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Heterosis study for earliness and yield attributing characters in bottle gourd [*Lagenaria siceraria* (Molina) Standl.]

Bandaru Venkata Rajkumar, Anand Kumar Singh, Harit Kumar and Bhagat Singh

Abstract
A study involving 10 lines and 4 testers namely VRBG-107, VRBG-408, VRBG-1001, VRBG-1003, IC-092467, IC-144389, NDBG-104, DVBG-2, PBOG-40, IC-042345(lines); PSPL, Pusa Naveen, Arka Bahar and Selection-1(testers) mated in line x tester fashion producing hybrids were evaluated at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) during the Spring-Summer 2015. The study revealed significant heterosis among the crosses, while the best heterotic combinations recorded for various earliness and yield attributing traits were VRBG-1003 × Pusa Naveen, IC-144389 × Pusa Naveen, VRBG-1003 × PSPL and VRBG-1001 × Arka Bahar for early flowering; VRBG-408 × Arka Bahar and VRBG-1003 × Arka Bahar for lower nodes of flowering; DVBG-2 × Pusa Naveen and DVBG-2 × Selection-1 for longer vine length; NDBG-104 × PSPL and NDBG-104 × Pusa Naveen for more number of primary branches; NDBG-104 × PSPL and IC-042345 × Selection-1 for fruit weight; DVBG-2 × Arka Bahar and VRBG-107 × Arka Bahar for fruit length; cross combinations DVBG-2 × Arka Bahar and DVBG-2 × Pusa Naveen for number of fruits per plant; and NDBG-104 × PSPL, IC-042345 × Pusa Naveen and DVBG-2 × Pusa Naveen for fruit yield per plant.

Keywords: Bottle gourd, heterosis, hybrids, earliness, fruit yield

Introduction
Bottle gourd [*Lagenaria siceraria* (Molina) Standl.] belongs to the family cucurbitaceae which comprises of 120 genera and 825 species out of which 36 genera and 100 species are available in India. In this family approximately 38 species are economically important and its cultivation is done throughout the world from tropical, subtropical and even to temperate zones. Mostly cucurbits have its importance mainly in the areas of their occurrence due to climatic change, physiographic diversity and adaptation. In the Indian sub-continent cucurbits have tremendous scope of acclimatization and they have not only contributed towards the food and but also a rich wild gene pool for several important traits. It is grown as rainy season and as well as summer season vegetable. It is also known as calabash gourd or white flowered gourd. Heterosis refers to the superiority or inferiority of F_1 hybrid in one or more characters over its parents. In other words, heterosis refers to increase of F_1 in fitness and vigour over the parental values. Heterosis leads to superiority in adaptation, yield, quality, disease resistance, maturity and general vigour over its parents. Generally, positive heterosis is considered as desirable, but in some cases negative heterosis is also desirable, for example, negative heterosis for flowering, maturity duration and toxic substances is desirable in many cases because it shows superiority over the parents.

Research Methods
Fourteen parental lines of bottle gourd including 10 lines and 4 testers namely VRBG-107, VRBG-408, VRBG-1001, VRBG-1003, IC-092467, IC-144389, NDBG-104, DVBG-2, PBOG-40, IC-042345(lines); PSPL, Pusa Naveen, Arka Bahar and Selection-1(testers) were used to mode crosses in line x tester mating design (Kemptrone, 1957) to produce 40 crosses. Crosses and their parents were grown with plant to plant 0.6 m and row to row 2.0 m at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) during the Spring-Summer 2015. The trial was conducted in Randomized Block Design with three replications. The observations were recorded on ten characters of bottle gourd *viz.*, days to fifty per cent staminate flowering, days to fifty per cent pistillate flowering, node at which first staminate flower appears, node at which first pistillate flower appears, vine length (m), number of primary branches per plant,

fruit weight (kg), fruit length (cm), number of fruits per plant and fruit yield per plant (kg). The data were analyzed statistically for all the characters studied. Magnitude of heterosis was calculated as percentage of F_1 performance in favourable direction over mid parent and better parent. The significant was tested by 't' test. (Hayes and Jones, 1916) [3]

Heterosis was estimated as an increase or decrease of F_1performance over mid parent value and better parent value for all the characters under study. The magnitude of heterosis over mid parent (MPH) and better parent (BPH) for ten characters of bottle gourd are presented in Table 1 and 2.

