effect due to expression of dominant gene over mid and better-parents was recorded in F_2 of JS335 x SDP 18 (37.09, 53.87%), JS 335 x SDP 36 (25.36, 26.36%) and JS 335 x SDP 10 (19.08, 26.38%), however F_2 of JS335 x SDP 30 expressed better parent heterosis (50.05% BPH). Among the F_3 generations the highest residual heterosis over mid parent and better parent observed in JS 335 x SDP 18 (20.91, 35.70%) and F_3 of JS335 x SDP 30 expressed significant better parent heterosis (37.40% BPH). Significance of dominance (h) gene effect indicates that high yield of soybean under dominant effect of genes. Significancy of dominant gene for governing yield character were reported earlier by this trait was reported by Halvankar and Patil (1993) [8], Sharma and Phul *et al.* (1994) [21].Wang *et al.* (2002) [23] and Manjarrez-Snadoval *et al.* (1997) also reported mid and better-parent heterosis for yield.

Table 1: Analysis of variance for combining ability (Line x Tester) for ten characters in soybean

Characters	Replications MSS 2 (d.f)	Crosses MSS 11 (d.f)	Line effect MSS 2 (d.f)	Tester effect MSS 3 (d.f)	Line x Tester effect MSS 6 (d.f)	Error Mss 22 (d.f)
Days to first flowering	6.027	12.81	32.52**	25.13**	0.0	0.08
Days to maturity	12.444	50.59**	44.194**	152.39**	2.00	12.89
Plant height (cm)	1.392	39.25**	23.95**	126.38**	0.79	4.84
Primary branches/plant	0.143	0.538**	1.374**	0.90**	0.075	0.22
Number of pod per cluster	0.27	0.105	0.301**	0.172**	0.005	0.07
Number of pod per plant	3.791	53.70**	54.43**	158.01**	1.30	7.19
100-seed weight (gm)	3.24	4.135**	17.577**	2.16	0.642	0.58
Seed yield/plant(gm)	3.34	4.30**	2.98	5.175	4.304**	0.96

** and * indicates significant at 1% and 5%, respectively

Table 1: Estimation of mean performance, mid and better-parent heterosis and residual heterosis of F_1, F_2, F_3 generations for yield and yield contributing characters in soybean

Cross	Genration	Mean value	Mid-parent (MPH)	Better parent (BPH)	SCA	Mean value	Mid-parent (MPH)	Better parent (BPH)	SCA	Mean value	Mid-parent (MPH)	Better parent (BPH)	SCA	Mean value	Mid-parent (MPH)	Better parent (BPH)	SCA
		Days to first flowering				Days to maturity				Plant height				Primary branches (No/plant)			
JS 335 x SDP 10	F_1	36.0	-3.14	-12.20	-0.22	93.00	1.45	-4.78	0.19	55.00	15.63**	4.17	0.19	5.07	17.83**	4.11	-0.04
JS 335 x SDP 18		37.0	-1.77	-9.76	0.00	96.00	2.31	-1.71	-0.47	64.00	25.08**	21.21**	0.30	4.80	26.32**	-1.37	0.02
JS 335 x SDP 30		35.0	-2.78	-14.63*	0.11	91.00	0.74	-6.83*	0.30	60.00	19.60**	13.64**	0.16	5.20	32.20**	6.85	0.21
JS 335 x SDP 36		39.0	-0.43	-4.88	0.11	100.0	4.90	2.39	-0.028	57.00	18.18**	7.95**	-0.66	4.20	17.76**	-13.70*	-0.18
JS 335 x SDP 10	F_2	38.33	3.14	-6.50	0.02	95.00	3.64	-2.73	0.44	53.65	12.79**	1.61	0.10	4.78	11.24*	-1.71	0.05
JS 335 x SDP 18		39.0	3.54	-4.88	-0.08	97.33	3.73	-0.34	-0.88	62.00	21.17**	17.42**	-0.43	4.42	16.40**	-9.11	0.03
JS 335 x SDP 30		37.0	2.78	-9.76	0.02	92.67	2.58	-5.12	0.22	58.87	17.34**	11.49**	0.29	4.50	14.41**	-7.53	-0.09
JS 335 x SDP 36		41.0	4.68	0.00	0.02	102.00	6.99*	4.44	0.22	56.43	17.00**	6.88	0.03	4.0	12.15*	-17.81**	0.002
JS 335 x SDP 10	F_3	39.67	6.73	-3.25	0.19	96.00	4.73	-1.71	-0.63	51.68	8.65*	-2.11	-0.30	4.43	3.10	-8.90	-0.008
JS 335 x SDP 18		40.33	7.08	-1.63	0.08	101.67	8.35**	4.10	1.36	61.00	19.22**	15.53**	0.12	4.05	6.58	-16.78	-0.05
JS 335 x SDP 30		38.0	5.56	-7.32	-0.13	94.00	4.06	-3.75	-0.52	56.57	12.76**	7.13*	-0.45	4.19	6.44	-13.97	-0.12
JS 335 x SDP 36		42.0	7.23	2.44	-0.13	103.67	8.74**	6.14	-0.19	55.47	15.00**	5.05	0.62	3.90	9.35	-19.86**	0.18

