Original Research Article

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Heterosis and Inbreeding Depression Studies for Yield and Yield Related Traits in Tomato (*Solanum lycopersicum* L.)

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ABSTRACT

Standard heterosis over two checks was studied in 30 crosses of tomato. Degree and direction of heterosis is important for commercially exploitation of tomato. All these crosses showed marked variations for yield and yield related traits in the expression of standard heterosis. Standard heterosis for total yield per plant was found to be 62.46 per cent over first check (SH1) and 30.84 per cent over second check (SH2). Highest heterotic effects for yield traits over SH1 was observed for number of seeds per fruit followed by plant height, number of fruits per cluster, number of fruits per plant and fruit diameter while the traits showing highest heterotic effects over SH2 were fruit diameter followed by plant height, number of seeds per fruit, number of fruits per plant and number of primary branches per plant. The maximum significant positive heterosis for total yield per plant was estimated for the cross Azad T-5 × DT-2 with 62.46 over SH1 and 30.84 over SH2 followed by Sel-7 × DT-2 with 56.08 over SH1 and 25.7 over SH2 and then the cross Punjab Upma × DT-2 with 50.76 over SH1 and 21.42 over SH2. In F_2 progenies inbreeding depression was also studied for 16 characters of 30 hybrids. In many crosses significant inbreeding depressions were found for the studied characters. In most of the crosses high heterosis for total yield per plant and its related traits was invariably accompanied by high inbreeding depression in F_2 generation. To develop high yielding tomato hybrids the most important criteria is the selection of good parents.

Introduction

Tomato is an indispensible vegetable in all parts of the world. It is an important source of vitamins and nutrients, and an economically important horticultural commodity. Tomato originated in Andean region. The modern name "tomato" is derived from "tomatl", the word for this plant in the native language of the Aztecs (Gould 1983). The tomato was classified by Miller (1754) as *Lycopersicon esculentum* and renamed by Child (1990) and Peralta and Spooner (2005) as *Solanum lycopersicum*. Tomato is a diploid species with 2n = 2x = 24 chromosomes. Considering the breeding behavior of crop species different breeding methods have been advocated. Breeding hybrids is one of the prominent techniques and is used in vegetable improvement. Hedrick and Booth (1968) first observed heterosis in tomato for higher yield and more number of fruits per plant. The

extensive utilization of heterosis to increase tomato production was emphasized by Choudhary *et al.,* (1965). Heterosis manifestation in tomato is in the form of the greater vigour, faster growth and development, earliness in maturity, increased productivity (Yordanov, 1983). So, by exploiting the heterosis for various yield contributing traits and earliness a speedy improvement in tomato can be done.

Materials and Methods

The present study was conducted during 2012-2013 and 2013-14 at Vegetable Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (Uttar Pradesh), India. It is situated at an altitude of 75.70 meters above mean sea level, 25°18' N latitude and 83°03' E longitude. This study was done with a view of generating information regarding heterosis and inbreeding depression for various yield and quality traits in tomato. The experimental material comprised of 13 genotypes of tomato. Out of them 10 genotypes were taken as lines and 3 genotypes as testers.

During *Rabi*, 2012 the nursery grown seedlings of 10 lines and 3 testers were transplanted in separate crossing block. The crossings were done in Line × Tester mating design given by Kempthorne (1957) to produce 30 cross combinations by hand emasculation and pollination to produce 30 F_1's. These thirty F_1's along with parents were raised in randomized block design (RBD) in three replications during *Kharif*, 2013. To know the inbreeding depression in tomato F_1's, F_2's along with parents and checks were raised in three replications during *Rabi*, 2013. All the intercultural operations were carried out in accordance with recommended package of practices from time to time. The observations were recorded for eleven growth parameters *viz.*, plant height

(cm), number of primary branches per plant, days to 50 per cent flowering, days to 50 per cent fruit setting, number of clusters per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, number of seeds per fruit, test weight of seeds (g) and total yield per plant (kg); five fruit physical parameters *viz.*, average fruit weight (g), number of locules per fruit, pericarp thickness (mm), fruit length (cm) and fruit diameter (cm); six fruit quality parameters *viz.*, total soluble solids (%), titratable acidity (%), ascorbic acid (mg/100 ml), fruit pH, lycopene content (mg/100g) and estimation of sugars (%).Analysis of variance (ANOVA) for design of experiment was carried out following Panse and Sukhatme (1967). The significance of differences among treatment means (parent and hybrids) was tested by 'F-test'. ANOVA for testing the differences among progenies and parents (line × tester) was done using standard procedure given by Singh and Chaudhary (1979).