As early flowering corresponding to early harvest is a desirable trait in bottle gourd, so negative and significant heterosis is desirable for flowering characters. For days to fifty per cent staminate flowering cross combinations VRBG-1003 × Pusa Naveen (-29.85%), VRBG-1003 × PSPL (-21.19%) and IC-144389 × Pusa Naveen (-20.53%) reported significant negative desirable heterosis over mid parent, while crosses VRBG-1003 × Pusa Naveen (-23.49%), IC-144389 × Pusa Naveen (-19.46%) and VRBG-1003 × PSPL (-16.98%) exhibited significant negative heterosis over better parent. 25 crosses over mid parent and 17 crosses over better parent exhibited significant negative heterosis for this trait. For days to fifty per cent pistillate flower appears significant negative mid parent heterosis was registered by cross combinations VRBG-1003 × Pusa Naveen (-19.66%), VRBG-1003 × PSPL (-15.93%) and IC-144389 × Pusa Naveen (-12.76%), whereas, crosses VRBG-1001 × Arka Bahar (-9.09%) followed by VRBG-1003 × Pusa Naveen (-9.03%) and VRBG-1003 × PSPL (-8.93%) exhibited significant negative heterosis with 15 crosses and 8 crosses over mid and better parent respectively. These findings are in concurrence with Sharma *et al*. (2004) [9] and Adarsh *et al.* (2017) [1].

The negative and significant heterosis is desirable for early node number to first flower. Cross combinations VRBG-408 × Arka Bahar (-12.90%), VRBG-1003 × Arka Bahar (-10.97%)and IC-042345 × Arka Bahar (-9.47%) exhibited significant negative heterosis over mid parent, similarly crosses VRBG-408 × Arka Bahar (-10.00%) followed by PBOG-40 × Arka Bahar (-6.00%) and VRBG-107 × Pusa Naveen (-5.26%) showed significant negative heterosis over better parent for node at which first staminate flower appears. Significant negative heterosis for the trait was recorded for 13 crosses and 6 crosses over mid-parent and better parent respectively. Similarly for node at which first pistillate flower appears, crosses VRBG-1003 × Arka Bahar (-14.89%) followed by VRBG-107 × PSPL (-14.21%), NDBG-104 × Pusa Naveen (-14.06%) exhibited significant desirable negative heterosis over mid parent, while crosses VRBG-1003 × Arka Bahar (-12.12%), VRBG-1001 × Selection-1 (-9.89%) and VRBG -107 × PSPL (-8.29%) registered significant negative heterosis over better parent, where 16 crosses over mid parent and 12 crosses over better parent recorded significant negative heterosis. Yadav and Kumar (2012) [11] and Janaranjani *et al.* (2016) [4] also reported similar findings.

The positive and significant heterosis for vine length and number of primary branches per plant are desirable because they are directly associated with increase of fruit yield. Among the 40 hybrids, cross combinations VRBG-408 × Arka Bahar (46.73%), VRBG-408 × PSPL (37.66%) and VRBG-1003 × Pusa Naveen (37.08%) exhibited significant positive heterosis over mid parent, similarly cross combinations VRBG-1001 × Arka Bahar (25.68%) followed by VRBG-1003 × Arka Bahar (19.58%) and IC-042345 × Pusa Naveen (18.87%) exhibited significant positive heterosis over better parent for vine length, whereas for number of primary branches per plant cross combinations VRBG-1003 × Arka Bahar (75.57%), PBOG-40 × Arka Bahar (68.97%) and PBOG-40 × PSPL (68.18%) exhibited significant positive heterosis over mid parent, while the cross combinations VRBG-1003 × Arka Bahar (64.36%), PBOG-40 × Arka Bahar (59.78%) and IC-092467 × Arka Bahar (40.87%) registered significant positive heterosis over better parent. Similar findings are reported by Pandey *et al.* (2003) [8].