Cross	Genration	Mean value	Mid-parent (MPH)	Better parent (BPH)	SCA	Mean value	Mid-parent (MPH)	Better parent (BPH)	SCA	Mean value	Mid-parent (MPH)	Better parent (BPH)	SCA	Mean value	Mid-parent (MPH)	Better parent (BPH)	SCA
		Pods (No/cluster)				Pods (No/plant)				100 seed weight				Seed yield (g/plant)			
JS 335 x SDP 10	F_1	3.87	18.37**	16.00*	0.018	42.00	27.02**	37.55**	-0.18	13.65	25.70**	21.69**	0.74	10.68	31.20**	39.23**	0.63
JS 335 x SDP 18		3.60	16.13*	8.00	-0.004	40.80	19.14**	33.84**	-4.46	13.45	33.85*	19.94**	-0.18	8.35	-2.95	8.93	-2.04
JS 335 x SDP 30		3.80	15.15*	14.00	0.015	50.33	31.42**	64.85**	0.55	13.56	34.83*	20.92**	-0.24	12.23	30.61**	59.48**	0.59
JS 335 x SDP 36		3.53	17.78*	6.00	-0.02	41.00	23.12**	34.28**	0.10	12.53	13.27*	11.77*	-0.31	10.86	32.90**	41.57**	0.82
JS 335 x SDP 10	F_2	3.73	14.03*	11.75	0.04	39.99	20.94**	30.98**	0.65	10.66	-1.81	-4.95	-0.52	9.69	19.08*	26.38*	-0.49
JS 335 x SDP 18		3.42	10.43	2.70	-0.009	38.14	11.20	24.91**	-0.34	12.24	21.81**	9.15	0.32	11.80	37.09**	53.87**	1.25
JS 335 x SDP 30		3.60	9.03	8.00	-0.014	47.00	22.72**	53.93**	0.06	12.13	20.61**	8.17	0.04	11.51	13.70	50.05**	-0.27
JS 335 x SDP 36		3.37	12.22	1.00	-0.025	37.67	13.11*	23.36**	-0.37	11.30	2.15	0.80	0.16	9.69	25.36*	26.36**	-0.48
JS 335 x SDP 10	F_3	3.47	6.12	4.00	-0.065	37.55	13.56*	22.98**	-0.47	10.35	-4.65	-7.70	-0.21	9.12	18.95	18.95	-0.13
JS 335 x SDP 18		3.30	6.45	-1.00	0.013	37.98	10.74	24.40**	0.81	11.16	11.06	-0.48	-0.13	10.41	20.91*	35.70**	0.79
JS 335 x SDP 30		3.47	5.05	7.13*	-0.002	45.00	17.49**	47.38	-0.61	11.66	15.94**	3.98	0.19	10.54	4.12	37.40**	-0.31
JS 335 x SDP 36		3.30	10.0	5.05	0.054	37.00	11.11	21.18**	0.27	3.30	10.0	5.05	0.15	8.92	15.39	16.32	-0.33

Conclusion

Maximum effect of heterosis, residual heterosis were observed for desirable direction of all character in non-segregating and segregating generations. The effect of dominant genes was recorded maximum in F_1 of all the four crosses and residual effect was recorded maximum in F_2 generations than F_3 of all of them Effect of heterosis and residual heterobeltosis goes on decreasing as increasing homozygocity in next generations.