Results and Discussion

The analysis of variance for line × tester mating design for 10 genotypes as lines (Arka Meghali, Punjab Upma, BT-12, Floradade, H-86, H-24, Sel-7, PS-1, Fla-7171 and Azad T-5) and three genotypes testers (H-88-78-4, DT-2 and Pant T-3) and 30 crosses was done. The source of variation showed positive significance for all the characters between treatments. Standard heterosis over first check (SH1) and second check (SH2) were presented (Table 1) along with inbreeding depression for top three crosses.

For Plant height, maximum positive heterosis was found in cross Floradade × Pant T-3 (76.12%) over first check and Floradade × Pant T-3 (52.15%) over second check. These results are in conformity with the findings of Sharma and Thakur (2008) and Premalakshmi *et al.,* (2006). For number of primary

branches per plant highest heterosis was found in cross PS-1 × DT-2 (49.32) over first check parent and cross Arka Meghali × Pant T-3 (34.44) over second check. These results are in line with the reports from Duhan *et al.,* (2005), Shalaby (2013) and Solieman *et al.,* (2013).

The negative heterosis is desirable for days to 50 per cent flowering and days to 50 per cent fruit setting. For days to 50 per cent flowering and days to 50 per cent fruit setting, the heterosis over first check and second check was maximum in Punjab Upma × DT-2 (-20.82) and Punjab Upma × DT-2 (-19.36), respectively. These results are in accordance with the findings of Mahendrakar (2004), Premalakshme *et al.,* (2005) and Duhan *et al.,* (2005).

For days to 50 per cent fruit setting, highest negative heterosis over first check parent and second check parent was observed in crosses, Sel-7 × DT-2 (-24.00) and Sel-7 × DT-2 (-22.46). Negative heterosis for this trait has also been reported by Mahendrakar (2004) and Premalakshme *et al.,* (2006).

For number of clusters per plant maximum positive heterosis was found in cross H-86 × Pant T-3 (18.09) over first check and H-86 × Pant T-3 (34.69) over second check. Similar reports were observed by Shalaby (2013) and Solieman *et al.,* (2013). For number of flowers per cluster highest heterosis was found in cross H-24 × H-88-78-4 (42.30) over first check parent and cross H-24 × H-88-78-4 (35.19) over second check parent. These results are in line with the reports from Kulkarni (2003) and Solieman *et al.,* (2013).

For number of fruits per cluster, heterosis over first check parent and second check parent was maximum in Arka Meghali × Pant T-3 (59.74) and Arka Meghali × Pant T-3 (29.20) respectively. These results are in

accordance with the findings of Sharma and Thakur (2008), Kumari and Sharma (2011) and Kumar *et al.,* (2012).

For number of fruits per plant, highest positive heterosis was observed in crosses, PS-1 × H-88-78-4 (52.54) and PS-1 × H-88-78-4 (40.19) over first check and second check respectively. Positive heterosis for this trait has also been reported by Duhan *et al.,* (2005), Rattan (2007), Kumari and Sharma (2011) and Kumar *et al.,* (2012). For number of seeds per fruit maximum positive heterosis was found in cross Sel-7 × DT-2 (78.41) over first check and Sel-7 × DT-2 (49.61) over second check. Similar reports were observed by Sako *et al.,* (2001) and Islam *et al.,* (2012). For test weight of seeds highest heterosis, over first check was found in cross Floradade × DT-2 (22.29) and over second check was found in Floradade × DT-2 (14.75). These results are in line with the reports from Kulkarni (2003) and Sako *et al.,* (2001).

For total yield per plant, maximum positive heterosis over first check and second check was maximum in Azad T-5 × DT-2 (62.46) and Azad T-5 × DT-2 (30.84) respectively.

These results are in accordance with the findings of Sharma and Thakur (2008), Kumari and Sharma (2011), Aisyah *et al.,* (2016) and Savale *et al.,* (2017). From the quality point of view, less number of locules per fruit is desirable and negative estimate of heterosis is economical. Maximum negative heterosis was found in cross Fla-7171 × DT-2 (-23.66) over first check and Fla-7171 × DT-2 (-19.57) over second check. These results are in line with the reports from Kulkarni (2003) and Duhan *et al.,* (2005).