Fruit weight and number of fruits per plant directly correlates to the yield where positive and significant heterosis would be beneficial. The cross combinations VRBG-1003 × Selection-1 (41.92%), VRBG-107 × Selection-1 (36.84%) and IC-042345 × Selection-1 (33.19%) reported significant positive heterosis over mid parent, while crosses NDBG-104 × PSPL (22.84%), IC-042345 × Selection-1 (21.94%) and IC-042345 × Arka Bahar (21.68%) exhibited significant positive heterosis over better parent for fruit weight. These findings are in accordance with Sharma *et al.* (2009) [10] and Gayakawad *et al.* (2016b) [2]. For fruit length DVBG-2 × Arka Bahar (54.91%) followed by DVBG-2 × Selection-1 (48.64%) and VRBG-107 × Arka Bahar (42.56%) exhibited significant positive heterosis over mid parent, whereas crosses DVBG-2 × Arka Bahar (40.13%) followed by VRBG-107 × Arka Bahar (27.95%) and IC-042345 × Arka Bahar (21.35%) registered significant positive heterosis over better parent. Kushwaha and Ram (2002) [7] also reported similar results.

Significant positive desirable heterosis was reported for number of fruits per plant of crosses, where the heterosis range varied between 3.03 to 125.20% for mid parent and -17.35 to 78.75% for better parent, where among the 40 crosses, DVBG-2 × Arka Bahar (125.20%) followed by VRBG-107 × Arka Bahar (108.62%) and IC-144389 × Arka Bahar (82.76%) exhibited significant desirable positive heterosis over mid parent, while crosses DVBG-2 × Arka Bahar (78.75%) followed by DVBG-2 × Pusa Naveen (76.47%) and VRBG-107 × Arka Bahar (75.36%) recorded significant positive heterosis over better parent. Similar findings are also reported by Sharma *et al.* (2009) [10] and Kumar *et al.* (2011) [6].

The positive and significant value for fruit yield per plant is desirable for exploitation of hybrid vigour. Such high heterosis for fruit yield per plant was due to additive heterotic effect of one or more components traits. The heterosis range for fruit yield per plant was recorded between 25.61 to 155.73% for mid parent and 6.83 to 106.93% for better parent where the hybrids DVBG-2 × Arka Bahar (155.73%) followed by VRBG-107 × Arka Bahar (144.05%) and IC-042345 × Selection-1 (115.33%) exhibited significant positive heterosis over mid parent, whereas crosses NDBG-104 × PSPL (106.93%), IC-042345 × Pusa Naveen (99.56%) and DVBG-2 × Pusa Naveen (96.26%) registered highly significant positive heterosis over better parent. These findings are in accordance with Kumar *et al.* (2011) [6], Gayakawad *et al.* (2016) [2] and Adarsh *et al.* (2017) [1].

Table 1: Estimation of mid parent and better parent heterosis 40 F_1 hybrids for flowering and yield traits in bottle gourd.

