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Estimation of heterosis for tuber yield and its components in potato (*Solanum tuberosum* L.)

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ABSTRACT : An experiment was conducted to estimate heterosis for tuber yield and its components under early harvest crop (75 day after planting) and medium harvest crop (90 day after planting) of potato in 32 crosses using line × tester (8 × 4) matting design. The results revealed that mean squares due to parents vs. hybrids were highly significant for all the characters, plant height (cm), number of stems per plant, fresh weight of tops per plant (g), number of tubers per plant, tuber yield per plant (g), average tuber weight (g), harvest index (%), tuber dry matter (%), chip colour index (1-10 scale), reducing sugar (%) and total soluble solids (%). The hybrids *viz.*, MS/95-117 × TPS 13 (26.92 %) and Kufri Laukar × Kufri Chipsona 1 (13.03 %) in 75 days harvest condition and hybrids *viz.*, MS/95-117 × TPS 13 (23.24 %), MS/95-117 × Kufri Chipsona 2 (22.29 %) and Kufri Jyoti × Kufri Chipsona 1 (12.50 %) in 90 days harvest condition exhibited significant positive heterobeltiosis for tuber yield per plant. This indicated that magnitude of heterosis varied within as well as between characters.

KEY **W**ORDS : Potato, *Solanum tuberosum* L., Heterosis, Line × tester analysis

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The potato is one of the main vegetable crops of the world which is popularly known as king of vegetable has emerged as fourth most important food crop in India after rice, wheat and maize. It belongs to the family Solanaceae and genus *Solanum*, containing over 2000 species of which only 150 are tuber bearing. However, only two tuber-bearing species namely, *Solanum tuberosum* and *Solanum andigenum* have been exploited worldwide for commercial cultivation (Sleper and Poehlman, 2006). The center of origin of potato (*Solanum tuberosum* L.) is in the Andean region of South America. The Indian vegetable basket is incomplete without potato. It has become an integral part of breakfast, lunch and dinner among the larger population. Being a short duration crop, it produces more quality of dry matter, edible energy and edible protein in lesser duration of time compared to cereals like rice and wheat. Hence, potato is considered to be an important crop to achieve nutritional security of the nation. Globally, India ranks 3rd in area, 2nd in production and 10th in productivity. India produced 44.73 Mt from 1.96 Mha with an average yield 22.76 t/ha of potato during 2012-13 (Anonymous, 2013).

Potato is a highly heterozygous crop where non-additive gene action is known to be important for most of the economic characters. An advantage of hybridization in potato is that once a hybrid with desired characters is identified, it can be multiplied vegetatively for a long time

without any risk of segregation. Heterosis is prerequisite for developing a good hybrid variety of potato. So, the study was undertaken to determine the heterotic hybrid combination.