For pericarp thickness, the cross H-24 × DT-2 (27.58) and H-24 × DT-2 (13.53) showed maximum heterosis over first and second checks respectively.

Table.1 Heterosis over Standard checks (SH1 and SH2) and inbreeding depression various traits in tomato

S.No.	Character	Best cross combinations	Standard Heterosis		Inbreeding depression
			Over first check parent (SH1)	Over second check parent (SH2)	
1.	Plant height (cm)	Floradade × Pant T-3	76.12	52.15	Floradade × Pant T-3 (18.38) Punjab Upma × Pant T-3 (16.35) H-86 × Pant T-3 (24.17)
		Punjab Upma × Pant T-3	67.82	44.97	
		H-86 × Pant T-3	66.63	43.95	
2.	Number of primary branches per plant	PS-1 × DT-2	49.32	32.27	PS-1 × DT-2 (14.23) Arka Meghali × Pant T-3 (12.41) PS-1 × Pant T-3 (10.9)
		Arka Meghali × Pant T-3	45.60	28.98	
		PS-1 × Pant T-3	39.90	23.93	
3.	Days to 50 per cent flowering	Punjab Upma × DT-2	-20.82	-19.36	H-86 × H-88-78-4 (-9.42), Floradade × H-88-78-4 (-9.35), H-24 × H-88-78-4 (-9.17)
		Sel-7× DT-2	-19.00	-17.50	
		Floradade × DT-2	-16.29	-14.74	
4.	Days to 50 per cent fruit setting	Sel-7× DT-2	-24.00	-22.46	H-86 × H-88-78-4 (-10.65), H-24 × H-88-78-4 (-10.48), Floradade × H-88-78-4 (-9.96)
		Punjab Upma × DT-2	-19.99	-18.37	
		Floradade × DT-2	-17.59	-15.92	
5.	Number of clusters per plant	H-86 × Pant T-3	18.09	34.69	H-86 × Pant T-3 (14.13), Floradade × Pant T-3 (11.48), Punjab Upma × H-88-78-4 (10.33)
		PS-1 × H-88-78-4	16.50	32.88	
		BT-12 × Pant T-3	11.13	26.76	
6.	Number of flowers per cluster	H-24 × H-88-78-4	42.30	35.19	H-24 × H-88-78-4 (16.03), Arka Meghali × H-88-78-4 (12.93), H-24 × DT-2 (11.54)
		Arka Meghali × H-88-78-4	41.72	34.63	
		Fla-7171 × Pant T-3	40.35	33.33	
7.	Number of fruits per cluster	Arka Meghali × Pant T-3	59.74	29.20	Arka Meghali × Pant T-3 (10.60), Floradade × H-88-78-4 (8.70), H-86 × Pant T-3 (7.50)
		H-24 × H-88-78-4	59.74	29.20	
		Sel-7 × DT-2	56.55	26.61	