Crosses	D50SF		D50PF		NFSF		NFPF		VL (m)	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
VRBG -107 × PSPL	-5.92**	-5.03**	-5.06**	0.6	0	6.96**	-14.21**	-8.29**	32.54**	16.84**
VRBG -107 × PUSA NAVEEN	-10.61**	-6.71**	-3.21*	7.1**	-5.68*	-5.26**	-13**	-4.09**	11.75**	2.63
VRBG -107 × ARKA BAHAR	-11.82**	-8.61**	-10.67**	-5.36**	-4.15	10.43**	-3.54*	5.83**	29.73**	13.68**
VRBG -107 × SELECTION-1	-3.83*	10.4**	-1.22	15.71**	1.29	2.61	-10.54**	-4.92**	17.29**	11.96**
VRBG-408 × PSPL	-16.77**	-12.58**	-10.51**	-1.19	-3.09	7.63**	-6**	3.87**	37.66**	9.66**
VRBG-408 × PUSA NAVEEN	-16.05**	-8.72**	-10.61**	3.23**	-7.3**	11.4**	2.56	16.96**	2.86	-20.75**
VRBG-408 × ARKA BAHAR	-4.29**	3.31**	-1.35	8.93**	-12.9**	-10**	-12.26**	-6.85**	46.72**	17.48**
VRBG-408 × SELECTION-1	0.00	20**	3.21*	26.43**	-0.72	16.95**	-11.94**	-3.28*	-8.47*	-35.41**
VRBG-1001 × PSPL	-5.88**	-2.04	-2.7	-1.82	7.38**	15.93**	-4.68*	-4.42**	18.77**	17.57**
VRBG-1001 × PUSA NAVEEN	-6.76**	-6.12**	1.25	4.52**	-1.32	-0.88	-2.55	0.58	15.31**	11.32**
VRBG-1001 × ARKA BAHAR	-15.44**	-14.29**	-9.91**	-9.09**	-5.7*	9.73**	1.4	19.23**	27.84**	25.68**
VRBG-1001 × SELECTION-1	-2.94	5.6**	4.26*	13.57**	-3.03	-0.88	-10.14**	-9.89**	-27.73**	-38.28**
VRBG-1003 × PSPL	-21.19**	-16.98**	-15.93**	-8.93**	4.67*	19.85**	-0.97	12.71**	6.72	-6.9**
VRBG-1003 × PUSA NAVEEN	-29.85**	-23.49**	-19.66**	-9.03**	2.47	27.19**	4.98*	23.39**	37.08**	15.09**
VRBG-1003 × ARKA BAHAR	-5.81**	1.99	-2.2	5.95**	-10.97**	-5.33**	-14.88**	-12.12**	36.25**	19.58**
VRBG-1003 × SELECTION-1	1.66	22.4**	3.57*	24.29**	-3.14	17.8**	6.28**	20.22**	-14.83**	-35.41**
IC-092467 × PSPL	-2.60	0.67	0	0	1.6	6.72**	6.56**	12.15**	-1.14	-15.94**
IC-092467 × PUSA NAVEEN	-0.67	-0.67	2.79	7.1**	-0.43	1.75	-0.81	7.6**	16.39**	2.9
IC-092467 × ARKA BAHAR	-12.00**	-11.41**	-5.36**	-5.36**	-0.37	12.61**	-3.14	8**	21.71**	2.9
IC-092467 × SELECTION-1	0.73	10.4**	1.3	11.43**	-4.64	-4.24*	0.78	5.46**	5.29	4.78**
IC-144389 × PSPL	-15.38**	-13.73**	-7.43**	-3.57**	-7**	0.89	4.07	6.08**	18.89**	7.87**
IC-144389 × PUSA NAVEEN	-20.53**	-19.46**	-12.76**	-5.16**	4.42	5.36**	-0.84	4.09**	1.48	-3.93
IC-144389 × ARKA BAHAR	-9.21**	-8.61**	-7.43**	-3.57**	3.05	20.54**	4.61*	20.74**	17.76**	6.18**
IC-144389 × SELECTION-1	-2.88	8**	0.62	15.71**	6.96**	9.82**	-5.66**	-4.37**	2.33	-5.26**
NDBG-104 × PSPL	-2.86	12.4**	8.31**	22.56**	7.92**	9.16**	2.03	11.05**	15.24**	3.28
NDBG-104 × PUSA NAVEEN	-8.89**	1.65	0	8.27**	3.23	12.28**	-14.06**	-3.51*	15.79**	8.2**
NDBG-104 × ARKA BAHAR	-20.59**	-10.74**	-12.29**	-0.75	-6.34**	-0.75	-9.8**	-2.82*	4.91	-6.56**
NDBG-104 × SELECTION-1	-7.32**	-5.79**	-1.1	1.5	-7.94**	-1.69	5.56**	14.21**	11.73**	4.78**
DVBG-2 × PSPL	-5.03**	-5.03**	-4.6**	-1.19	-1.54	-0.78	-1.92	-1.1	18.75**	-4.6**
DVBG-2 × PUSA NAVEEN	-4.55**	-1.34	-1.49	6.45**	3.7	10.53**	6.48**	10.53**	26.63**	5.44**
DVBG-2 × ARKA BAHAR	-5.16**	-2.65*	-3.45*	0	-2.51	5.43**	1.4	18.48**	13.09**	-9.62**
DVBG-2 × SELECTION-1	2.11	16**	1.88	16.43**	-2.02	2.54	-3	-2.73	8.48**	1.67
PBOG-40 × PSPL	-0.36	16.95**	0.65	9.86**	-1.73	8.4**	2.51	12.71**	-4.55	-13.1**
PBOG-40 × PUSA NAVEEN	-5.62**	6.78**	1.01	5.63**	-7.35**	10.53**	-6.19**	6.43**	-7.19	-18.87**
PBOG-40 × ARKA BAHAR	0.37	14.41**	4.52**	14.08**	-8.44**	-6**	-7.99**	-1.84	-19.85**	-26.57**
PBOG-40 × SELECTION-1	-1.23	1.69	-2.13	-1.43	-5.07*	11.02**	-0.5	8.74**	-3.05	-23.92**
IC042345 × PSPL	-3.16	9.52**	2.91	12.77**	1.5	3.05*	8.43**	10.29**	19.1**	9.66**
IC042345 × PUSA NAVEEN	-1.82	7.14**	7.43**	12.77**	3.61	13.16**	3.47	4.68**	34.52**	18.87**
IC042345 × ARKA BAHAR	-3.97*	5.56**	-0.32	9.22**	-9.47**	-4.44**	4.51*	25.71**	24.53**	15.38**
IC042345 × SELECTION-1	-1.99	-1.6	0.36	0.71	-5.93*	0.85	-6.15**	-4**	14.2**	-9.57**