RESEARCH PROCEDURE

Eight females (Kufri Laukar, JX 161, Kufri Pukhraj, Kufri Pushkar, Kufri Jyoti, Kufri Chipsona 3, MS/94-899 and MS/95-117) and three males (TPS 13, Kufri Chipsona 1 and Kufri Chipsona 2) potato genotypes belonging to *Solanum tuberosum* spp. *tuberosum* while, one male *viz.*, EX/A 680-16 belonging to *Solanum tuberosum* spp. *andigena* were selected for the present study. The crossing programme was carried out at the Main Potato Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa (Gujarat) during *Rabi*, 2010. The male clones were planted about a week earlier to females so that pollen is available for pollination as soon as female clones start blooming. The photoperiod was artificially extended to 14 to 16 hrs/day with the help of sodium vapour lamps to induce flowering in the parental plants. For crossing, flower bunches in female parents were thinned to retain only 6-8 large size buds per bunch. Hand emasculation was done on the previous day in the afternoon and the buds were tagged. On the next day in the morning pollens were collected and pollination was done. At the maturity the hybrid berries were harvested and seeds were extracted. The 32 crosses were made in a line × tester mating design among eight lines and four testers. All the crossed seeds of parental genotypes were harvested, cleaned and handled properly in seed bags for sowing in the next season. The true seeds of 32 crosses were raised in nursery bed at Main Potato Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa (Gujarat) during *Rabi*, 2011. Randomly selected seedlings of each cross at 6-7 leaf stage were transplanted in Randomized Block Design (RBD) with three replications using plot size of 1.0 × 3.0 m (2 rows of 15 plants each) in 50 × 20 cm spacing. At harvest, from one replication, three tubers per seedling for each of 24 randomly selected plants per progeny were retained to form three replications of first clonal generation (FCG) for set –I (75 days harvest). The same procedure was applied in another replication to form material for first clonal generation (FCG) for set –II (90 days harvest). The 45 entries, comprising of 8 females (lines), 4 males (testers), 32 hybrids and one standard check Kufri Badshah were grown in Randomized Block Design (RBD) with three replications at Main Potato Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa (Gujarat). The experimental material was planted in second week of November in the year 2012-13 in both the sets *i.e.* 75 days (C_1) and 90 days (C_2) harvest. Each genotype was represented by two rows plot of 2.4 m length. The inter and intra row distances were 50 cm and 20 cm, respectively which accommodated 24 plants per plot. All the recommended agronomical practices and plant protection measures were followed for raising a good crop. The observation were recorded and calculated on the ten randomly selected competitive plants from each plot for 11 traits *viz.*, plant height (cm), number of stems per hill, fresh weight of tops per plant (g), number of tubers per plant, tuber yield per plant (g), average tuber weight (g), harvest index (%), tuber dry matter (%), chip colour index (1-10), reducing sugar (%) and total soluble solids (%). The expression of heterosis in 32 hybrids involving eight lines and four testers was measured in terms of relative heterosis in relation to mid parents, heterobeltiosis in relation to better parent and standard heterosis in comparison with Kufri Badshah, the hybrid as the standard.

RESEARCH ANALYSIS AND REASONING

The analysis of variance for tuber yield and other attributing traits revealed that the parents and their hybrids involved in the present study significantly for all the characters under both the harvest conditions. The results indicated existence of variability was observed for all the characters in males and females under both the harvest condition. Mean values and range of tuber yield and yield component characters of parents (line and tester) and their hybrids under both the harvest conditions are presented in Table 1. The range of mid parent heterosis, heterobeltiosis and standard heterosis as well as number of hybrids showing significant heterosis in desirable direction in both the harvest condition was presented in Table 2.

For the plant height, (10, 3) hybrids for relative heterosis, (5, 1) for heterobeltiosis and none of the hybrids for standard heterosis recorded significant heterosis under C_1 and C_2 conditions, respectively. The hybrid MS/95-117

× TPS 13 recorded highest significant positive relative heterosis under both the harvest conditions and under C_1 condition for heterobeltiosis whereas, the hybrid Kufri Luakar × Kufri Chipsona 1 observed significant positive under C_2 condition. With respect to heterosis for plant height, positive heterosis of hybrids was considered desirable which is also reported by Biswas *et al.* (2005) and Patel *et al.* (2007).

The number of stems per hill, (20, 15) for relative heterosis, (12, 10) for heterobeltiosis and (27, 19) for standard heterosis recorded significant positive heterosis under C_1 and C_2 conditions, respectively. The highest significant positive relative heterosis and heterobeltiosis was observed in the crosses, MS/95-117 × EX/A-680-16 and Kufri Luakar × EX/A-680-16 under C_1 condition and MS/95-117 × TPS 13 under C_2 condition. Highly significant positive standard heterosis was recorded in Kufri Pushakar × Kufri Chipsona 2 under C_1 condition whereas, JX 161 × EX/A-680-16 under C_2 condition. The (10, 7) hybrids in C_1 condition and (18, 9) hybrids in C_2 condition showed significant positive heterosis over mid and better parental value for fresh weight of tops per plant, respectively. While none of the hybrids expressed significant heterosis over standard parent in desired direction under both the harvest conditions. Similar observation has been reported by Patel *et al.* (2007).