References

1. Alghamdi SS. Heterosis and combining ability in a diallel cross of eight faba bean (*Vicia faba* L.) genotypes. Asian Journal of Crop Science 2009;1(2):66-76
2. Bhatade SS, Singh CB, Tiwari AS. Diallel analysis of yield and its components in soybean. Indian Journal of Agricultural Sciences 1977;47:324-7.
3. Bhosle SV, Taware SP, Raut VM. Heterosis and inbreeding depression in three soybean (*Glycine max* (L.) Merrill) crosses. Indian Journal of Gene- tics and Plant Breeding 2005;65(3):233-235
4. Burton 1987. Genetic analysis of soybean hard seededness with molecular markers published therotical and applied genetics 1990;79:465-469
5. Datt Shiv, Noren SK, Bhadana VP, Sharma PR. Gene action for yield and its components in soybean (*Glycine max* (L.) Merrill). Vegetos- An International Journal of Plant Research 2011;24(1):89-92.
6. Fonesca, Patterson. Hybrid vigour in seven parental diallel crosses in common wheat (*Triticum aestivum* L.). Crop Sci 1968;8:85-8
7. Ghassemi F, Yazdi-Samadi B. Genetic estimation of eight quantitative characters in soybean (*G. max* (L.) Merrill). Iran Journal Agricultural Sciences 1987;17(3-4):31-43.
8. Halvankar GB, Patil VP. Combining ability studies. In: Soybean. Journal of Maharashtra Agricultural Universities 1993;18(1): 46-9.
9. Harer PN, Deshmukh RB. Components of genetic variation in soybean. (*G. max.* (L.) Merrill). Journal Oilseeds Research 1991;8(2):220-5.
10. Hulse. Soybean biodiversity and butritional quality, pp.1-13. In A. Buchanan, (ed.). Proc. of the 2nd International Soybean Processing and Utilization Conference. Bangkok 1996.
11. Kempthorne, An Introduction to Genetic Statistics, John Wiley & Sons, New York, NY, USA 1957.
12. Khattab AB. Genetical analysis of some quantitative traits in soybean (*Glycine max* (L Merrill). Annals of Agricultural Science, Moshtohor 1998;36(1):133-42.
13. Liu XB, Jin J, Herbert SJ, Zhang Q, Wang G. Yield components, dry matter, LAI and LAD of soybeans in Northeast China. Field Crops Research 2005;93(1):85-93
14. Matzinger DF, Mannand TJ, Cockerham CC. Diallel cross in Nicotiana tabacum. Crop Sci 1962;2:238-286.
15. Pandini F, Vello NA, Lopes AC-de-A. Heterosis in soybeans for seed yield components and associated traits. Brazilian Archives of Biology and Technology 2002;45(4):401-412
16. Ponnusamy K, Harer PN. Heterosis and combining ability in soybean. Journal of Maharashtra Agricultural Universities 1998;23(2):115-117
17. Rahangdale SR, Raut VM. Gene effects for oil content and other quantitative traits in soybean (*Glycine max* (L.) Merrill). The Indian journal of Genetics and Plant Breeding 2002;62(4):322-7.
18. Ramana MV, Satyanarayana A. Heterosis in soybean. (*Glycine max* L. Merrill) Legume Res 2006;29(4):247-251.
19. Sayad ZS, Soliman MM, Mokhtar SA, Shaboury HMG, Hafez GAA. Heterosis combining ability and gene action in F_1 and F_2 diallel crosses among six soybean genotypes. Annals of Agricultural Science, Moshtohor 2005;43(2):545-59.
20. Sudaric A, Vrataric M, Volenik M, Matosa M, Duvnjak V. Heterosis and heterobeltiosis for grain yield components in soybean. (Croatian) Poljoprivreda / Agriculture 2009;15(2):26-31.
21. Sharma SR, Phul PS. Combining ability analysis in soybean. Indian Journal Genet 1994;54(3):281-286.
22. Talwar ML, Singh SP. Genetic analysis of yield and its components in soybean. Crop Improvement 1983;10(2):111-4.
23. Wang SM, Sun HA, Wang YQ, Zhao LM, Li N, Fu LS *et al*. Studies on heterosis and screening of highly heterotic combinations in soybean. I. F1 seed yield heterosis and screening of highly heterotic combinations. Soybean Science 2002;21(3):161-167.