* Significant at p= 0.05, ** Significant at p= 0.01

D50SF: days to50% staminate flowering; D50PF: days to 50% pistillate flowering; NFSF: node at which first staminate flower appears; NFPF: node at which first pistillate flower appears; VL: vine length;

Table 2: Estimation of mid parent and better parent heterosis 40 F_1 hybrids for flowering and yield traits in bottle gourd.

Crosses	NPB		FW (g)		FL (cm)		No. Frts		YPP (kg)	
	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH	MPH	BPH
VRBG -107 × PSPL	-7.66*	-23.67**	22.06**	20.84**	22.13**	-2.67	10.18	-6.12	34.97*	13.84
VRBG -107 × PUSA NAVEEN	-3.98	-15.23**	17.05**	5.36	27.38**	-2.64	55.84**	41.18**	86.65**	84.58**
VRBG -107 × ARKA BAHAR	40.56**	29.08**	19.3**	6.49	42.56**	27.95**	108.62**	75.36**	144.05**	88.29**
VRBG -107 × SELECTION-1	-2.51	-17.38**	36.84**	13.32**	40**	11.68**	57.48**	44.93**	111.19**	65.00**
VRBG-408 × PSPL	2.85	-15.67**	21.92**	18.35**	11.35*	9.28**	6.67	-10.2	29.89	6.88
VRBG-408 × PUSA NAVEEN	22.77**	7.42**	15.16*	5.55	-1.18	-4.91	36.84*	22.35*	59.81**	56.7**
VRBG-408 × ARKA BAHAR	46.07**	35.42**	25.6**	14.14**	29**	10.89**	63.16**	38.81**	99.58**	57.45**
VRBG-408 × SELECTION-1	36.29**	14.54**	30.08**	9.47*	3.91	1.84	37.6	28.36*	75.99**	40.67**
VRBG-1001 × PSPL	11.88**	10.78**	0.98	-0.63	-14.97**	-21.47**	23.62	21.78**	25.61	24.87*
VRBG-1001 × PUSA NAVEEN	29.18**	18.63**	11.36	0.79	-18.22**	-20.2**	18.28	8.91	33.69	12.29
VRBG-1001 × ARKA BAHAR	50.64**	15.69**	20.11**	7.8*	5.82	-13.6**	33.78*	-1.98	55.11*	6.83
VRBG-1001 × SELECTION-1	36.05**	30.72**	24.58**	3.68	3.11	-4.88	47.17**	15.84*	73.70**	20.81*
VRBG-1003 × PSPL	3.28	-16**	17.83**	-1.82	-12.45**	-30.12**	3.85	-17.35*	29.17	22.13*
VRBG-1003 × PUSA NAVEEN	37.39**	19.14**	11.47*	-15.13**	10.66**	-7.59**	20.28	1.18	43.55*	25.89*
VRBG-1003 × ARKA BAHAR	75.57**	64.36**	21.25**	-8.28**	37.91**	-0.32	60**	44.83**	87.12**	32.73**
VRBG-1003 × SELECTION-1	44.26**	20.21**	41.92**	1.38	28.08**	2.14	32.76	32.76*	86.82**	33.93**
IC-092467 × PSPL	11.81**	-5.33*	14.07**	6.1*	-20.58**	-29.48**	3.03	-13.27	19.98	7.73
IC-092467 × PUSA NAVEEN	31.9**	19.53**	-1.61	-17.61**	-25.12**	-29.92**	39.47*	24.71**	42.03*	30.96*