Out of the 32 hybrids, (18, 19) for relative heterosis, (12, 15) for heterobeltiosis and (27, 22) for standard heterosis showed positive significant for number of tubers per plant under both the harvest condition, respectively. The hybrids, MS/95-117 × EX/A-680-16 and Kufri Jyoti × EX/A-680-16 under C_1 condition whereas, MS/95-117 × TPS 13 and Kufri Jyoti × TPS 13 in C_2 condition recorded highly significant positive relative heterosis and heterobeltiosis for number of tuber per plant, respectively. The hybrid Kufri Pushkar × Kufri Chipsona 2 (113.85 and 67.47 %) and JX 161 × Kufri Chipsona 2 (95.38 and 57.83 %) recorded highly significant positive standard heterosis under C_1 and C_2 conditions, respectively. The findings are congruence with Biswas *et al.* (2005); Luthra (2006); Kumar and Kang (2006); Patel *et al.* (2007) and Manivel *et al.* (2010).

The estimate of relative heterosis revealed that eight hybrids in C_1 condition and seven hybrids in C_2 condition

Table 1: Mean values of tuber yield and different traits of potato among parents (line and tester) and their hybrids

Traits		Line		Tester		Hybrids		S.E.±	CD (P=0.05)	C.V. %
		Mean	Range	Mean	Range	Mean	Range			
Plant height (cm)	C_1	47.29	37.16 to 54.80	49.53	38.52 to 61.76	48.74	36.02 to 60.88	1.73	4.85	6.16
	C_2	51.58	38.70 to 59.98	59.79	50.28 to 69.16	49.66	40.12 to 61.62	2.00	5.62	6.80
Number of stems per	C_1	2.61	1.93 to 3.93	2.52	1.87 to 3.27	2.89	1.87 to 4.13	0.09	0.26	5.77
hill	C_2	2.61	2.07 to 3.93	2.65	1.93 to 3.87	3.00	1.93 to 4.13	0.11	0.31	6.55
Fresh weight of tops	C_1	235.20	160.92 to 282.10	183.44	168.10 to 201.78	199.14	103.04 to 318.52	7.79	21.90	6.61
per plant (g)	C_2	189.23	100.52 to 235.58	150.75	113.52 to 181.44	200.31	98.10 to 330.90	7.60	21.36	6.79
Number of tubers per	C_1	5.82	4.47 to 7.93	5.32	4.07 to 6.73	6.28	3.87 to 9.27	0.16	0.44	4.44
plant	C_2	5.93	4.07 to 8.73	5.42	4.27 to 6.47	6.62	4.27 to 9.27	0.18	0.52	5.01
Tuber yield per plant	C_1	378.17	249.15 to 511.07	223.88	165.93 to 278.27	254.75	144.89 to 370.27	10.30	28.97	6.50
(g)	C_2	545.38	343.96 to 803.20	361.22	270.58 to 418.86	397.25	221.96 to 533.84	15.45	43.44	6.36
Average tuber	C_1	67.52	48.53 to 98.22	43.24	35.63 to 51.16	41.97	26.22 to 68.42	2.26	6.37	8.39
weight (g)	C_2	99.54	67.06 to 200.81	69.37	54.02 to 90.35	61.82	39.32 to 101.28	3.17	8.91	7.91
Harvest index (%)	C_1	61.29	55.23 to 67.41	54.41	49.40 to 60.90	56.29	46.62 to 63.45	1.23	3.46	3.73
	C_2	73.38	64.68 to 83.24	70.34	65.50 to 77.12	66.54	56.58 to 77.55	1.16	3.26	2.95
Tuber dry matter (%)	C_1	15.88	14.31 to 17.27	17.57	17.09 to 18.29	16.07	14.54 to 17.57	0.49	1.37	5.21
	C_2	17.66	15.43 to 20.16	19.16	17.41 to 20.85	18.50	15.64 to 21.68	0.58	1.63	5.46
Chip colour index	C_1	3.68	1.87 to 4.53	2.55	1.27 to 3.87	3.55	2.27 to 5.93	0.09	0.24	4.33
(1-10)	C_2	2.42	1.20 to 3.73	1.92	1.07 to 2.80	2.61	1.33 to 4.13	0.10	0.27	6.61
Reducing sugar (%)	C_1	7.24	3.6 to 9.21	4.97	2.42 to 5.89	7.02	4.43 to 11.67	0.15	0.43	3.88
	C_2	4.73	2.20 to 7.35	3.72	2.02 to 5.52	5.10	2.26 to 8.20	0.16	0.45	5.66
Total soluble solids	C_1	4.17	3.73 to 4.42	3.85	3.55 to 4.18	4.14	3.82 to 4.73	0.06	0.16	2.33
(%)	C_2	3.85	3.57 to 4.22	3.73	3.52 to 3.95	3.90	3.58 to 4.28	0.06	0.17	2.71