8.	Number of fruits per plant	PS-1 × H-88-78-4	52.54	40.19	Azad T-5 × DT-2 (20.45), H-24 × DT-2 (16.59), Sel-7 × H-88-78-4 (14.12)
		H-86 × Pant T-3	50.83	38.61	
		Sel-7 × DT-2	40.92	29.51	
9.	Number of seeds per fruit	Sel-7 × DT-2	78.41	49.61	BT-12 × H-88-78-4 (22.69), Punjab Upma × H-88-78-4 (19.55), Azad T-5 × H-88-78-4 (19.49)
		Azad T-5 × DT-2	40.37	17.71	
		Punjab Upma × DT-2	35.41	13.56	
10.	Test weight of seeds (g)	Floradade × DT-2	22.29	14.75	H-24 × H-88-78-4 (5.53), Sel-7 × DT-2 (5.5), H-86 × Pant T-3(3.88)
		H-86 × DT-2	20.60	13.17	
		Fla-7171 × DT-2	19.40	12.04	
11.	Total yield per plant (kg)	Azad T-5 × DT-2	62.46	30.84	Azad T-5 × DT-2 (24.09), Sel-7 × DT-2 (18.27), Azad T-5 × Pant T-3 (16.42)
		Sel-7 × DT-2	56.08	25.70	
		Punjab Upma × DT-2	50.76	21.42	
12.	Average fruit weight (g)	Punjab Upma × DT-2	35.94	22.96	Punjab Upma × DT-2 (14.04), PS-1 × DT-2 (10.78), Floradade × DT-2 (10.63)
		Floradade × DT-2	36.19	19.35	
		Fla-7171 × DT-2	35.94	19.13	
13.	Number of locules per fruit	Fla-7171 × DT-2	-23.66	-19.57	Punjab Upma × H-88-78-4 (-9.00), BT-12 × Pant T-3 (-8.63), Floradade × H-88-78-4 (-7.67)
		Floradade × H-88-78-4	-23.66	-19.57	
		Punjab Upma × H-88-78-4	-23.66	-19.57	
14.	Pericarp thickness (mm)	H-24 × DT-2	27.58	13.53	Sel-7 × DT-2 (9.87), H-24 × H-88-78-4 (9.73), Floradade × H-88-78-4 (9.25)
		Sel-7 × DT-2	24.48	10.78	
		BT-12 × Pant T-3	21.13	7.80	
15.	Fruit length (cm)	Punjab Upma × DT-2	39.78	26.42	H-24 × DT-2 (9.94), Sel-7 × H-88-78-4 (8.97), PS-1 × DT-2 (8.86)
		Floradade × DT-2	35.41	22.47	
		Arka Meghali × DT-2	33.71	20.93	
16.	Fruit diameter (cm)	Fla-7171 × DT-2	38.40	25.16	Fla-7171 × DT-2 (9.01), Azad T-5 × DT-2 (8.82), H-86 × Pant T-3 (8.40)
		Punjab Upma × DT-2	36.12	23.11	
		Azad T-5 × DT-2	32.48	19.81	

These results are in accordance with the findings of Joshi *et al.,* (2005) and Rattan (2007). For fruit length highest positive heterosis was observed in cross Punjab Upma × DT-2 (39.78) over first check and Punjab Upma × DT-2 (26.42) over second check. These results are in line with the reports from, Islam *et al.,* (2012) and Aisyah *et al.,* (2016). For fruit diameter, highest positive heterosis over first check and second check was observed in crosses, Fla-7171 × DT-2 (38.40) and Fla-7171 × DT-2 (25.16) respectively. Positive heterosis for this trait has also been reported by Islam *et al.,* (2012) and Aisyah *et al.,* (2016).

The hybrid vigour expressed in F_1 usually breaks down in F_2 and later generations due to segregation of the favourable genes that govern the expression of the vigour. As a result, there is generally a decrease in the yield. To estimate decline in the performance of hybrid, the extent of inbreeding depression was recorded for the various characters and top three crosses showing maximum inbreeding depression for all the characters in the present study are presented in Table 1. Highest inbreeding depression was observed in crosses H-86 × Pant T-3 (24.17) for plant height, PS-1 × DT-2 (14.23) for number of primary branches per plant, Sel-7 × H-88-78-4 (-9.42) for days to 50% flowering, Sel-7 × H-88-78-4 (-10.65) for days to 50% fruit setting, H-86 × Pant T-3 (14.13) for number of clusters per plant, H-24 × H-88-78-4 (16.03) for number of flowers per cluster, Arka Meghali × Pant T-3 (10.60) for number of fruits per cluster, Azad T-5 × DT-2 (20.45) for number of fruits per plant, BT-12 × H-88-78-4 (22.69) for number of seeds per fruit, H-24 × H-88-78-4 (5.53) for test weight of seeds (g), Azad T-5 × DT-2 (24.09) for total yield per plant (kg), Punjab Upma × DT-2 (14.04) for average fruit weight (g), Punjab Upma × H-88-78-4 (-9.00) for number of locules per fruit, Sel-7 × DT-2 (9.87) for Pericarp

thickness (mm), H-24 × DT-2 (9.94) for fruit length (cm), H-86 × H-88-78-4 (8.83) for fruit diameter (cm). It is inferred from the results that crosses showing higher estimates of heterosis exhibited high inbreeding depression. This might be due to presence of non-additive gene action for the characters under study. However, some crosses showed high heterosis with low inbreeding depression. This might be due to presence of large number of transgressive segregants in the F_2 generation. These results are in conformity with the findings of Patel *et al.,* (2010), Nosser (2012) and Dagade *et al.,* (2015).

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