IC-092467 × ARKA BAHAR	57.53**	40.87**	6.89	-11.17**	-12.7*	-31.05**	63.16**	38.81**	66.24**	22.09
IC-092467 × SELECTION-1	38.37**	20.21**	3.21	-19.85**	-12.97**	-22.81**	58.4**	47.76**	59.88*	18.77
IC-144389 × PSPL	-17.13**	-28.4**	14.62**	10.01**	-0.92	-17.78**	23.35	5.1	42.31*	24.93*
IC-144389 × PUSA NAVEEN	-5.69*	-23.54**	1.05	-13.04**	-3.53	-16.02**	55.84**	41.18**	62.57**	53.52**
IC-144389 × ARKA BAHAR	1.39	-29.13**	15.93**	-1.01	3.43	-22.8**	82.76**	53.62**	105.63**	53.56**
IC-144389 × SELECTION-1	22.19**	2.91	3.64	-17.54**	-8.09*	-23.81**	81.1**	66.67**	83.51**	38.67**
NDBG-104 × PSPL	32.83**	21.15**	23.62**	22.84**	-7.04	-12.94**	68.37**	68.37**	108.58**	106.93**
NDBG-104 × PUSA NAVEEN	33.55**	13.74**	26.27**	13.28**	-14.86**	-15.68**	63.93**	53.06**	106.55**	73.76**
NDBG-104 × ARKA BAHAR	28.41**	-6.87**	18.79**	5.7	-13.48*	-28.52**	54.48**	14.29	77.98**	22.72*
NDBG-104 × SELECTION-1	21.36**	7.69**	29.24**	6.71	2.21	-4.39	48.72**	18.37*	81.91**	26.67**
DVBG-2 × PSPL	4.3	3.62	22.84**	18.34**	26.93**	1.83	21.35	10.2	48.39**	30.44**
DVBG-2 × PUSA NAVEEN	33.93**	23.36**	13.58*	4.85	20.13**	-7.62*	81.82**	76.47**	108.11**	96.26**
DVBG-2 × ARKA BAHAR	67.52**	28.95**	17.15**	7.22	54.91**	40.13**	125.2**	78.75**	155.72**	90.78**
DVBG-2 × SELECTION-1	10.24**	6.25**	21.37**	2.8	48.64**	19.36**	60.87**	38.75**	87.38**	41.45**
PBOG-40 × PSPL	68.18**	35.67**	-1.79	-8.02*	-21.22**	-25.26**	41.49**	35.71**	39.25*	25.51**
PBOG-40 × PUSA NAVEEN	47.27**	26.56**	7.61	2.13	-20.51**	-28.51**	26.86	23.33**	36.45	25.32*
PBOG-40 × ARKA BAHAR	68.97**	59.78**	8.09	1.68	-10.01	-17.54**	38.69*	5.56	46.31	7.16
PBOG-40 × SELECTION-1	33.91**	10.64**	19.08**	3.39	-9.71	-14.24**	39.19*	14.44	58.51*	17.42
IC042345 × PSPL	7.95*	-14**	22.39**	8.56*	-1.68	-10.99**	20.63	16.33*	47.87**	27.17**
IC042345 × PUSA NAVEEN	34.56**	14.06**	22.28**	21.48**	-9.04	-21.71**	67.05**	61.54**	106.48**	99.56**
IC042345 × ARKA BAHAR	39.18**	33.71**	22.02**	21.68**	26.3**	21.35**	52.17**	15.38	84.25**	39.86**
IC042345 × SELECTION-1	32.61**	8.16**	33.19**	21.94**	4.14	-5.61	66.44**	36.26**	115.33**	65.46**
* Significant at p= 0.05, ** Significant at p= 0.01			NPB: number of primary branches per plant; FW: fruit weight; FL: fruit length; No. FRTS: number of fruits per plant; YPP: yield per plant							

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