C_1= 75 days harvest, C_2= 90 days harvest, K.= Kufri

exhibited significant positive heterosis for tuber yield per plant. The heterosis ranged from -59.17 per cent (Kufri Pukhraj × Kufri Chipsona 1) to 36.76 per cent (MS/95-117 × TPS 13) in C_1 condition and from -58.66 per cent (Kufri Pukhraj × EX/A-680-16) to 29.41 per cent (Kufri Chipsona 3 × EX/A-680-16) in C_2 condition. With respect to heterobeltiosis, two crosses *viz*., MS/95-117 × TPS 13 (26.92 %) and Kufri Laukar × Kufri Chipsona 1 (13.03 %) in C_1 condition and three crosses, MS/95-117 × TPS 13 (23.24 %), MS/95-117 × Kufri Chipsona 2 (22.29 %) and Kufri Jyoti × Kufri Chipsona 1 (12.50 %) under C_2 condition recorded significant positive. Among 32 hybrids, none of the hybrids expressed significant positive heterosis over Kufri Badshah in both harvest conditions and is in agreement with the finding of the Luthra (2006), Kumar and Kang (2006); Patel *et al.* (2007); Buso *et al.* (2008) and Manivel *et al.* (2010). Comparatively small number of crosses showing positive heterosis for tuber yield may be due to the fact as majorities of the parents were of high yielding *tuberosum* type, which is known to have a narrow genetic base (Mendoza and Haynes, 1974 and Luthra, 2006).

For average tuber weight only one hybrid, Kufri Laukar × TPS 13 (16.35 %) under C_1 condition and Kufri Chipsona 3 × EX/A-680-16 (23.68 %) under C_2 condition was observed significant positive relative heterosis. None of the hybrids exhibited significant heterosis over better parent and standard parent in both harvest conditions.

The significant positive relative heterosis for harvest index was manifested by five and two hybrids in C_1 and C_2 conditions, respectively. The extent of relative heterosis varied between -18.83 per cent (Kufri Laukar × Kufri Chipsona 1) to 11.67 per cent (MS/94-899 × EX/A-680-16) in C_1 condition and -26.95 per cent (Kufri Laukar × EX/A-680-16) to 13.75 per cent (MS/95-117 × TPS 13) in C_2 condition. In case of heterobeltiosis, none of the hybrids in C_1 condition and only one hybrid, MS/95-117 × TPS 13 (11.72 %) in C_2 condition expressed significant heterosis in desired direction. The estimates of heterosis over Kufri Badshah revealed that 16 hybrids in C_1 condition and 9 hybrids in C_2 condition exhibited significant positive relative heterosis. The heterosis over Kufri Badshah for harvest index ranged from -12.04 per cent (JX 161 × EX/A-680-16) to 19.71 per cent (JX 161

Table 2 : Range of heterosis and number of crosses showing significant heterosis in desirable direction in potato

Traits		Heterosis (%) over mid parent		Heterosis (%) over better parent		Heterosis (%) over standard check	
		Range	No. of crosses	Range	No. of crosses	Range	No. of crosses
Plant height (cm)	C_1	-28.62 to 51.11	10	-35.91 to 48.44	5	-40.44 to 0.66	0
	C_2	-29.58 to 19.96	3	-37.59 to 19.41	1	-44.52 to -14.80	0
Number of stems per hill	C_1	-13.92 to 42.03	20	-30.51 to 40.00	12	-9.68 to 100.00	27
	C_2	-18.92 to 63.93	15	-30.51 to 56.25	10	-25.64 to 58.97	19
Fresh weight of tops per	C_1	-54.22 to 87.94	10	-63.47 to 78.90	7	-71.07 to -10.58	0
plant (g)	C_2	-30.42 to 148.80	18	-45.93 to 120.07	9	-70.90 to -1.83	0
Number of tubers per plant	C_1	-20.00 to 62.32	18	-25.58 to 45.45	12	-10.77 to 113.85	27
	C_2	-9.88 to 62.32	19	-25.51 to 55.22	15	-22.89 to 67.47	22
Tuber yield per plant (g)	C_1	-59.17 to 36.76	8	-71.65 to 26.92	2	-63.97 to -7.91	0
	C_2	-58.66 to 29.41	7	-72.37 to 23.24	3	-67.58 to -22.04	0
Average tuber weight (g)	C_1	16.35 to -63.00	1	-71.05 to 11.42	0	-72.22 to -27.50	0
	C_2	23.68 to -57.27	1	-71.57 to 11.66	0	-68.90 to -19.89	0
Harvest index (%)	C_1	-18.83 to 11.67	5	-21.07 to 4.79	0	-12.04 to 19.71	16
	C_2	-26.95 to 13.75	2	-32.03 to 11.72	1	-15.56 to 15.73	9
Tuber dry matter (%)	C_1	-15.08 to 3.47	0	-20.48 to 10.86	0	-4.24 to 15.72	12
	C_2	-9.71 to 12.25	4	-16.47 to 6.58	0	-14.24 to 18.90	5
Chip colour index (1-10)	C_1	-25.27 to 103.03	9	-24.44 to 252.63	3	-44.26 to 45.90	23[1]
	C_2	-42.03 to 139.02	8[1]	-6.06 to 241.18	0	-62.96 to 241.18	28[1]
Reducing sugar (%)	C_1	-25.54 to 106.59	9[1]	-24.89 to 266.30	3[1]	-44.64 to 45.98	23[1]
	C_2	-49.80 to 147.82	9[1]	-4.91 to 273.21	0	-68.61 to 14.09	28[1]
Total soluble solids (%)	C_1	-5.79 to 15.68	4[1]	-3.56 to 25.66	0	-11.24 to 10.08	20[1]
	C_2	-6.32 to 13.23	3[1]	-0.91 to 19.34	0	-13.65 to 3.21	22[1]

[1] Number of hybrids showing negative heterosis was recorded for chip colour index, reducing sugar and total soluble solids

× Kufri Chipsona 1) in C_1 condition and -15.56 per cent (Kufri Laukar × Kufri Chipsona 1) to 15.73 per cent (Kufri Laukar × TPS 13) in C_2 condition. The results are congruence with Patel *et al.* (2007).

With regard to quality traits, the hybrid Kufri Jyoti × EX/A-680-16 in C_1 condition while, Kufri Pushakar × Kufri Chipsona 1 in C_2 condition exhibited the highest significant desirable (negative) relative heterosis and standard heterosis for all three quality traits *viz.*, chip colour index (Gopal *et al.*, 2000 and Manivel *et al.*, 2010), reducing sugar and total soluble solids (Buso *et al.*, 2008). For tuber dry matter, Kufri Jyoti × Kufri Chipsona 2 (12.25 and 18.90 %) followed by Kufri Chipsona 3 × TPS 13 (10.29 and 14.92 %) exhibited the highest significant positive relative heterosis and standard heterosis at C_2 condition, respectively. Similar results were reported by Kumar and Kang, 2006; Patel *et al.* (2007) and Manivel *et al.* (2010) in potato.

The results revealed that degree of heterosis varied from cross to cross for all the characters. The high heterosis was obtained for fresh weight of tops per plant, chip colour index and reducing sugar. The moderate level of heterosis was recorded for plant height, number stems per hill, number of tubers per plant and tuber yield per plant while, it was low for average tuber weight, harvest index, tuber dry matter and total soluble solids which revealed that the nature of gene action varied with genetic architecture of parents. Similarly Gopal and Minocha (1997); Buso *et al*. (2003) and Patel *et al*. (2007) reported that the magnitude of heterosis varied within as well as between characters.

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